Environmental sustainability and architectural design analysis of Taihu Olympic sports center gymnasium

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Abstract. There is often a close relationship between architectural creation and environmental Sustainability. The rapid development of green buildings. Ecological considerations, local resources, material choices, energy consumption and carbon emissions will all play an important role. This paper use Citespace software which was utilized to conduct keyword searches for "green building" in 300 Chinese papers and 500 SCI papers, followed by an analysis of the clustering patterns among domestic and international publications related to green building. Then this paper analyzes the green building design from three aspects: the selection of single form, planning and design, and the surrounding ecological environment, and explores the Taihu Olympic Sports Center gymnasium from the perspective of sustainable development. The characteristics of sustainable building and green building design are summarized. By examining case studies on green buildings that prioritize energy efficiency and environmental sustainability, this study aims to promote the harmonious coexistence of human beings and nature through architecture. Through the implementation of green design principles, users can enjoy enhanced functionality while effectively improving urban residents' quality of life, maximizing urban development benefits, and ultimately achieving long-term sustainable development for both humanity and nature.

1 Introduction

The development strategy of the "sustainable development concept," "green building," and "energy-saving building" was explored in developed countries as early as the 1970s. Although various concepts have emerged during development, their connotations are consistent, focusing on the relationship between the ecological environment, architecture, and people. Famous architects utilize resources, energy, and background to the maximum extent through technological innovation. Integrate architectural creation perfectly into the ecological environment. For example, the famous German architect Thomas Herzog often breaks through the boundaries of architecture and conducts creative research with multiple disciplines. In architecture, energy science, physics, medicine, materials science, biology, and other fields, he integrates them in a complex and precise manner, making the building far beyond the ecological benefits created by sensory design.

In the current wave of rapid development of green buildings, this article mainly focuses on rational analysis of the individual design, planning design, and surrounding environment design of buildings as essential considerations. These rational considerations play an absolutely dominant role in the creation of a large number of buildings[1]. In the face of the global energy crisis, greenhouse effect, and high-density carbon emissions, the design concept of the perceptual category is often avoided in the practical stage in pursuing architectural formalism in a small number of buildings. To ensure the comfort, energy efficiency, and health of the building.

The citespace software retrieved 300 Chinese CSSCI articles and 500 SCI articles by searching for the keyword "green building." The Chinese search found 9 keywords clustered by green building, as shown in Figure 1: sustainable development, architectural design, chief architect, building economy, engineering management, Sustainability, republican texture, teaching system, and building energy conservation. The search of foreign articles showed that the United Kingdom, the United States, and Canada published more articles on green building earlier, as shown in Figure 2. China began to appear in more articles on green building in foreign articles around 2007 and currently ranks as the country with the highest number of publications. Keywords focused on green building abroad include green building, energy conservation, climate, energy-saving software, envelope structure, and evaluation.

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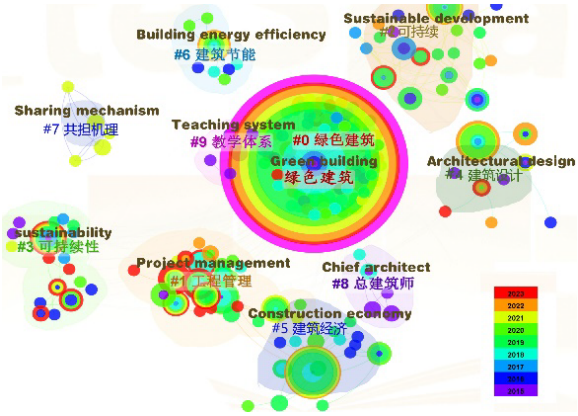

Fig. 1. Searching for Chinese Literature.

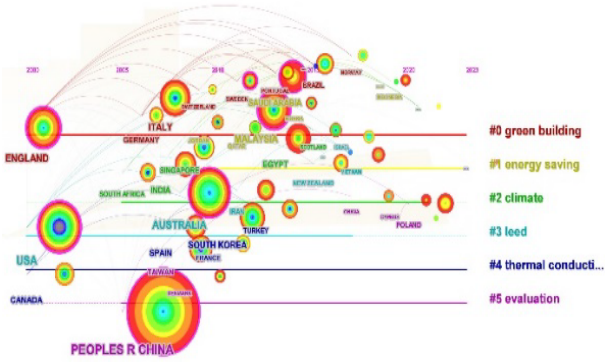

Fig. 2. Searching for Foreign Literature.

2 Sustainable design of single buildings

Since the Industrial Revolution, the design of individual buildings has broken through the limitations of existing building materials and shaken off the constraints of inherent building technology. While pursuing more possibilities through technological innovations in air conditioning, lighting, and illumination, it has continuously pursued higher heights and larger spaces. At the same time, it has also brought more damage and threats to the living environment. With the fragility of the ecological environment and the further scarcity of resources and energy, people gradually awakened from blind design, and the awe of nature in architectural design slowly emerged. In the trend of green building design, architecture should not only reflect the aspects of land conservation, energy conservation, water conservation, and material conservation but also pay attention to adapting to local conditions and the whole life cycle in the design process. Among them, the sustainable development strategies that affect individual design include natural ventilation, lighting, building shading, enclosure structure design, and solar energy utilization of buildings. The functional realization of architecture advocates using passive design strategies of "passive priority and active optimization." In individual design, more ideologies of energy service, system optimization, technical energy conservation, and dynamic transformation of individuals are cultivated.

The single shape of the Taihu Lake Olympic Sports Center Gymnasium should show the local regionalism and tradition and integrate and show the local climate, cultural factors, economic strength and sports spirit. In this stadium design, we should incorporate and meet the needs of different levels and extract the image of a lily from many cultural symbolic elements. As shown in Figure 3, the main stadium has a total construction area of about 86,300 square meters, with an aboveground construction area of about 65,200 square meters, which can accommodate 40,000 people to watch the game simultaneously. The sculptural roof between the two layers of petals extends from the central flower to the surrounding area. The transparent box is embedded in the petals, and the metal is rotated 180 degrees, making the curved shape more vivid and passionate.

From the perspective of natural ventilation, the Huzhou Stadium has six openings on the roof, which are opened and closed in multiple ways to adapt to the changes in wind direction throughout the seasons, thus meeting the requirements of natural ventilation under different conditions. From the perspective of the external envelope structure, the steel structure of the stadium roof adopts a double-layer open-mesh shell structure system composed of two tops of different heights. The flexible connection between the inner and outer mesh shells enhances the overall seismic performance. It can reduce the multiple impacts of local loads on other parts. The primary materials used for the exterior of the building are honeycomb aluminium panels and perforated metal panels[2].

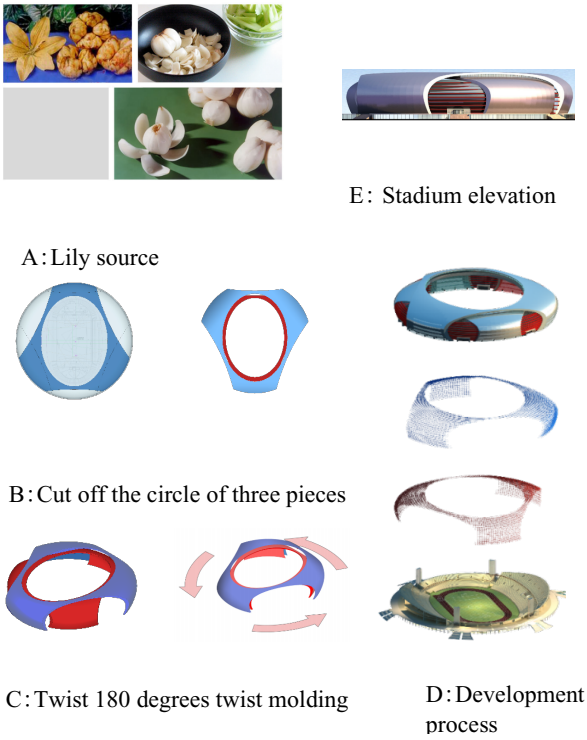

Fig. 3. Unit scheme design - lily shape.

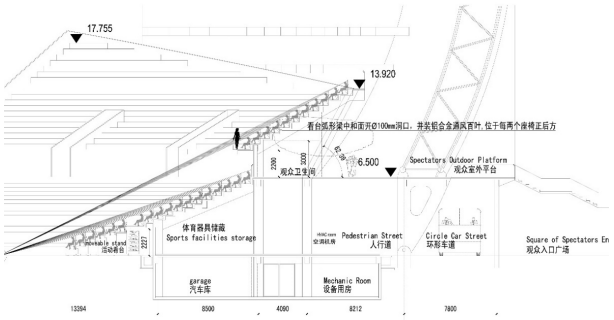

Fig. 4. Schematic diagram of VIP sky box.

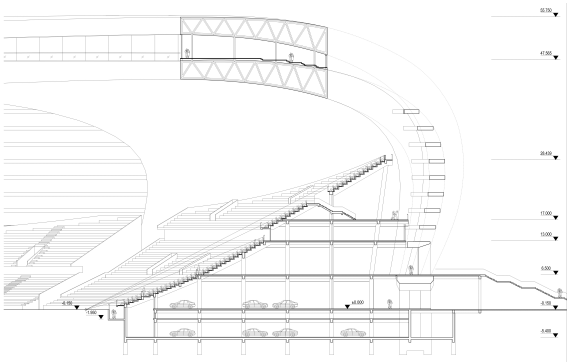

Fig. 5. Structural sectional view.

The honeycomb aluminium panel material forms countless air layers inside, increasing the internal materials' air contact area. At the same outdoor air velocity and temperature, the air layers can reduce the energy transmitted from the outdoors to the indoors, effectively reducing the heat transfer caused by the external envelope structure. In terms of lighting, multi-layer polycarbonate is used locally[3]. A hollow ribbed sunlight panel roof is adopted to maximize the introduction of natural lighting, increasing the unique experience of VIP viewing boxes in the air, as shown in Figure 4. At the same time, it makes the space transparent from front to back, allowing for viewing of surrounding wetland parks and ecological landscapes. In terms of structure, the main structural grid structure is not directly connected to the concrete of the auditorium. It is connected to the ground through six support points, which not only reduces the load borne by the concrete structure. It also reduces the structural component's excessive thickness and defects while saving costs achieving the sustainable development needs of applicability, economy, and aesthetics. As shown in Figure 5.

3 Sustainability of planning and design

At the micro level, the planning and layout of buildings often produce subtle changes in the wind environment of the building. This is reflected in changes in wind speed and direction. The planning and structure of building groups can be divided into several types, such as row-type, staggered-type, diagonal-type, free-type, and surrounding-type. In terms of three-dimensional layout, if a low-front and high-rear or regular high-low staggered approach is adopted, this will benefit the ventilation of the building group environment [4]. Reasonable planning and layout not only impact the ventilation of group buildings but also significantly impact the radiation and lighting of group buildings. For example, in winter, effectively blocking cold winds and reasonably planning the spacing between group buildings can effectively increase the sunshine duration of low-rise buildings, improve the thermal comfort of the indoor environment, and increase sustainable planning. It also reflects the perfect use of building functions through planning, design, and more convenient transportation.

In the macro dimension, sustainable planning and design are the core content of urban ecological planning. It is essential in developing an urban circular economy, transforming the natural environment, and sculpting an ecological civilization society. Sustainable planning and design involve many fields [5], including residents' industrial and economic status, disposable income, etc. Attaching importance to sustainable planning and design in urban development, urban environmental planning, urban economic growth, and social Sustainability plays an essential role.

In the planning and design of the Huzhou Olympic Sports Center Gymnasium, macro and micro-level planning content is fully considered, and the city's natural resources are used rationally. It will not only be a landmark building with a sense of place but also become a popular destination for tourists from other places to take photos in addition to sports events in the gymnasium. In daily life, the nighttime is also illuminated with colourful lights, making it a place for local residents to rest and enjoy themselves after meals. It fully reflects the use of sports buildings for people of various consumption levels.

Fig. 6. Landscape analysis diagram.

Fig. 7. Traffic analysis diagram.

Fig. 8. Traffic analysis diagram during the Games.

Fig. 9. Fire analysis diagram.

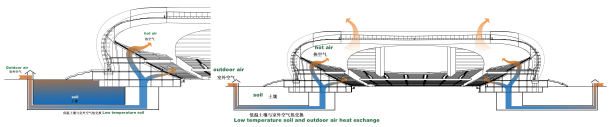

Fig. 10. Schematic diagram of tunnel wind.

Fig. 11. Airflow analysis diagram.

In addition, the location of the planned land for the Olympic Sports Center Stadium is Taihu Lake in the north, the main urban area of Huzhou in the south, Shanghai in the east, and Junjun Mountain in the west. Surrounded by mountains in the west and south, the site is rich in water resources, so the plan still extensively uses water sources to create a sports and cultural venue with mountains and rivers.

As a sports building, it pays more attention to planning the transportation system during the competition stage, with no congestion of vehicles and no crossovers of lines, so visitors, competitors, and logistics personnel can arrange the driving process reasonably. As shown in Figures 7, 8, and 9.

In terms of wind and heat environment, Due to the openness of the surrounding area and the low height of the surrounding buildings, the impact of group planning on the wind environment of the venue is not reflected in this design. In the later stage, with the changes in urban construction in the region, the sustainable impact of planning and design on this building will be further explored. In addition, to increase the passive ventilation effect of the gymnasium in the energy-saving design, the form of tunnel wind is adopted, which effectively utilizes the heat of the land and reduces the energy consumption inside the building. As shown in Figures 10&11.

4 Sustainability of the surrounding environment design

When designing green buildings, designers should also pay more attention to the surrounding environment, focusing on analyzing the coordination between the design content and the surrounding environment to ensure that the construction project and the surrounding environment coexist harmoniously [6]. The design of the surrounding environment in architectural design requires multidimensional scrutiny and layout. For example, the setting of green vegetation. greening not only can reduce the urban heat island effect but also can increase the effective green area. Other examples are the ground pavement, rainwater collection, water body design, etc., Using the role of landscape to redistribute resources to achieve the use of the natural state of the ecosystem.

The design of the Huzhou Olympic Sports Center Gymnasium includes a significant pebble depression in the middle of the square. Figure 6 is the landscape analysis diagram, which plans and designs the landscape of the region and organically combines the natural landscape, lakes, buildings and roads. As a natural demonstration area for rainwater collection, other rainwater is purified by biological processes, As shown in Figure 6. such as reeds through drainage pipes and then discharged into the lake from different locations, making full use of pebbles' filtering and sedimentation effects. Figures 12 and 14 show that the stadium's edge is set with a natural boundary contour, and the reed planting area is located here. This creates the longest efficient biological waterfront and enhances the ecological space of the site, returning to nature. The outdoor space is composed of greening, including island-style grassland, scattered trees, perforated ground, natural swamps, etc. Figures 13 and 15 show that it can slow down the heat caused by rugged land and buildings, improve the surrounding microclimate, and harmonize with existing scenery. The shape and function complement each other. As shown in Figure 16, the Olympic Sports Center Gymnasium blends into the surrounding environment, creating a sustainable building and environment. That is a combination of renderings of the stadium and real-life photos, the sky, the building, and the surrounding scenery to form a natural unity of sustainable space.

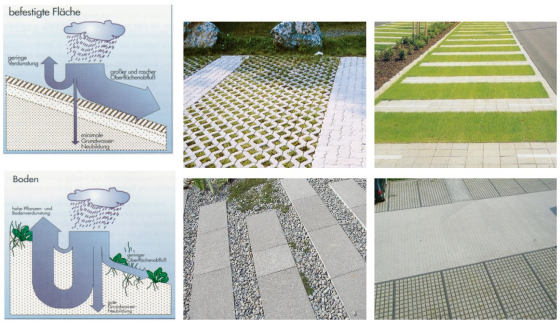

Fig. 12. Rainwater collection system.

Fig. 13. Permeable ground.

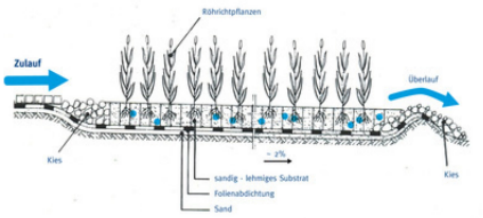

Fig. 14. Rainwater collection and filtration system.

Fig. 15. Permeable stone ground.

5 Conclusion

Architectural design is based on respect for natural features to further integrate architecture and the environment. Sustainable development is essential for today's green architecture design methods. It can achieve the sustainable use of the ecological environment and natural resources and architecture's green, energy-saving, comfortable, and healthy humanistic goals. Compared with ordinary architectural design, green building design reduces energy consumption, highlights local customs, harmonizes with nature, is environmentally friendly, and is people-oriented. In previous green designs, more emphasis was placed on energy conservation and environmental protection. After the current epidemic,

green buildings should focus on health performance and epidemic prevention functions. This way, architecture, environment, and people can achieve true Sustainability.

Fig. 16. Effect and scene of the gymnasium.

The Huzhou Olympic Sports Center Gymnasium is designed from green architecture. It carries out ecological design from a single method, overall planning, and surrounding environment design while pursuing harmony between people, nature, and architecture while energy conservation and environmental protection. Through green design, it achieves comfortable use functions for users, effectively improves the quality of life for urban residents, maximizes the benefits of urban development, and ultimately achieves long-term and sustainable development between people and nature.

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