2025 International Conference on Architecture, Civil Engineering, and Landscaping (ICACEL 2025)

Application of Ecological Architecture Theory in Residential Building Design

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Keywords: Ecological architecture theory; residential building design; sustainable development; resource recycling; application strategies

Abstract: Against the backdrop of the global advancement of sustainable development concepts and the green transformation of the construction industry, ecological architecture theory provides scientific methodological guidance for residential design. This paper mainly analyzes the application of ecological architecture theory in residential building design. It first provides an overview of the basic content, application characteristics, and usage principles of ecological architecture theory, then examines the current application status of this theory in residential building design, and finally discusses and summarizes effective strategies for enhancing the application level of ecological architecture theory in residential building design, hoping to offer a path reference for the sustainable transformation of residential design models.

1. Introduction

Currently, the world is facing severe challenges such as resource shortages, environmental pollution, and climate warming. As a major energy-consuming and carbon-emitting sector, the green transformation of the construction industry has become a key link in achieving sustainable development goals. Residential buildings, as a type of architecture closely related to human life, have a direct impact on residents' quality of life and the carrying capacity of the ecological environment through their design models. Therefore, exploring the specific application of ecological architecture theory in residential design can not only provide effective solutions to the ecological dilemmas currently faced by residential design but also drive the construction industry towards sustainable development. It holds significant practical and long-term value for achieving the coordinated development of the human living environment and the natural ecosystem.

2. Overview of Ecological Architecture Theory

2.1 Basic Content

As a product of the in-depth integration of architecture and ecology, ecological architecture theory is an important theoretical system for addressing global ecological crises and resource constraints. Its core essence lies in reconstructing the relationship between architecture and nature, as well as humans and the environment, abandoning the linear development model of "resource consumption - product output - waste discharge" in traditional architecture, and shifting towards a sustainable development path of "resource recycling - low consumption and high efficiency - ecological coordination." From a theoretical perspective, ecological architecture theory takes "harmonious coexistence between humans and nature" as its fundamental orientation. It emphasizes placing resource utilization efficiency and ecological protection at a crucial position throughout the entire lifecycle of a building, from planning and conception to final demolition and recycling. It aims to minimize dependence on and consumption of non-renewable resources, reduce the interference and damage caused by construction activities to ecosystems, and fully ensure the comfort, health, safety, and psychological pleasure of building occupants, achieving the coordinated unity of ecological, social, and economic benefits.

2.2 Application Characteristics

In practical application, ecological architecture theory exhibits distinct characteristics that

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significantly differ from traditional architectural design concepts. These characteristics not only reflect the core values of the theory but also determine its application logic and implementation path in actual projects. One of the prominent characteristics is its systemic nature. In ecological architectural design practice, it is necessary to comprehensively consider design elements across multiple dimensions, such as site conditions, energy systems, water resource systems, material selection, and spatial layout, ensuring that all elements coordinate and support each other to form a complete ecological design system. This helps avoid the problem of "partial ecologicalization and overall high consumption" caused by the disconnection between local design and overall goals, thereby maximizing the ecological benefits of buildings[1].

Ecological architecture theory also demonstrates a clear dynamic characteristic. It is not a static theoretical system. With the increasing emphasis on ecological and environmental protection in society and the introduction of policy orientations such as global "dual carbon" goals, the evaluation criteria and design specifications for ecological architecture are constantly being adjusted and improved. The evaluation dimensions have gradually expanded from early resource conservation to multiple fields, including ecological protection, healthy living environments, and carbon footprint accounting, leading to higher design requirements for ecological architecture. This dynamic characteristic enables ecological architecture theory to keep pace with the times, maintain its advanced nature and practical timeliness, and adapt to changing ecological environments and social needs.

2.3 Usage Principles

In practical application, ecological architecture theory needs to adhere to a series of core principles. These principles are not only important guarantees for the implementation of the theory but also key guidelines for ensuring that ecological architectural design does not deviate from the core goals of "ecological and sustainable development." The principle of ecological priority is the fundamental guideline of ecological architecture theory, emphasizing that ecological protection should always be given priority in all decision-making and design aspects throughout the entire lifecycle of a building. It requires prioritizing the impact of construction activities on natural ecosystems rather than solely pursuing functional effects or economic benefits of the building. Designers should always take ecological protection as a prerequisite, balance building needs and ecological constraints, and ensure the coordinated coexistence of buildings and natural ecosystems.

The principle of the whole lifecycle requires breaking away from the limitation of "emphasizing design and construction while neglecting operation and recycling" in traditional architectural design. It advocates integrating ecological concepts throughout the entire process of a building, from planning and design, construction, operation and use, to demolition and recycling. It calls for a comprehensive consideration of ecological benefits, resource consumption, and environmental impacts throughout the entire lifecycle of a building, rather than focusing only on the ecological performance of a single stage or aspect. This ensures that the application of ecological architecture theory covers the entire process of a building, thereby achieving maximum resource utilization and minimum environmental damage.

Since the ultimate service object of ecological architecture is humans, the principle of "people-orientation" must be consistently adhered to during the application of the theory. It is essential to find a balance between ecological protection and human living comfort, avoiding sacrificing living experience for the pursuit of ecological indicators. Through the value orientation of "ecology as the foundation and humans as the core" in ecological architecture theory, it ensures that ecological architecture can fully meet humans' demands for a beautiful living space while achieving ecological benefits.

3. Current Application Status of Ecological Architecture Theory in Residential Building Design

3.1 Predominantly Local Penetration with Insufficient Systemic Integration

Currently, in the technical application of ecological architecture theory in residential design, there is a characteristic of "local penetration but systemic deficiency." Most projects only incorporate ecological technologies in single or a few aspects, such as selecting water-saving fixtures and installing solar collectors, without constructing a complete ecosystem from the perspective of the entire lifecycle of the building. During the design process, aspects such as energy utilization, water resource recycling, and material selection often lack coordinated planning, resulting in the isolation of various technological modules and difficulty in achieving a synergistic effect of ecological benefits. Although some projects introduce advanced ecological technologies, their actual effectiveness is not fully realized due to insufficient compatibility with building functions and site conditions or the lack of post-operation and maintenance mechanisms, failing to truly achieve the goal of "whole-process ecologicalization" advocated by the theory.

3.2 Gradual Popularization of Concepts with Insufficient In-depth Practice

With the promotion of sustainable development concepts, the awareness of ecological architecture theory has gradually spread in the construction industry, and most design units mention ecological design concepts in residential projects. However, from the perspective of the depth of practice, there is still a significant gap. Some design teams have a superficial understanding of the theory, equating "ecology" with the "use of green building materials" or "landscape greening," and ignoring the systemic thinking and whole-lifecycle concepts at the core of the theory. During project implementation, ecological design aspects are often reduced due to factors such as cost control and time pressure, resulting in a large gap between the finally completed projects and the requirements of ecological theory. The phenomenon of a disconnect between theory and practice is quite prominent.

3.3 Preliminary Establishment of Support Systems with Incomplete Implementation Guarantees

At present, support systems related to ecological architecture have been initially established in various regions, such as the introduction of green building evaluation standards and the provision of subsidies or floor area ratio incentives for ecological residential projects, offering policy guidance for the application of the theory. However, the guarantee mechanisms for policy implementation still need to be improved. On the one hand, some policy clauses are too general and lack specific implementation rules for residential design, resulting in a lack of clear guidance for design units during implementation. On the other hand, the policy supervision and evaluation mechanisms are not well-established, with insufficient whole-lifecycle supervision of ecological residential projects. Some projects focus on certification rather than operation to obtain policy benefits, making it difficult to ensure the long-term effective implementation of ecological design schemes.

4. Effective Strategies for Enhancing the Application Level of Ecological Architecture Theory in Residential Building Design

4.1 Strengthen Technological System Integration and Construct a Whole-lifecycle Design Framework

To address the issue of "more local applications and less systemic integration" of ecological architectural technologies in residential design, it is necessary to reshape the technological application logic from the design source and establish an integrated ecological design framework covering the entire lifecycle of a building. At the project initiation stage, barriers between different professional teams in traditional architectural design should be broken down, and multi-professional teams including architecture, structure, mechanical and electrical engineering, landscape, and environmental engineering should be involved early and work collaboratively. Ecological technology modules such as energy utilization, water resource recycling, material selection, and indoor environment optimization should be incorporated into a unified design system. During the planning phase, with the whole-lifecycle concept at the core, not only should the ecological requirements during the construction phase of the building be considered, but also the energy consumption patterns, water resource demand characteristics during the operation phase, and the resource recycling potential during the demolition phase should be predicted. Through preliminary technological simulations and collaborative demonstrations, the connection mechanisms and functional matching logic between various ecological modules should be clarified to avoid the disconnection between technological applications and building functions and site conditions[2].

A dynamic optimization plan should also be established to adjust operation and maintenance strategies or technological parameters in a timely manner based on the feedback of technological operation deviations from monitoring data, avoiding the gradual decline in the effectiveness of ecological technologies due to a lack of post-management. Through the synergistic effects of dynamic adaptation and post-guarantee, ecological architecture theory can be further promoted from the technological planning stage of design to the efficiency maintenance stage of operation and then to the resource recycling stage of demolition, achieving whole-process ecological implementation and fully and continuously releasing the technological value of ecological architecture theory throughout the entire lifecycle of residential buildings.

4.2 Deepen Industry Cognition Cultivation and Improve Professional Capacity Enhancement Systems

The effective implementation of ecological architecture theory in the field of residential design highly depends on the depth of cognition and corresponding professional technological capabilities of industry entities regarding the theory. The problems of "superficial understanding and fragmented practice" in the application of ecological theory by some design teams at present essentially reflect the dual shortcomings of industry cognition and professional capabilities, which urgently require coordinated efforts from the dimensions of cognition reshaping and capacity building to construct a systematic enhancement path.

In the dimension of industry cognition cultivation, it is necessary to break away from a single knowledge dissemination model and construct a multi-subject and multi-level cognition deepening system. Industry associations can take the lead in organizing targeted specialized training, focusing on the systemic framework and practical logic of ecological architecture theory rather than just scattered explanations of technological points. As the frontier of academic research, universities can promote the in-depth integration of ecological theory with architecture, ecology, material science, and other disciplines through regular academic seminars and the offering of interdisciplinary specialized courses, providing the industry with professionals with systemic thinking. Industry media should undertake the responsibility of in-depth interpretation, breaking down the one-sided cognition that "ecological design is equivalent to the selection of green building materials or the improvement of landscape greening" through columns such as case analysis and theoretical tracing, guiding market entities such as design units, developers, and construction enterprises to fully recognize that ecological design is a comprehensive project that runs through the entire lifecycle of residential buildings, covering technological integration, material selection, spatial planning, and operation management. Its value not only lies in the direct improvement of residential quality but also in the reduction of long-term operation costs and the construction of a sustainable development path for the industry[3].

4.3 Optimize Policy Guarantee Mechanisms and Strengthen Whole-process Supervision and Evaluation

Policy guidance and guarantees are important supports for the widespread application of ecological architecture theory in residential design. To address the problem of "the framework has been established but the implementation effect needs to be improved" in current policies, it is necessary to improve the guarantee mechanisms from the dimensions of policy refinement, supervision strengthening, and incentive optimization. In terms of policy refinement, existing policies related to ecological architecture should be supplemented and refined in combination with the characteristics and needs of residential design. Specialized implementation rules for residential projects should be formulated to clarify ecological design requirements, technological application standards, and acceptance specifications for different types and positions of residential projects. Clear and operable quantitative standards should be provided in key areas such as energy consumption limits, water resource recycling ratios, and indoor environmental quality indicators to offer clear implementation bases for design units and avoid ambiguity and arbitrariness in policy implementation.

At the level of supervision strengthening, a whole-lifecycle supervision mechanism for ecological residential projects should be established, extending the supervision scope from the project completion stage to the operation and use stage. A digital monitoring platform should be built to track indicators such as energy consumption, water resource utilization, and pollutant emissions of residential buildings in real time and regularly evaluate the actual effects of ecological design schemes, preventing some projects from focusing on certification rather than operation to obtain policy benefits and ensuring the implementation of ecological design goals. In terms of incentive optimization, in addition to continuing existing measures such as subsidies and floor area ratio incentives, the connection between ecological residential projects and financial policies such as green credit and tax reductions can be explored to reduce the ecological design costs for developers. At the same time, an ecological design credit evaluation system can be established to link the ecological performance of projects with the credit ratings of enterprises, the enthusiasm of market entities to participate in ecological design through a combination of positive incentives and negative constraints, providing a stable and effective policy environment for the in-depth application of ecological architecture theory in residential design[4].

5. Conclusion

In conclusion, the application of ecological architecture theory in residential design provides multi-dimensional and whole-process ecological solutions for residential design. It not only effectively alleviates the pressure exerted by traditional residential design on resources and the environment but also genuinely responds to residents' demands for healthy and livable spaces. Currently, although the application of ecological architecture theory in residential design has achieved phased progress, with the in-depth advancement of global sustainable development goals and the continuous iteration of green technologies, there is still broad space for its development. In the future, with the continuous innovation and improvement of green technologies, the application of ecological architecture theory in residential design will become more in-depth and extensive, gradually laying a solid foundation for achieving sustainable development in the construction industry and building a beautiful homeland where humans and nature coexist harmoniously.

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