Sustainable design of Wuhan Citizen's Home project

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Abstract: Through the sustainable design practice of the Wuhan Citizen's Home project, we explore design strategies and methods for achieving sustainable development in architecture, accumulating experience for research on sustainable design in architecture.

1. Introduction Sustainable design of buildings

The sustainable development design of buildings is a comprehensive strategy aimed at reducing resource consumption and environmental load throughout the entire life cycle of buildings through energy-saving, environmental protection, and humanized means. Its core includes efficient utilization of energy and water resources, adoption of green building materials, emphasis on natural lighting and ventilation, and emphasis on harmonious coexistence with the surrounding ecological environment. Sustainable development design not only helps reduce carbon emissions, but also enhances the health and comfort of users, and is a key path to achieving long-term coordinated development between buildings and the environment. There is still a significant gap between China's research on sustainable design in architecture and developed countries such as Europe and America, especially the lack of detailed case studies to demonstrate comprehensive sustainable design strategies in large public buildings in China.

The article takes the Wuhan Citizen's Home project, which I led as the chief designer during my tenure as the project director at the Shanghai branch of French architectural design company Charpentier, as an example to explore the sustainable development design strategies and methods of architecture.

2. Sustainable design concept

The Wuhan Citizen's Home (Administrative Service Center) project is located on Jinqiao Avenue in Jiang'an District, Wuhan City, Hubei Province, covering an area of 99,200m^2 and a building scale of 123,400m^2. The project was listed by the Wuhan Municipal Government as the first of the "Ten Practical Matters" for the people in 2012, and is also expected to be built into an important landmark and landscape building in Wuhan City.(See Figure 1 and Figure 2). The design concept of Wuhan Citizen's Home is deeply rooted in the practical needs of sustainable development, and was strictly planned according to the "Green Three Star" standard from the beginning of the design. The "Green Samsung" is the highest level of the "Green Building Evaluation Standard (GB/T 50378-2006)" launched by the Chinese government in 2006[1]. Compared with previous evaluation systems in China, it is more comprehensive and balanced, and more suitable for China's national conditions than other foreign evaluation systems. Sustainable design strategies, including energy-efficient retrofitting, passive design principles, and renewable energy integration, can mitigate their environmental impact[2]. The Wuhan Citizen's Home is organically integrated with the urban transportation system, located near subway stations and bus hubs, and encourages the use of public transportation; More than 600 bicycle parking spaces have been set up to encourage green travel; The underground parking lot is equipped with electric vehicle charging stations to promote the use of new energy vehicles. The flexibility and adaptability of architectural design also take into account long-term usage needs. The spatial layout can be adjusted according to functional requirements, avoiding large-scale demolition and renovation caused by functional changes. These designs embody the concept of sustainable development throughout the entire lifecycle, not only considering current needs but also anticipating future changes.

Figure. 1. Southeast perspective view

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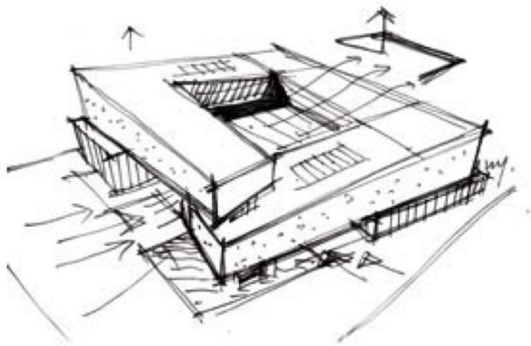
Figure. 2. Night view perspective

3. Sustainable architectural layout

We have demonstrated the enormous potential of passive energy-saving strategies through countless digital model simulations and 3D dynamic demonstrations, ultimately successfully leading homeowners to abandon the traditional grand public building's pursuit of a closed and majestic image, and instead adopt a semi enclosed layout that cleverly utilizes geographical and climatic characteristics, which is conducive to the sustainable development of the building and opens towards the southeast direction. The building opens up to the southeast direction of the dominant summer wind, embracing nature and guiding the hot summer air into the courtyard area. On this path of air flow, landscape water surfaces are arranged. When the flowing air passes through the water surface, it undergoes a natural evaporative cooling effect, effectively reducing the temperature and sending a cool and humid airflow into the "heart" of the building - the atrium space. At the same time, in order to form a complete and efficient airflow circulation system, a narrow horizontal opening was carefully designed on the upper part of the north wall opposite it. This slit has a modern appearance, but its function is not simply decoration. It plays a key role in the "chimney effect" that drives the operation of the entire system physically. The air density in the courtyard, which is heated by the sun, decreases and naturally rises. It is discharged outward through the narrow slit in the north, while the colder air in the southeast is continuously sucked in and replenished. This "suction" and "row" together shape a stable and strong natural wind pressure difference inside the building. This pressure difference greatly enhances the vertical and horizontal convection of indoor air, thereby creating an efficient, energy-saving, and comfortable natural ventilation environment without consuming one kilowatt hour of electricity. This system is particularly effective in summer, as it can significantly reduce the building's reliance on mechanical refrigeration (air conditioning systems), directly leading to a significant reduction in energy consumption and carbon emissions during the operational phase (See Figure 3). This design thinking that combines natural ventilation with evaporative cooling demonstrates a deep ecological wisdom that collaborates with nature rather than opposing it. It goes beyond the traditional concept of viewing natural elements as a threat, and instead transforms the wind, water, and sun of nature into free and sustainable energy-saving system components inside buildings, ultimately achieving a harmonious unity of building performance, user experience, and environmental protection.



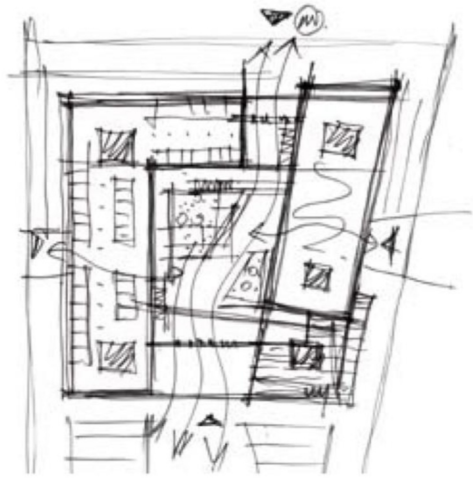


Figure. 3. Conceptual diagram of natural ventilation

4. Facade skin design for sustainable development

The building facade is not made of uniform materials and treatment methods, but is designed differently based on different functional requirements and external environmental influences. The adoption of sustainable materials, such as mass timber, is gaining traction due to its lower environmental impact and recyclability [3]. The lower facade of the building extensively uses energy-saving stone, which has the greatest advantage of excellent thermal inertia. It can effectively store heat and delay the speed of external temperature changes transmitted to the interior, like putting on a "thermal insulation suit" for the building. It plays a crucial role in stabilizing indoor temperature and reducing the frequency of air conditioning start stop. In contrast to the stability of the lower stone, there is a lightweight and modern metal perforated panel maintenance system in the upper part of the building (See Figure 4). This design is not just for the pursuit of visual modernity and lightness, but also hides precise environmental performance calculations behind it. The holes on these metal plates are not uniformly distributed, and their perforation rate (i.e. the ratio of openings to the solid) has undergone rigorous computer simulation and optimization design. The distribution of density is dynamically adjusted according to the intensity of solar radiation received from different positions: in directions with strong solar radiation, the perforation rate is lower to provide better shading effect; In orientations that require more natural lighting, the perforation rate increases accordingly. They are like wearing an intelligent and variable "sunglasses" or "optical veil" on buildings, cleverly balancing the core contradiction of lighting and shading. This system ensures sufficient and soft diffused light indoors, thereby reducing the energy consumption of artificial lighting during the day. At the same time, it efficiently filters and blocks strong direct sunlight from different angles, greatly reducing the building's solar radiation heat from the source and directly reducing the peak load pressure of the internal cooling system.The roof of the building is equipped with three rooftop gardens with a total area of 128 701 m^2, which not only improves the insulation performance of the building, but also creates additional green space, helping to alleviate the urban heat island effect. This facade design strategy of "heavy on the bottom and light on the top" and "solid on the bottom and virtual on the top" is a highly unified combination of function and form, and a perfect combination of aesthetic expression and technical requirements. In addition, exterior wall systems are increasingly being evaluated for their ability to balance energy performance and building costs, further enhancing the economic feasibility of sustainable materials[4].

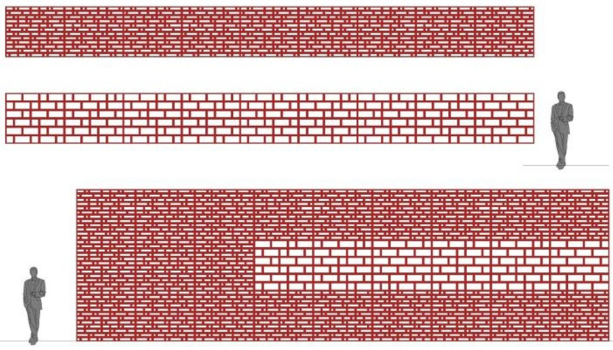


Figure. 4. Detail drawing of metal perforated plate

5. Application of sustainable technology

The "Green Samsung" standard has met strict requirements in six aspects: land conservation, energy conservation, water conservation, material conservation, indoor environmental quality, and operational management, and requires a balance of all aspects without any shortcomings, which is the most difficult technical difficulty to overcome. The sustainable development design of Wuhan Citizen's Home has undergone numerous technical adjustments and data testing and verification, and finally achieved through a set of extremely specific and quantifiable 6 energy-saving and environmental protection indicators and 23 green ecological designs(See Figure 5).

01.sprinkling irrigation of greening;
02.green construction during jobsite;
03.light guide tube;04.greening operation;
05.comprehensive shading system;
06.intelligent monitoring and controlling system;
07.roof greening ; 08.indoor air quality test;
09.indoor natural ventilation; 10.recyclable materials;
11.resource saving structural system;
12.mechanical heat recovery ; 13.energy consumption metering;
14.reinforced curtain wall ; 15.geothermal system;
16.sewage treatment; 17.high performance cold & heat source;
18.energy-saving lighting; 19.rain water re-use system;
20.water-saving appliances; 21.grey water re-use system ;
22.demountable partition; 23.solar energy us

Figure. 5. Main technologies

Water conservation and water resource utilization are important components of the sustainable development design of Wuhan Citizen's Home. The building adopts a comprehensive rainwater collection system, which collects rainwater from the roof and site into underground reservoirs. After treatment, it is used for greening irrigation, landscape water, and bathroom flushing, with an annual rainwater capacity of 15000 cubic meters. All sanitary ware adopts water-saving products, including low flow faucets, water-saving toilets and urinals, which can save more than 30% of water compared to traditional sanitary ware. The landscape design adopts drought resistant local plants, reducing the water demand for greening irrigation. The reclaimed water reuse system collects and treats the greywater generated in the building before reuse, further improving the efficiency of water resource utilization. Through these measures, the utilization rate of non-traditional water sources in Wuhan Citizen's Home has reached 30%, significantly reducing the pressure on the urban water supply system and demonstrating the advanced concept of water resource recycling.

In terms of energy conservation, Wuhan Citizen's Home integrates and applies various advanced technologies. The building adopts an efficient ground source heat pump system, which utilizes the relatively stable temperature characteristics of underground soil to provide heating and cooling services for the building, saving more than 30% energy compared to traditional air conditioning systems. The solar photovoltaic power generation system is ingeniously integrated into the building design, with 5000 m^2 photovoltaic panels laid on the roof to provide basement lighting with a load of 28 kw. The annual power generation can reach about 15% of the total building electricity consumption. Using light guides to reflect direct sunlight to the desired location, 10 light guides are designed on both sides of the south entrance of the building light guide tubes are installed on the six floors over ground, collect natural lights to improve underground lighting. The intelligent lighting system automatically adjusts the lighting intensity through light sensing and personnel movement sensing, maximizing energy savings while ensuring usage needs. The elevator system adopts energy feedback technology to convert the energy generated during the braking process into electrical energy and feed it back to the power grid. The Building Energy Management System (BMS) monitors various energy consumption data in real-time, continuously optimizes equipment operation strategies through data analysis, and ensures that all systems are in the most efficient operating state. The comprehensive application of these technologies has reduced the energy consumption per unit area of Wuhan Citizen's Home by more than 40% compared to similar traditional buildings, truly achieving the goal of energy conservation and emission reduction.

The quality of indoor environment is directly related to the health and comfort of users, and Wuhan Citizen Home has also made many innovations in this regard. The building adopts a carbon dioxide concentration monitoring system, which automatically adjusts the fresh air volume according to the indoor personnel density to ensure that the indoor air quality is always at an excellent level. The total heat exchange fresh air system recovers energy from the exhaust during the ventilation process, ensuring the supply of fresh air and reducing energy loss. All indoor decoration materials are made of low volatile organic compound (VOC) materials, which effectively controls indoor air pollution from the source. The building adopts good acoustic design, and through the optimization of sound-absorbing materials and spatial layout, the indoor noise level is reduced, creating a quiet and comfortable office environment. The natural lighting design maximizes the use of sunlight, not only saving lighting energy, but also providing a healthier lighting environment for indoor personnel.

Operation management is a key link in ensuring the sustained effectiveness of buildings. Wuhan Citizen's Home has established a comprehensive operational management system, including energy management, water resource management, waste management, and other aspects. The building is equipped with advanced building automation systems that monitor and intelligently control all energy consuming equipment in real-time, ensuring that each system is always in optimal operating condition. Regularly conduct energy audits and system adjustments to promptly identify and resolve energy efficiency issues. The photovoltaic intelligent control system can dynamically adjust the operating status of photovoltaic modules based on real-time environmental parameters such as sunlight intensity and temperature, such as changing the tilt angle of the modules or blocking some light, to optimize power generation efficiency and avoid module overheating [5].We have established a garbage classification, collection, and treatment system to promote the recycling and utilization of resources. These management measures ensure that the sustainable performance of Wuhan Citizen's Home can be maintained for a long time, truly achieving the goal of sustainable development.

6. Conclusion

As a public building with demonstrative significance, the sustainable development design practice of Wuhan Citizen's Home shows that sustainable development of buildings is a complete systematic project. It is necessary to consider the entire process from planning, design, construction to operation in a coordinated manner, and to combine innovative thinking with a pragmatic attitude. The actual existence and operation of the Wuhan Citizen's Home eloquently proves that sustainable development is not an unattainable ideal, but a realistic path that can be successfully achieved in large public buildings through careful design, mature technology, and pragmatic attitude. It provides a vivid model worth further research and reference for the design and renovation of public buildings in China and even the world in the future.

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