Application of Ecological Architecture Theory in Residential Building Design

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Abstract: With the global promotes of sustainable development concepts and green transformation of the construction industry, ecological architecture theory provides scientific method guidance for residential design. This paper primarily investigates the implementation of ecological design theory on residential-building architecture. In this paper, it firstly introduces the basic content, application characteristics and usage principles of ecological architecture theory, then analyzes the situation of theoretical application in residential building design of all aspects based on case studies in recent years little by little, after that discusses and summarizes effective path for improving the application level of ecological architecture theory in residential building design methods meeting to provide a valuable path reference to 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. The essence of ecological architecture is to reconstruct the relationship between architecture and nature, human beings and environment, abandon linear development mode "resource consumption-product output-waste discharge" in traditional architecture, and turn to sustainable development path of resource recycling-low consumption high efficiency-ecological coordination. The theoretical orientation of ecological architecture theory is "harmonious coexistence between man and nature" from a theoretical perspective. It should be noted that wherever it is placed, resource use efficiency and environmental protection must be at the heart of the entire life cycle process of a building, from planning and design to demolition recycling. It intends to reduce dependency and use of non-renewable resources, limit the disturbance and destruction of ecosystems caused by construction activities, and fully guarantee the comfort, health, safety, and psychological enjoyment of building occupants so that ecological benefits, social benefits, and economic benefits can be developed in a coordinated manner.

2.2 Application Characteristics

The ecological architecture theory applied in practice shows unique attributes that are markedly

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different from the conventional architectural design ideas. These traits not only just embody the principles of the theory, but also define its application logic and actual implementation during project phases. One of the key traits is systemic nature. In ecological architectural design practice, it is necessary to comprehensively consider design elements across multiple dimensions, so as to ensure that the various elements work together and support each other, and form a complete ecological design system. This prevents the disconnect between local design and overall goals which leads to "partial ecologicalization and overall high consumption", thus maximizing ecological benefits of buildings [1].

Also, ecological architecture theory has a dynamic quality, this is not a fixed theoretical system. As ecological and environmental protection is increasingly valued by society, policy orientations such as global "dual carbon" goals are proposed one after another, evaluation criteria and design specifications of ecological architecture also need to be revised and improved. From the early resource conservation to the multi-field performance, such as ecological protection, healthy living environment and carbon footprint accounting, etc for data type of bank training goes along with other dimensions of evaluation have been progressively expanded at a higher level design requirements on ecological architecture. This dynamic quality allows ecological architecture theory to keep pace with the times, retain its advanced nature and practical timeliness and adapt to new changes in ecological environment and social needs.

2.3 Usage Principles

Ecological architecture theory needs to be somewhat grounded with a series of principles that have stood the test of practical implementation. Not only are these principles a major guarantee for the implementation of the theory, but also the "pragmatic guidelines" to ensure that ecological architectural design does not deviate from its core goal of "ecological and sustainable development." Ecological priority is the chief principle of ecological architecture theory, which stipulates that ecological protection must prevail in decision-making and design throughout the entire lifecycle of a building. This requires considering what the effects construction actions have on natural ecosystems, and not just how functional or economic those effects are with respect to the building. Despite the ecological protection always been one of the preconditions for designers, it is still necessary to balance the construction needs and ecological constraints, coordinate with nature to achieve harmonious coexistence between building and natural ecosystems.

The essence of whole lifecycle lies in overcoming the limitation that "the design and construction are emphasized while the operation and recycling are neglected" in traditional architecture. It argues that ecological ideas should be put into practice in every phase of a building, from planning and design (in the firm's case) to construction and operation and use right up until demolition and recycling. This requires to holistic assessment of the lifecycle services, resources and life cycle impacts of whole buildings instead of solely assessing one system or component during one stage impact. This makes sure that Ecological Architecture theory is applied at all stages of a building and thus we achieve maximal resource use with minimum environmental harm.

As the ultimate service object of ecological architecture is people, when applying theory, the principle of "people-orientation" should always be adhered to. A reasonable adjustment is to compromise the pursuit of ecological indicators. Under the guidance of the value orientation theory of ecological architecture of "Ecology as the foundation, Human being is in the Core", it guarantees that ecology architecture can realize ecology benefits and meet humans' demand to an all-round beautiful living space.

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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