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# Strategies for the Application of Ecological Building Materials in Architectural Design

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**Abstract:** The application of ecological building materials in architectural design is in line with the concept of green development and can promote the transformation and upgrading of the construction industry. Against this background, this article systematically explains the definition, characteristics, and classification of ecological building materials, and discusses the selection criteria and application scenarios of ecological building materials. On the basis of the previous analysis, the article proposes that the application of ecological building materials in architectural design needs to do a good job in the integration of materials, system expression, digital synergy, and total life cycle management. Thus, it expands the application scenarios of ecological building materials in architectural design and helps the industry to develop sustainably.

**Keywords:** Building design; Ecological building materials; Concrete; Life cycle

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## 1. Introduction

Ecological building materials are building materials with low environmental impact and characterized by renewability, low carbon, recyclability, and health and harmlessness in the whole life cycle of raw material collection, production and processing, use, maintenance, and disposal. For example, natural materials such as bamboo, wood, and rammed earth, recycled materials such as recycled concrete and recycled metals, and high-performance environmentally friendly materials such as photocatalytic coatings and phase-change energy storage materials are all ecological building materials [1]. Ecological building materials can effectively reduce resource consumption and carbon emissions in the construction industry and alleviate the pressure on the environment caused by the industry's economic production process. Therefore, with the global resource shortage and environmental problems becoming more and more serious, the application of ecological building materials, especially the application of ecological building materials to building design, is an inevitable choice to promote the development of the construction industry.

## 2. Characteristics and selection criteria of ecological building materials

### 2.1. Material characteristics

Through the above analysis, it can be seen that ecological building materials have low-carbon, renewable,

recyclable, and healthy characteristics. Low-carbon characteristics refers to the whole life cycle of the material to minimize energy consumption and carbon emissions. The renewable characteristic means that the material resources can be supplied sustainably. Recyclability refers to the fact that materials can be utilized multiple times, thus reducing material waste [2]. Healthy properties mean that the production, processing, and use of materials do not release harmful substances and provide a safe and healthy environment for users. Overall, the above characteristics are interrelated and complementary, which together constitute the unique advantages of ecological building materials over traditional building materials.

## 2.2. Selection criteria

When selecting ecological building materials, designers should work on four aspects: environmental performance, functional suitability, economic cost, and aesthetic and cultural expression. Environmental performance refers to a comprehensive understanding of the environmental impact of the whole process of raw material acquisition, production and processing, transportation, use, and disposal of materials through carbon footprint calculation and life cycle evaluation. For example, wood absorbs carbon dioxide during growth, but logging and processing, and transportation still produce carbon emissions. Therefore, when applying wood to building design, it is important to select specific categories with sustainable sources and environmentally friendly processing.

Functional adaptation emphasizes that ecological building materials should meet the functional needs of different parts of the building [3]. For example, when designing large-span building spaces, high-strength recycled steel should be selected to ensure structural safety. When designing building maintenance structures, straw panels with efficient thermal insulation performance should be selected, along with sealing design to reduce heat loss from the building. The economic cost standard refers to the use of full life cycle analysis methods, comprehensive consideration of the cost of materials in the entire life cycle. Taking self-repairing concrete as an example, although the initial purchase price of the material is high, the building repair cost can be reduced by automatically repairing cracks in the later stages of use. Therefore, the whole life cycle cost of the material is lower than that of traditional materials. And then, aesthetics and cultural expression mainly refers to the design of the building to fully consider the texture, color, and texture of the material and other aesthetic elements, so that the material and the overall style of the building to coordinate. For example, if you design a rural B&B (Bed and Breakfast), you can choose natural rammed earth and wood to make the building complement the rural environment; if you design an urban building, you can choose recycled concrete with geometric shapes to create a unique industrial style [4].

## 2.3. Applicable scenes

The characteristics of different types of ecological building materials vary significantly. Therefore, when designing, designers not only need to select materials according to the above criteria, but should also take into account the reality of the optimization of the use of materials scene. For example, bamboo, recycled steel, and cross-laminated timber are more suitable as structural materials. Among them, bamboo is more suitable for lightweight building structures; recycled steel can better meet the structural strength requirements; and cross-laminated timber can be used for multi-story wooden structures. Straw panels, rammed earth walls, and green concrete are more suitable as maintenance materials for buildings, either to improve the thermal insulation performance of the building, or to improve the thermal storage capacity of the building space, or to improve the durability of the building while meeting the strength requirements of the building maintenance structure. Materials such as phase change energy storage gypsum boards and photocatalytic air purification coatings are more suitable as functional materials for buildings to regulate indoor temperature fluctuations by storing and releasing thermal energy [5].

## 3. Core application strategy of ecological building materials in architectural design

### 3.1. Material integration strategy in the early stage

The use of ecological building materials in architectural design should do a good job of material integration: first of all, designers should fully consider the natural resources of the project site and the availability of materials, and prefer regional materials. For example, the Yi traditional folk house, Tupa house, chooses the most common local soil and stone, wood, and bamboo to build rammed earth wall as the main maintenance structure of the building. When designing modern lodgings in Yunnan, designers can refer to the design concept of the earth palm house and use common local thatch and straw to improve the traditional rammed earth wall. At the same time, binder is added appropriately to improve the strength and durability of the B&B structure, and to make the ecological architectural concepts continue in modern architecture [6]. Secondly, designers should consider the climatic characteristics of different regions, choose ecological building materials adapted to meteorological conditions, and carry out targeted design. For example, buildings in low-latitude hot and humid areas should have good ventilation and air permeability, so designers can prioritize the use of local natural materials in bamboo as ecological building materials.

The good air permeability of bamboo itself is utilized to promote indoor air circulation, and the indoor temperature is further reduced through the shading structure built with bamboo [7]. As for designing buildings in high-altitude cold regions, designers should take into account the need for building thermal insulation by using straw boards and phase change materials, so as to achieve effective thermal insulation and heat storage in the building space, and to reduce the energy consumption for building heating in winter. Then, designers can promote the modularization and prefabrication design of ecological materials. For example, after determining the application of bamboo materials to build building maintenance structures, designers can provide detailed parameters for the factory to produce prefabricated bamboo structural components. This factory unified, standardized material processing and production can reduce material waste. The on-site assembly and use of prefabricated components can in turn improve construction efficiency and facilitate the later remodeling of the building.

### 3.2. Material expression in system design

After effectively integrating ecological building materials, designers need to use materials to express design concepts in the system design according to the needs of building function realization. Firstly, designers can consider ecological building materials as part of the exposed structure to show the unique texture and aesthetics of the building. For example, the wood structure beams and columns common in Chinese architecture not only conform to the mechanical logic of the building, but also reflect the wisdom of traditional architectural craftsmanship. It also shows the unique aesthetics of Chinese architecture through the graceful lines and natural texture of wood. The use of recycled concrete as a decorative material can expose the rough texture of concrete. This texture complements the modern industrial style and creates a unique spatial atmosphere. In the case of the headquarters of the International Olympic Committee in Switzerland, for example, cross-laminated timber is used extensively in the structural part. The natural grain of the wood is clearly visible, giving it a rustic and warm feel. The external structure of the building is also perfectly integrated with the surrounding natural environment, further emphasizing the eco-friendly aesthetic view of the building [8].

Secondly, designers should take into account the functional characteristics of different types of ecological building materials and realize the composite design of material functions based on building characteristics. Taking the headquarters building of the International Olympic Committee in Switzerland as an example again, when designing the maintenance structure, the designer selected high-performance insulating glass and renewable hemp fiber insulation materials. The comprehensive use of materials effectively reduces heat loss from the interior of the

building and reflects the concept of building design that prioritizes environmental performance. At the same time, the building utilizes photocatalytic coatings to decompose harmful pollutants in the air under light conditions. Thus, the dual functions of high-performance environmentally friendly materials in wall decoration and air purification can be achieved.

Third, designers should use ecological building materials to promote the modernization and translation of cultural symbols. For example, designers can try to improve traditional building techniques with high-performance ecological materials. In the case of the restoration project of the ancient city of Pingyao, for example, the designers combined traditional rammed earth technology with modern material science, and optimized the granular ratio of the wall by mixing 5% quicklime into the damaged wall. This method enhances the compactness and waterproofness of the wall while maintaining the original texture and historical appearance of the wall. At the same time, the design reduces the amount of new materials to be extracted by recycling the old collapsed soil, and realizes the dual goals of cultural heritage preservation and ecological protection through the low carbon process of non-high-temperature firing. Alternatively, designers can modernize and reconstruct traditional ecological building materials. For example, using three-dimensional weaving technology to transform traditional thatch into concrete-like thatched walls, making the building maintenance structure both waterproof, heat-insulating and aesthetically pleasing. As well, natural building materials such as palm leaves, which are common in the local area, are covered on the outside of the clear-water concrete structure. While preserving the regional cultural symbols, the modern combination of materials gives the building a unique aesthetic sense [9].

## 3.3. Collaborative strategy of digital technology

In order to improve the quality of the application of ecological building materials in architectural design, designers also need to use digital technology for collaborative design. For example, the three-dimensional weaving technology mentioned earlier is a specific application of BIM technology and parametric design. This type of technology mainly generates building models based on the building data collected in the early stage. The designer then imports information such as the usage locations and basic quantities of bamboo materials, recycled steel materials, etc. into the model. The model will then simulate the ecological architectural design scheme, accurately calculate the amount of materials used, and reduce material waste. At the same time, parametric design can be used to optimize the design scheme according to the material properties. Designers can follow the suggestions to adjust the design scheme, which can further improve the efficiency of eco-building material use and the quality of building design. In addition, designers can also combine smart eco-materials with passive design concepts. For example, glass is an indispensable part of modern architecture. Using temperature-sensitive glass as a smart material, the glass can automatically adjust the light transmission rate according to the ambient temperature, thus reducing the energy consumption of architectural lighting.

## 3.4. Full life-cycle management strategy

Ecological building material is a full life cycle concept. Using this material for building design, designers should naturally introduce the full life cycle theory. That is, in the design stage, considering the possibility of secondary utilization of materials, reserving the material recycling interface [10]. At the same time, taking into account the building maintenance needs, the use of low-maintenance material application programs. For example, in the De Flat Kleiburg residential renovation project in Rotterdam, the Netherlands, the designers used high-strength bolted steel frames. This design approach reduces the impact of thermal stresses on the steel's performance while facilitating the recycling and secondary use of steel components. Toranomon Hills Mori Tower in Tokyo, Japan, uses a peelable nano-coating material. If a secondary renovation is required, the construction crew can quickly

separate the old coating by simply processing it with low-pressure steam, which improves operational efficiency and prevents the mixing of materials that would result from shoveling out the old material. And when designing projects for bridges, designers can consider using microcapsule-encapsulated microbial self-healing concrete materials. The material can automatically fill internal cracks in concrete by releasing Bacillus spores and calcium carbonate precursors through capsule rupture when cracks appear, thus reducing the frequency and cost of post-construction maintenance.

## 4. Practical difficulties and solutions in the design of applying ecological building materials

### 4.1. Practical difficulties

At this stage, various types of ecological materials have been widely used in building design. However, the practice faces a number of challenges, namely, the lack of performance of natural ecological building materials, the high cost of recycled materials and high-performance environmental protection materials, and the lack of ecological building construction specifications. For example, buildings designed with natural materials such as bamboo and wood are more prone to structural safety hazards due to insect infestation. New eco-materials such as seaweed-based eco-coatings are complex and low in production, and are generally sold at 1–3 times the market price of traditional building materials. Eco-materials can only be used in high-end projects, making it difficult to promote them in the market. At the same time, due to the failure of some enterprises and workers to master the construction process of ecological building materials, construction quality problems such as large-scale deformation of building walls often occur.

### 4.2. Solutions

In order to cope with problems such as the above, the architectural design unit should put forward specific suggestions to strengthen the performance of materials when choosing ecological building materials. For example, carbonization treatment can improve the corrosion resistance and insect resistance of bamboo; boric acid impregnation not only improves the corrosion resistance of wood, but also extends the service life of the material; and the addition of reinforcing agents in recycled aggregate concrete helps to improve the strength and durability of the material. At the same time, industry associations and leading enterprises should organize the development of guidelines and standard specifications for the use of ecological building materials, clarifying the construction process and specific quality requirements for this type of building. For instance, we need to establish standards for controlling the moisture content during the construction of rammed earth walls, or clarify the construction specifications for the connection nodes of the main structure. It not only provides clear guidance for specific construction operations to ensure the implementation of the ecological building design concept, but also enhances the market acceptance of ecological buildings through the “Good House” project. In addition, the relevant government departments should introduce preferential policies for the production and application of ecological building materials to give concessions and subsidies. Only the state, to guide enterprises to expand the production and use of ecological building materials to reduce the cost of materials, and ultimately promote the widespread use of ecological building materials. Only when the state takes action can it reduce material costs by guiding enterprises to expand the production and use scale of ecological building materials, and ultimately promote the wide application of ecological building materials.

## 5. Conclusion

In summary, the application of ecological building materials in architectural design is an important way to realize the sustainable development of architecture. In practice, designers should select materials based on performance indicators such as ecological building material characteristics and environmental protection. Then, through various strategies such as systematic design expression, the advantages of ecological building materials are fully utilized. In this process, the government, industry associations, and enterprises need to take the initiative to assume responsibility and actively act. By improving policy support measures, revising industry standards, and other means, we can further promote the wide application of ecological building materials in the industry and enhance the quality of material application.

## Disclosure statement

The authors declare no conflict of interest.

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