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Exploration of High-Rise Building Design from the Perspective of Standardization

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Abstract: ***In the face of the trend of intensive land use, the "standardized unit" high-rise buildings achieve ecological, green, and low-carbon construction goals on the basis of limited land space. Based on this, this article studies the design principles and development directions of "standardized unit building" high-rise buildings from four aspects: building unit composition, facade design, spatial organization, and green ecological design. Taking a high-rise building design as an example, the architectural form is studied and the spatial composition is analyzed. The aim is to design eco-friendly and resource saving high-rise buildings, providing new ideas for the development of such buildings.***

Keywords: High-rise buildings, Standardized unit, Prefabricated building**.**

1. Introduction

Today, with the rapid advancement of globalization, population and resources are rapidly converging into regions with rapid economic development. While cities enjoy the convenience of economic development, ecological and land resource pressures come one after another. Urban residents face many problems such as reduced green space, insufficient public resources, tight living space, and inability to match actual needs with the speed of infrastructure construction. Urban construction cannot adapt to the needs of urban residents for their living environment.

In the 1970s, Japanese architects designed a representative high-rise prefabricated building - Capsule Tower. The appearance of the Capsule Tower indicated a new direction for prefabricated high-rise buildings. Its advantages in cost savings, material conservation, simple design, and unique appearance became distinctive features of architecture during that period. However, the issues of safety, environmental hygiene, and limited space cannot be ignored. This became one of the reasons why the Japanese government decided to demolish the Capsule Tower in 2022.

With the rapid development of cities, traditional architectural forms and construction methods are facing challenges. The widespread use of prefabrication technology and a large number of prefabricated components appear in the construction process. Building construction is gradually shifting from on-site manufacturing to factory prefabrication and on-site assembly. However, the use of a large number of prefabricated components limits the continuity and fluidity of the space, resulting in a single internal form and monotonous style in the building space.

2. Conceptual Evolution

For high-rise building design, technological advancements and the rapid changes in building materials have made it possible to express architectural concepts that were previously only imagined. The emergence of software such as Rhino and Grasshopper allows for more comprehensive simulation and analysis of the process of building design and construction. For "standardized unit" high-rise buildings, different block overlapping, different functional block combinations, and different types of space shaping can be achieved in software to design high-rise buildings that are more in line with the concept of green ecology and environmental protection. This article will analyze and study the design of a high-rise building located in the central business district of the Beiguan Canal in Tongzhou District, Beijing, and explore the performance and advantages of the "standardized unit" architectural form in high-rise building design.

The site has significant location characteristics, with the increasing scarcity of land resources, so a high-rise hotel apartment is needed to meet the surrounding business, tourism, and other needs. Considering the need to ensure a high indoor greening rate and a more suitable living environment, the "container style" design was chosen as the starting point for the design; It can break the division form of "inside" and "outside" in architecture; It can also serve as a medium to connect indoor spaces, building blocks, and even urban scenes[1]. "Container style" design is a standardized, modular, and convenient approach. But the "container style" design needs to rely on the existing container size and material, and cannot exist as a permanent building. Therefore, the design elements of the "container style" building are extracted to transform the entire high-rise building into a "standardized unit", which is convenient for production, construction, and expansion of usage. The combination of prefabricated buildings and "standardized unit" buildings assists in the diversified development of high-rise building forms.

3. Modular High-rise Building Design

The spatial diversity, environmental adaptability, and ecological friendliness of modular high-rise building design are reflected in three aspects: unit space combination, shape and facade, and green ecological system

3.1 Unit Space Combination

The flexible and diverse spatial organization form of the "standardized unit" can meet various spatial and functional needs, and can meet the needs of different groups of people for living space, office space, learning space, and

communication space. The ways of spatial combination include parallel and hybrid connection.

1) Parallel connection

The parallel block is composed of two or more standard blocks, mainly connected horizontal head-to-tail and in parallel on the side. For spaces that require longer traffic flow lines, the head-to-tail connection method can extend the passability and accessibility of the traffic space while maintaining the same cross-sectional size. The outer contour of high-rise buildings can be arranged with circular observation walkways or observation platforms. The connection method of connecting the head-to-tail of unit blocks can solve some problems that traditional construction methods cannot solve temporarily, such as the construction of glass curtain walls in circular observation walkways (Figure 1). Traditional curtain walls require high technical expertise from construction personnel during the assembly process. In addition, the various impacts imposed by the environment make it difficult to control the construction process [2]. The use of standard blocks allows for the installation of curtain wall glass and its components on the surface of the block before construction, and the recording of relevant information in the construction management system, which is beneficial for improving construction efficiency. When facing large space requirements such as rest rooms, reception rooms, and reading rooms, standard blocks can be connected in parallel to create a horizontal connection and expand spatial functionality.

The internal design of high-rise buildings needs to cater to the functional and spatial needs of different groups of people. Standard blocks can become the "basic unit" of the design, and diversified combinations of blocks can be used to design units that meet the needs of the target audience. As the basic construction unit of high-rise buildings, standard floors are the foundation of construction standardization.

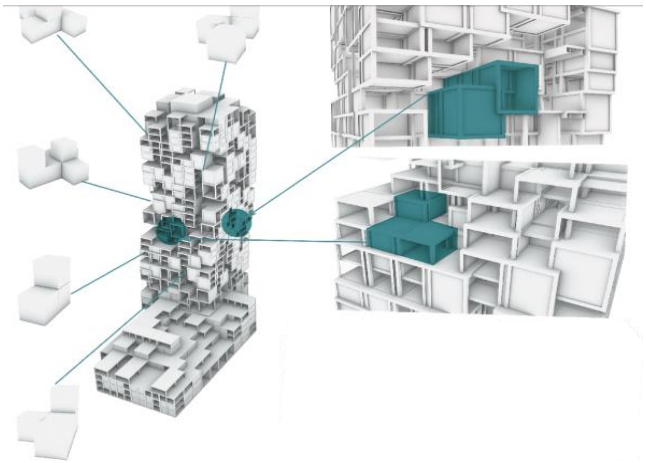

Figure 1: Block diagram
Source: Self drawn by the author.

2) Hybrid connection

The hybrid body block is composed of multiple standard body blocks interspersed. The hybrid block can achieve multi-directional ductility, and multiple spatial requirements that can be achieved in the same composite space. As a standardized and intensive construction method, "standardized unit" building high-rise buildings require flexible combinations to meet the actual construction needs due to the influence of different geographical environmental factors such as temperature and humidity differences on standard blocks of different sizes and materials. A standard block is equivalent to a subsystem, with each subsystem module having its own specific function. All subsystem modules are equipped in a specific way to form an architecture that effectively completes the required functions in the entire system engineering [3]. Due to inherent limitations in construction, high-rise buildings are unable to expand their space horizontally freely. Hybrid blocks can maximize space utilization in a certain space, placing different functional blocks in standard blocks of different sizes to create personalized spaces. When creating a single person living space, use two rectangular blocks that intersect at a 90° angle, and stack a similar sized cube block at the intersection of the two. The overlapping areas of the three can be designed as functional areas with strong commonality, such as entrance/dining areas, with reception areas and living areas on both sides; make the dynamic and static zoning of the entire space clear, while both have good landscape space (Figure 2). Mixed standard blocks are formed through the splicing, stacking, and rotation of standard blocks to form various spatial forms such as elevation space and staggered space. The combination space is implemented in the form of data on the factory machine, so before the construction phase, the correspondence between the "design elements design indicators" of the plane is used as the basis to highlight the consistency between the "elements indicators data" of the in-process plane design [4].

Figure 2: Schematic diagram of spatial effect
Source: Reference 11.

3.2 Modeling and Facade

The "standardized unit structure" of high-rise buildings is composed of countless stacked standard blocks, and the exterior contour of the building exhibits a "pixelated" undulating feature. The external spatial form design of high-rise buildings (Figure 3) can be understood as the intermediate area between high-rise buildings and nearby buildings, as well as urban nodes, belonging to an orderly artificial environment [5].

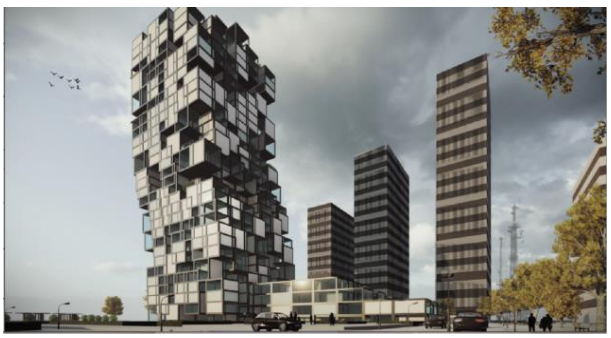

Figure 3: Architectural Form Map
Source: Author's Self drawn.

1) The overall design reflects the urban image

Considering the height differences between blocks, outdoor stairs or ladders can be used as the traffic path for outdoor balconies, viewing platforms, ecological platforms, and other facilities. The hybrid block combination method to a certain extent disrupts the continuity of the building facade, creating a dynamic outdoor space with its internal and external concave and convex changes. The entire high-rise building interface is full of changes, growing like "building blocks" in the city. From the perspective of the urban skyline, high-rise buildings are an indispensable part of the urban skyline; the affinity between urban skylines and high-rise buildings, the fit with natural mountain shapes, and the fusion with urban imagery[6]. The architectural form composed of countless standard blocks, like a huge LEGO building block that breaks the seriousness of the city's towering buildings and adds to the undulating city pulse.

2) The facade elements reflect geometric aesthetics

The facade of a building is one of the manifestations of the external space of the building. For a "standardized unit" high-rise building, the design language of the facade is geometric elements. From the perspective of the foundation of facade changes, the geometric elements extracted from standard blocks constitute the basic changes of building facades. Quadrilateral shapes are parallel, intersect, and overlap in three-dimensional space, resulting in relative displacement changes. The change style is simple and easy to use. To some extent, it reduces the waste of resources waste caused by the use of complex materials or techniques to represent the facade.

3) The facade materials reflect green ecology

In the material selection of the exterior facade, metal rods are selected to connect the outer contour of the block, forming a complete metal frame network (Figure 4). Suitable vines are chosen to attach to the metal frame network, integrating the original color of the metal with the plants, enriching the facade color while reducing the monotony of the facade composed of geometric elements. The metal frame mesh mixed with vines and green plants is different from the traditional high-rise building facade design method, which increases the utilization rate of ecological green space in the external space of the building. The glass curtain wall is hidden within the vine and metal frame mesh, integrating geometric and ecological elements into the facade design unit, reducing light pollution caused by lighting issues. In the overall shaping of the building facade effect, the virtual and real changes formed by the block space and the interweaving of light and shadow formed by the plant metal components jointly give the building a lively atmosphere. To achieve the goal of harmonious coexistence with the surrounding environment in the exterior form, rather than appearing out of place or even damaging the original spatial environment.

Figure 4: Renderings of Vine Metal Frame Mesh
Source: self drawn by the author.

3.3 Green Ecosystem

The development of future cities will undoubtedly be diversified and sustainable, and "green, energy-saving, environmentally friendly economy" is the foundation[8]. The "standardized unit" high-rise building is composed of standard blocks that form the foundation of the internal green space. The hybrid block can also be created as a green landscape space inside the building. By utilizing the height difference formed by overlapping different blocks, large steps, ramps, viewing platforms, and planting plants with different growth heights can be designed to enrich indoor greenery.

In relatively closed building spaces, a suitable living environment can be created, creating a fusion and vibrant natural space, achieving physiological intimacy and spiritual fit between humans and nature[9]. Green plant layers can be set on the surface of standard blocks inside the building to improve indoor greening rate, and evergreen plants that require less light and are easy to grow can be selected. For the water and nutrients required by the plants inside the building, the vine metal frame network in the external space can be combined with the building rainwater collection system to improve the overall ecological resilience of the building.

1) "Biomimetic Vine" Ecological Pipeline System

For high-rise buildings, the "biomimetic vine" ecological pipeline is like a vine plant entangled in the trunk, coexisting with the building (Figure 5). Ecological pipelines utilize the concept of "biomimetic vines" to connect them with rainwater collection devices on the ground and building surfaces, fully utilizing natural water to irrigate plants and reducing waste of excess resources. To a certain extent, ecological pipelines improve the ecological friendliness of building living environments, but rely more on building resources to increase the oxygen supply of the building. It utilizes plant transpiration to regulate indoor microclimate, reducing the frequency of indoor air conditioning usage, saving energy, and reducing emissions. However, during the construction process, it is necessary to strengthen the waterproof and drainage design of standard blocks to prevent excessive humidity inside the building. The design of ecological pipelines can have a certain impact on the airtightness of high-rise buildings, and practical construction issues such as pipeline location, pipeline direction, and pipeline connection methods should be carefully considered to extend pipeline life and reduce maintenance costs.

Figure 5: Stereoscopic Ecological System
Source: Self drawn by the author.

2) A three-dimensional ecological system

The external space of the building can fully utilize the diversity of green space forms such as balconies, landscape platforms, and outdoor activity platforms (Figure 3). By planting herbaceous plants with strong wind resistance, easy survival, and fast growth, a stable ecological interface is formed with vine plants. Two ecological pipelines running through the entire building internally connect indoor plants, green spaces within the building, and external green spaces, forming an ecological green belt surrounding high-rise buildings. At the same time, relying on a three-dimensional ecosystem a natural ventilation system is built, enhancing the natural ventilation effect inside high-rise buildings, using the facade vine metal frame network to reduce solar radiation, improving indoor shading effect, and effectively reducing indoor temperature. The construction of a three-dimensional ecological system for high-rise buildings is of great significance for improving the visual beauty of urban reinforced concrete, improving the urban ecological environment, and reducing energy and noise [10]. Implement the concept of ecological development in the design and construction of high-rise buildings, and unify it with the construction principles of green, low-carbon, and beautiful ecology in cities. Integrating the ecological development concept into the design and construction of high-rise buildings, it is unified with the urban construction principles of green, low-carbon, ecological and beautiful.

4. Conclusion

The "standardized unit" high-rise building has positive significance in reducing land use, optimizing building space design, improving urban greening, accelerating construction speed, improving construction efficiency, and facilitating construction management. Firstly, during the production and construction phase, the Internet of Things technology is utilized to manage the entire process of standardized block production, transportation, and installation, ensuring construction quality, improving construction accuracy, and reducing later maintenance and usage costs. Secondly, in the drawing design stage, traditional design thinking should be shifted towards standardization, modularization, and assembly. Utilize "standardized unit volume" to quantify space, enhance spatial plasticity, and improve spatial utilization. Furthermore, regional cultural symbols and elements are applied to architectural design, transforming high-rise buildings into part of the urban cultural context, showcasing urban culture, and reflecting urban aesthetics. Finally, the combination of green and low-carbon concepts with those of ecological livability leads to the application of new technologies and materials, reducing energy consumption. This creates sustainable living spaces that better serve urban populations.

Acknowledgments

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