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Practice Exploration of Green Building Design in Prefabricated Residential Building Design

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Abstract: Prefabricated residential building design fully embodies the concept of green building and aligns with China's strategic plan for sustainable development. However, there is a need to further optimize green building design methods, enhance the design quality of prefabricated residential buildings, and improve energy and resource utilization. Compared to traditional construction methods, prefabricated residential building design still faces several challenges during the actual construction process. These challenges include difficulties in design, material selection and processing, and the high demands for construction coordination. To strengthen the application of green building concepts in prefabricated residential design and effectively promote the sustainable development of the construction industry, this paper discusses practical measures for implementing green building design in prefabricated residential projects for reference.

Keywords: Green building design; Prefabricated housing; Architectural design

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1. Introduction

At present, the construction industry is in a critical period of rapid economic development, transformation, and high-quality construction. To further improve the living conditions of the people, solve the common problems of prefabricated residential buildings such as low performance of the whole life cycle of buildings, the large energy consumption of residential construction, large impact on the construction environment, and unbalanced green and low-carbon development, it is necessary to comprehensively promote the green, low-carbon, livable and high-quality development of prefabricated residential buildings. Furthermore, it is essential to strengthen the practice and application of green building design in prefabricated residential construction. Accordingly, the primary focus of this paper is to analyze and study the implementation of green building concepts in the design of prefabricated residential buildings, with the aim of promoting sustainable construction practices in this sector.

2. Green environmental protection characteristics of prefabricated residential buildings

From the perspective of green environmental protection, prefabricated steel structure residential buildings have natural advantages in green building design [1]. Currently, prefabricated buildings mainly include prefabricated concrete structure buildings and prefabricated steel structure buildings, among which prefabricated concrete structures have good durability and stability, and occupy a large proportion in practical applications.

Specifically, prefabricated concrete structure residential buildings have the following advantages. Firstly, quality control, as the components are produced in the factory, which allows for better control of the quality of concrete and the precision of the components. Secondly, the construction efficiency is high. The prefabricated components can be directly transported to the construction site for assembly, reducing the time required for formwork construction and maintenance compared to on-site pouring. Thirdly, for economic and environmental protection, especially large-scale projects, the cost of prefabricated components is often lower than the cost of traditional cast-in-place structures, and many prefabricated components can be reused to reduce waste.

Following this, prefabricated steel structure residential buildings have the following advantages. Firstly, the steel structure has recycling characteristics, allowing the steel used in the building to be recycled at the end of its life cycle. After professional treatment, it can be repurposed for other engineering projects, including production and manufacturing. According to statistics, the recovery rate of steel in steel structures can be up to 90% [2]. This not only reduces the consumption of resources in other areas during production but also reduces the waste generated after the dismantlement of the building.

Secondly, since steel has the characteristics of structural stability, high hardness, strong corrosion resistance, and many more, the solid waste and ecological waste generated during the building service cycle are less and the maintenance frequency is lower, which effectively reduces the impact of the building itself on the surrounding ecological environment. Thirdly, it emits less carbon. Compared to traditional reinforced concrete buildings, prefabricated building design has shown advantages in many aspects, such as water saving, environmental protection, energy saving, and carbon emission reduction, with carbon emission reduction being the most significant. Statistically, the expected carbon emissions of prefabricated steel structure buildings are about 450 ± 20 kg/m^2, while the carbon emissions of traditional reinforced concrete buildings are about 800 kg/m^2.

Finally, based on the high efficiency and modular production characteristics of prefabricated steel structures, the time and material waste of on-site construction can be effectively reduced during the actual construction. In the production process, resource use can be optimized through precise design and control, thus reducing unnecessary energy consumption [3]. Simultaneously, most of the prefabricated components can be processed in the factory, thus reducing the noise pollution and dust pollution of the construction site, and further improving the effect of environmental protection [4].

3. Practical application of green building design in prefabricated residential building design

3.1. Building site selection and site green design

Building site selection and site design are critical steps before building design and construction. Effective site selection and design can significantly ensure the overall quality of the building [5]. Under the framework of green building design, construction and design parties should actively explore the path of organic integration between architectural design schemes and the surrounding ecological environment based on the site's actual

conditions. They should coordinate the relationship between humans and nature, as well as between humans and ecology, through scientific and reasonable construction methods and techniques, ensuring economic benefits while also prioritizing ecological benefits.

Therefore, during the site selection process for prefabricated residential buildings, relevant staff must conduct a thorough investigation of the surrounding environment in advance. This includes identifying the characteristics of the surrounding area, such as the presence of residential areas, commercial zones, campuses, or any special pipelines and their specific underground locations at the construction site. Subsequently, effective measures should be adopted to minimize the impact on the surrounding environment during actual construction, ensuring harmonious coexistence between humans and nature [6]. Simultaneously, the construction party should also ensure the scientific and rational location of the residential building, taking into account construction technology, construction standards, environmental characteristics, human conditions, climate conditions, and many more, to ensure that the structural design and exterior design of the residential building meet the environmental requirements and technical requirements [7]. For example, if the residential building is located in a remote area, it will reduce the travel convenience of the current residential building users, increasing carbon emissions. If it is a low-lying area, the phenomenon of cold winter and hot summer may occur, resulting in increased dependence of residents on heating facilities, air conditioning, and other equipment, and thus a serious waste of resources, which does not meet the design standards of green buildings [8].

3.2. Selection of residential building materials

The design of prefabricated residential buildings under the concept of green building design requires the use of new roofing materials and wall materials, which are made of composite and fibrotic materials and have the characteristics of a simple installation process, low environmental pollution, lightweight, etc., which can greatly reduce the demand for human resources in construction and effectively enhance the thermal insulation effect of residential buildings [9]. Additionally, in the design of prefabricated residential buildings in green building design, many factors such as heat insulation, sound insulation, fire prevention, lighting, and ventilation should be comprehensively considered. Materials such as aluminum alloy and plastic steel alloy can be selected during actual construction, which can not only meet the design requirements of green buildings but also bring certain economic benefits to the builders and constructors [10].

For example, when applying aluminum alloy doors and windows, it is necessary to fill an appropriate amount of waterproof mortar between the energy-saving frame and the wall based on the local climate characteristics, and the thickness of the mortar should be less than the thickness of the energy-saving frame, so as not to affect the stability of the energy-saving frame after the mortar swelling. After the waterproof mortar is filled and air-dried, professional acceptance should be carried out, and the installation of the aluminum alloy main frame can be carried out after acceptance. In the design of doors and windows, insulating glass, heat reflection coated glass and other materials with excellent insulation and energy-saving characteristics can be selected. This not only improves the sealing of doors and windows, but also increases the shading, and achieves an indoor adjustable heat control effect, to achieve summer insulation and winter insulation. During the design period, insulation materials with strong water absorption should be avoided as much as possible, because such materials will absorb water and moisture seriously in areas with frequent rainfall, which will increase the internal humidity of the wall and easily cause damage to the building.

3.3. Green design for ventilation and lighting

Ventilation and daylighting are important items to be considered when designing the interior space layout of prefabricated residential buildings. In the actual design process, designers need to rationally design and utilize natural light, ventilation windows, new technologies, and new materials according to the requirements of natural ventilation and lighting, combined with indoor orientation and lighting conditions [11]. In particular, the design of the building ventilation system must conform to the concept of energy saving, make full use of natural wind, and strengthen indoor ventilation and exhaust. Generally speaking, indoor natural ventilation mainly uses the characteristics of building space layout, temperature difference effect, and air pressure. For example, the temperature difference and pressure difference between the indoor and outdoor parts of the building are different. By opening the doors and windows of the building, outdoor air can enter the room to achieve the role of ventilation. If the architectural design uses the concept of windward side to leeward side, it can further improve the indoor ventilation effect of the building. Although the reasonable design of residential doors and windows has a good ventilation effect, it also needs to carefully consider the ventilation area. According to the design requirements of conventional prefabricated residential buildings, the ventilation area ratio between the opening area of the bedroom and the ground should not exceed 19:20, the ventilation area of the kitchen should be greater than 0.6 m^2, and the opening angle of the windward side should be 90°.

Ventilation and lighting in the interior of the building not only need to meet the relevant architectural design and building energy conservation requirements but also need to ensure that users can get a good visual experience. Therefore, designers also need to optimize the ventilation and lighting of the building according to the specific building type and make the indoor lighting have a certain uniformity by improving the indoor lighting indicators. For example, insulating glass and adjustable shutters can be used to match the design. Adjustable shutters can freely adjust the indoor light area according to user needs, improving the quality of life and comfort of users. Not only that, adjustable shutter types, product appearance, color, and other options, according to the overall layout and color collocation of the interior, not only to meet the daily lighting needs but also to create a livable, comfortable atmosphere. Moreover, according to the indoor lighting design standards, the lighting uniformity of class I to IV lighting levels should not be less than 0.7 when lighting the top, and the distance between the midline of two adjacent skylights should not be greater than two times the height from the working face to the lower edge of the skylight [12].

3.4. Green design of indoor environment

Air quality is directly related to human health and living comfort, so designers need to pay attention to the optimization of air quality when designing the interior environment of prefabricated residential buildings. Furniture materials, decoration materials, indoor ventilation, and other comprehensive factors will affect the indoor air quality index [13]. Therefore, when decorating, we should try to choose non-toxic, green, and environmentally friendly materials, and after the decoration is completed, we should do a good job of ventilation to reduce formaldehyde levels. At the same time, the selection of furniture materials should also choose low-volatile organic building materials, and set up air cleaners or green plants in a reasonable area to help purify indoor air, to effectively optimize indoor air quality.

Moreover, it is essential to design and select the fresh air conditioning system thoughtfully. This involves fully considering the spatial layout of the building's interior, choosing the appropriate installation location, and adhering strictly to construction standards and specifications. In particular, it is important to seal the fresh

air intake on the building wall to prevent rain, outdoor mosquitoes, reptiles, and other pests from entering the room. It should be noted that during the process of interior decoration construction, attention must also be paid to the air-tightness transformation and optimization of key areas such as doors, windows, and structural gaps. By improving construction quality and standardization, prefabricated residential buildings can achieve good air-tightness, which helps reduce the impact of cold air in winter on indoor temperatures and plays an important role in lowering building energy consumption. Additionally, good air tightness can minimize outdoor noise, reduce outdoor air pollution, prevent mold growth, and protect against structural corrosion.

3.5. Green design of residential building insulation

The wall is an important part of the residential building structure, and its quality is directly related to the safety of the residential building. Under the concept of green building design, the construction quality and stability of the wall should be ensured, and the environmental protection and energy saving of the wall should also be comprehensively considered [14]. To this end, the composite wall can be applied to the building's thermal insulation design according to the actual situation. The composite wall can effectively enhance the thermal insulation performance of the wall itself, achieve the effect of heat insulation and cooling in summer and cold insulation and warmth in winter, and then reduce the dependence of residential users on temperature control facilities such as air conditioning thus reducing resource consumption. Furthermore, with the continuous development of science and technology, a variety of green building materials have gradually appeared in the construction market. Some new organic materials with biodegradable performance, good thermal insulation performance, etc., can effectively meet the current era of green building in the context of energy conservation, insulation, and other aspects of the design standards.

Taking silicon ink as an example, it is a new type of external wall insulation material, which has the advantages of one-time pouring molding and permanent non-demolition convenience in actual construction and can integrate the main body of the building structure with the thermal insulation layer. The surface layer of the silicon ink exterior insulation material is a decorative layer, which can be flexibly adjusted according to building standards or user requirements, including but not limited to surface texture, color, and shape. Additionally, the silicon ink mold-free insulation board also has excellent weather resistance, water resistance, and crack resistance, which can significantly improve the stability and firmness of the external wall structure of residential buildings. In actual application, it is necessary to reserve about 500 mm space on the top of the non-removable thermal insulation template and use wooden boards to temporarily fix it to prevent pulp leakage on the top surface. Planks can be removed after concrete placement is completed [15].

4. Conclusion

To sum up, incorporating the concept of green building into the design of prefabricated homes can enhance the environmental performance of the building and greatly improve the health and comfort of the occupants. By fully integrating the concept of green building into the site selection and site design of prefabricated residential buildings, building materials selection, ventilation and lighting design, interior environment design, and other links, not only the goal of energy conservation and emission reduction is achieved, but also the operating cost is reduced, and the overall value of the building is enhanced. In the future, the application of green building design in prefabricated housing design needs to be further explored in terms of carbon reduction, livable, and sustainability, to create long-term excellent housing.

Disclosure statement

The author declares no conflict of interest.

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