Journal of World Architecture, 2024, Volume 8, Issue 3
https://ojs.bbwpublisher.com/index.php/JWA
Online ISSN: 2208-3499
Print ISSN: 2208-3480

Application of Key Technologies in Green School Buildings: Taking Sino-German Future City Primary School as an Example

Yang Liu[1], Dong Huang[2]*, Chunhua Yang[2], Jian Zhou[1], Yunda Tang[2]

[1]Jianke EET Co., Ltd., Beijing 100020, China
[2]China Academy of Building Research, Beijing 100020, China

***Corresponding author:** Dong Huang, 1016456900@qq.com

Abstract: Green building is a manifestation of the response to the national "dual carbon" strategy. With the large-scale promotion of green buildings, the country has successively issued multiple evaluation standards for green buildings. Schools are places for preaching, teaching, and solving doubts, and the campus environment plays an important role in improving students' learning efficiency and promoting their physical and mental health. This article is based on the "Green Building Evaluation Standards" GB/T 50378-2019, analyzing and exploring the integration and application of key technologies in green schools, providing reference for green building designers.

Keywords: Green buildings; Energy conservation and environmental protection; Key technologies; High-quality buildings

Online publication: July 11, 2024

1. Introduction

Green building is a type of building that emphasizes environmental protection and sustainable development. It offers advantages such as reducing carbon emissions, promoting sustainable resource utilization, reducing energy and water waste, and improving indoor air quality compared to traditional buildings [1]. Green buildings are high-quality buildings that save resources, protect the environment, reduce pollution, provide people with healthy, applicable, and efficient usage space throughout their entire lifecycle, and maximize the harmonious coexistence between humans and nature [2]. With the increasingly prominent issues of global climate change and environmental sustainability, green building design and green energy-saving buildings have become important ways to address these challenges. Research shows that the satisfaction level of green buildings is much higher than that of traditional buildings, indicating that the energy-saving effect of green buildings is remarkable [3].

Singapore is an active pioneer in green building and has introduced different green building policies at different stages of its development [4]. Africa actively promotes the development of green buildings, and the coverage of green building research in Africa is in line with the global level [5]. Southeast Asia is located in the tropics and is affected by the tropical monsoon climate. The proportion of refrigeration demand is high, and renewable energy is easy to obtain. In the application of green building technology, the building envelope structure, equipment, renewable energy, water conservation, greening, etc. are all key factors [6]. Abdelaal *et al.* conducted a survey on multiple stakeholders in the green building industry in New Zealand using a questionnaire, and the results showed that these stakeholders had sufficient knowledge and positive attitudes towards green building design and certification [7]. Ohueri *et al.* used quantitative research methods to investigate 180 architects in Malaysia and analyzed factors using factor analysis. They identified the best method for implementing BIM processes in green building design practices, which can assist architects in delivering buildings with high sustainability [8].

China's green buildings have entered a stage of comprehensive development, and the level of green building technology is constantly improving, showing a trend of benign development. Green school buildings are guided by the theory of sustainable development, creating a healthy, safe, green, and environmentally friendly environment for teachers and students, which is more conducive to the physical and mental health of students. In terms of optimizing the design of school buildings, Deng *et al*. used Revit software to optimize the design of Shuiquan Primary School and Kindergarten in Tai'an City. The school project was rated from four aspects: wind environment, light environment, HVAC, and sound environment, ensuring that the project reached a two-star rating [9]. Ding proposed that for schools, the overall layout, indoor and outdoor teaching and activity spaces of primary and secondary school buildings should be improved and designed according to the needs of different groups and terrain environments, in order to create a high-quality educational space environment that is in line with the times [10]. Fu *et al.* took Kaiyuan Middle School in Hangzhou as an example and proposed a suitable technical system for the green renovation of existing school buildings. By optimizing the building and site, the outdoor sound, light, and thermal environment were improved. By reducing energy and water consumption through HVAC systems, water supply and drainage systems, lighting, and energy consumption monitoring systems, renewable energy was utilized to reduce carbon emissions [11].

2. Standard requirements

The Green Building Evaluation Standards is a specific practice in the field of green development in China, aimed at implementing the concept of green development and promoting high-quality development of green buildings [12]. In 2019, the Ministry of Housing and Urban Rural Development issued the "Green Building Evaluation Standards" (GB/T 50378-2019), which clarified the green building evaluation index system, mainly including five categories of indicators: safety and durability, health and comfort, convenience, resource conservation, and livability.

3. Project overview

The Sino-German Future City Primary School construction project is located in the Hongshiya Street Office of Huangdao District, Qingdao City, south of Tuanjie Road and east of Kunlun Mountain Road. The total land area is 33468 m^2, with a total construction area of 29366.66 m^2. The main functions include the primary school comprehensive building, multifunctional hall, sports activity center, equipment room, generator room substation, guard room, and underground parking lot.

4. Key technologies

4.1. Safety and durability

"Safety and durability" refers to the enhanced durability measures that need to be considered in the design stage of buildings, which have stronger guidance for building design and are easier to operate in the evaluation of green buildings [13]. The basic requirements for safety and durability include site safety, structural safety, external shading, and the safety and durability design of internal facilities, fundamentally eliminating safety hazards. Green building technology is elaborated from two aspects: safety and durability.

(1) Safety

The location of the project site is safe with no risk of radioactive contamination. Invisible anti-theft nets are installed to improve the security of the windows. Door hoppers and canopies are installed at the entrances and exits of the building to prevent accidental detachment of door and window glass, which may affect pedestrian safety. Green isolation belts are reasonably set up around buildings as buffer zones to increase pedestrian safety. Door and window glass selection complies with the "Technical Regulations for Building Applications" (JGJ 113-2015) [14] and the "Management Regulations for Building Safety Glass" (Development, Reform, and Operation No. 2116) [15]. Outdoor lighting should follow the "green lighting" principle to meet environmental and energy conservation standards. The outdoor lighting control system is divided into multiple circuits based on system distribution and functional requirements, allowing for flexible scheduling according to the season for ease of maintenance and management. All equipment and materials selected for outdoor lighting have a testing certificate (3C certification) from the National Testing Center.

(2) Durability

The project includes adaptive indoor functions, with comprehensive activity spaces on each floor of the teaching building. These spaces can be divided into different functions according to teaching needs to support daily teaching and student activities. A folding stand is set up on the mezzanine of the sports activity center, serving as an activity space in daily life. During school events, it provides sufficient space for the audience, enhancing space utilization. Water supply and drainage, as well as electrical equipment, should use pipes, pipelines, and pipe fittings that are corrosion-resistant, aging-resistant, and durable. The durability of the structure is improved by increasing the thickness of the steel reinforcement protective layer, and the thickness of the concrete protective layer is increased by 5 mm beyond the requirements specified in the "Code for Design of Concrete Structure" [16]. External decorative materials should be durable, and waterproof and sealing materials must have green product certification to meet durability requirements. Interior decoration materials should be made of wear-resistant materials.

4.2. Health and comfort

Health and comfort fully encompasses the principles of healthy buildings, emphasizing the impact of decoration materials, water quality, indoor acoustic environment, hot and humid environment, natural ventilation, thermal comfort, and other factors on human health. The design for health and comfort should elaborate on aspects such as indoor air quality, water quality, sound and light environment, and hot and humid environment.

(1) Indoor air quality

Measures to ensure excellent indoor air quality involve adopting green products, reducing indoor air pollutants, and ensuring that the air quality meets the requirements of current national standards.

(2) Water quality

Disinfection facilities are installed in the domestic drinking water pool (water tank). The water supply facilities are cleaned and disinfected before use, and the water quality is regularly inspected to ensure it meets standard requirements. This project includes a rainwater collection and reuse system, with separate pipelines for rainwater reuse and domestic water applications. The outer wall of the rainwater reuse pipeline should be painted or marked according to relevant standards. The water tank, valve, water meter, water supply hydrant, and water intake should all have clear "rainwater reuse" signs. The fire hydrant pipeline is red, with a red ring mark on the sprinkler pipeline. The fire hydrant pipeline should be marked "fire hydrant," and the sprinkler pipeline should be marked "spray."

(3) Sound and light environments

The indoor sound environment is excellent, with environmental noise levels at 32.83 dB. The soundproof performance of the main functional rooms also meets the requirements. Shading facilities are reasonably set up to prevent glare. Regarding the indoor hot and humid environment, research [17,18] shows that significant deviations from design parameters in indoor temperature and humidity can lead to Sick Building Syndrome (SBS). Excessive indoor temperatures can cause symptoms such as headaches and throat discomfort, while low indoor temperatures can lead to high levels of dissatisfaction among occupants. Reasonably controlling the opening area of external windows can effectively enhance natural ventilation. Adjustable external shading are used to improve indoor comfort during summer.

4.3. Convenience

The ultimate goal of architecture is to serve people. Research shows people spend 90% of their time indoors [19], so various serves should be available in their surroundings for better convenience. Convenience primarily reflects the needs of occupants for public transportation facilities, bicycle parking, accessibility, fitness facilities, intelligent detection systems, and other aspects.

(1) Accessible public transport

There are two bus routes within 800 meters of the site, making transportation convenient. A coherent barrier-free facility is created both inside and outside the venue.

(2) Service facilities in the surrounding area

The school's swimming pool, wind and rain playground, and outdoor playground are open to the public on holidays, aiming to provide convenient amenities for nearby residents. Engaging in sports and fitness activities can significantly enhance cardiovascular health, muscle strength, flexibility, balance, and overall physical fitness, thereby improving overall health levels. To support these activities, the project includes well-planned indoor and outdoor fitness facilities [20]. The outdoor fitness area spans 10,468 m² and includes amenities such as basketball courts, volleyball courts, and a circular track. Indoors, there is a 1,208 m² fitness space equipped with a windproof playground and a swimming pool. These facilities are designed to cater to diverse fitness needs and promote a healthy lifestyle for the community.

(3) Intelligent operation

the project implements a building energy efficiency supervision platform that complies with the "Technical Specification for Energy Monitoring System of Public Buildings" (DBJ/T14-071-2010). This platform facilitates statistical analysis of electricity, water, cooling, and heating consumption within the building. It provides targeted energy-saving management recommendations based on consumption patterns. Electricity monitoring includes sub-item monitoring of electricity from the low-voltage distribution system's outgoing side and floor-level electricity monitoring. The system categorizes electricity into lighting, sockets, air conditioning, general power usage, and specialized areas. Additionally, PM_{10}/$PM_{2.5}$/CO2 three-in-one air quality sensors are installed in the building to monitor indoor environmental parameters continuously. The system collects front-end water meter data through a data collector to measure municipal water supply, total water consumption per unit, and usage in specific areas such as restaurants. An online water quality monitoring system is established to monitor tap water and rainwater quality indicators in real-time.

4.4. Resource conservation

Resource conservation mainly includes several aspects, including land use and conservation, energy conservation and utilization, water conservation and utilization, and material conservation and using green building materials. Through resource conservation, the rational utilization of energy resources can be achieved.

(1) Energy conservation and utilization

The thermal performance of the building envelope is designed to meet the requirements of ultra-low energy consumption standards. Compared to conventional buildings, HVAC load is reduced by 63%, with an additional reduction of over 20% in remaining energy consumption. Cold and heat sources employ ultra-low temperature screw air-cooled heat pump units and air-cooled heat pump units, effectively saving energy.

For lighting, while ensuring design illuminance and quality, compact fluorescent lamps, circular fluorescent lamps, T5 straight tube fluorescent lamps, or LED lamps are typically used in general areas. Metal halide lamps or LED lamps are chosen for larger spaces or outdoor areas, prioritizing high efficiency and meeting glare limitations and lighting standards.

The project implements a centralized hot water system using renewable energy sources. A large solar energy collector and low-temperature air source heat pump are installed on the roof to provide hot water. Solar energy primarily heats domestic shower water, supplemented by air-source heat pumps. The system aims for a 45% guarantee rate from solar energy, with scheduled daily hot water supply maintaining a temperature of 60°C for water supply and 50°C for return water.

(2) Water-saving and water resource utilization

The water efficiency level of all water appliances reaches level 1, and water-saving irrigation is used for outdoor greening irrigation. Rainwater collection and reuse facilities are set up for greening irrigation, garage and road flushing, and car washing.

(3) Material conservation and green building materials

All parts of the building are designed and constructed using an integrated approach of civil engineering and architecture. The proportion of ordinary steel bars with a stress level of 400 MPa or above is 96.7%, and the proportion of green building materials application reaches 50%.

4.5. Livability

Livability prioritizes human well-being by creating a healthy and enjoyable environment at the site. This approach focuses on factors such as sunlight, thermal comfort, outdoor greenery, sound quality, wind conditions, and mitigating heat island effects. By optimizing these elements comprehensively, a livable environment is cultivated for residents.

(1) Site ecology and landscape

The project achieves a green space rate of 20%, enhancing the ecological foundation with a combination of trees and shrubs. It maintains a total annual runoff control rate of 85%. Public green spaces are accessible to enhance the overall green environment for community enjoyment.

(2) Outdoor environment

The outdoor sound environment meets Class 2 standards, ensuring minimal noise disturbance. The visible light reflection ratio of the curtain wall is carefully controlled to prevent light pollution. Optimal building layout contributes to a favorable outdoor wind environment.

4.6. Improvement and innovation

Improvement and innovation in construction involve adopting advanced, practical, and cost-effective technologies, products, and management methods at various stages of construction. These efforts aim to enhance performance and integrate innovative technologies, marking significant advancements in construction practices and technology. Key aspects include further reducing HVAC energy consumption, integrating regional architectural heritage, designing green spaces thoughtfully, promoting industrialized construction, implementing BIM technology, adopting green building practices, and ensuring engineering quality through defect insurance. These advancements enable buildings to better embody principles of green and low-carbon development, fostering sustainable and environmentally responsible construction practices.

By adopting efficient cold and heat sources and equipment systems, the energy consumption of HVAC can be reduced by more than 40% compared to current standards. The entire process applies building information model (BIM) technology to achieve information sharing and collaborative work. During the design phase, the entire process of building carbon emissions is carried out to effectively control the amount of building carbon emissions. After sorting out the evolutionary process of the development of primary education architecture at home and abroad, this project shares the three educational cores of art, reading, and sports with the public, making the educational community more socially significant and providing more platforms for communication and sharing for the growth of young people. Provide independent and shared community-based campuses for minors of different ages.

5. Conclusion

This project actively innovates and practices the construction concept of green, low-carbon, and ecological protection, and the ecological standards meet the requirements of the new era. Choosing and implementing appropriate green building measures based on local and project conditions not only saves costs but also achieves the expected results. The materials selected for green building design in this project can serve as a reference and model for future architectural design in other projects, for reasonable comparison and promotion.

Disclosure statement

The authors declare no conflict of interest.

References

[1] Ministry of Housing and Urban Rural Development of the People's Republic of China, 2019, Green Building Evaluation Standards, GB/T 50378-2019, viewed June 14, 2024.

[2] Li R, Wang R, 2017, Analysis of Building Energy Efficiency Design in Xizang: Taking the Small Enterprise Incubation Base in Qushui Industrial Park as an Example. Green technology, 2017(2): 111–114.

[3] Zhang Y, He Z, 2020, Brief Analysis of the Development and Application of Green Building Design and Green Energy-Saving Buildings. Iranian Journal of Science and Technology-Transactions of Civil Engineering, 48(2): 1131–1141.

[4] Li Y, Liu Z, Li C, 2022, Review of Government Strategies on Green Building in Singapore. Journal of Green Building. 17(4): 219–241.

[5] Mushi FV, Huba N, Kihila J, 2022, A Critical Review of African Green Building Research. Building Research and Information, 50(6): 610–627.

[6] Lai F, Zhou J, Lu L, et al., 2023, Green Building Technologies in Southeast Asia: A Review. Sustainable Energy Technologies and Assessments, 55: 102946.

[7] Abdelaal F, Guo BHW, 2021, Knowledge, Attitude and Practice of Green Building Design and Assessment: New

Zealand Case. Building and Environment, 2021(201): 107960.

[8] Ohueri CC, Bamgbade JA, Liew ASC, et al., 2022, Best Practices in Building Information Modelling Process Implementation in Green Building Design: Architects' Insights. Journal of Construction in Developing Countries, 27(1): 79–93.

[9] Deng Y, Xiao S, Sun Q, et al., 2022, Integrated Optimization Design of School Buildings Based on Green Building Technology: A Case Study of Shuiquan Primary School and Kindergarten in Tai'an City. Journal of Shandong Agricultural University (Natural Science Edition), 53(6): 941–946.

[10] Ding J, 2024, Research on Planning and Design of Primary and Secondary School Buildings: Taking the Project of Yuexi County Chengxi Compulsory Education School as an Example. Anhui Architecture, 2024(02): 26–27 + 79.

[11] Fu W, Cong L, Shen J, et al., 2024, Research on the Suitability Technical System for Green Renovation of Existing School Buildings: Taking Kaiyuan Middle School in Hangzhou as an Example. Urban Architecture, 2024(02): 144–148.

[12] Li Z, Wu K, Cao J, et al., 2024, Comparative Study of Evaluation Standards for Green and Low Carbon Buildings between China and Foreign Countries: A Comparative Study of Evaluation Standard Systems between China and Germany. Construction Technology, 2024(07): 58–60 + 72.

[13] Zhang Y, 2023, Research on the Application of Green Ecological Technology: Taking a Residential Project in Baoding City as an Example. Green Buildings.2023(4): 40–42.

[14] Ministry of Housing and Urban Rural Development, 2015, Technical Regulations for Building Applications, JGJ 113-2015, viewed June 14, 2024.

[15] National Development and Reform Commission, 2003, Notice on Issuing the Regulations on the Management of Building Safety Glass, viewed June 14, 2024. https://www.ndrc.gov.cn/fzggw/jgsj/yxj/sjdt/200511/t20051128_987828.html

[16] Ministry of Housing and Urban Rural Development, 2015, Design Code for Concrete Structures, GB 50010-2010 (2015 Edition), viewed June 14, 2024.

[17] Fang L, Wyon DP, Clausen G, et al., 2004, Impact of Indoor Air Temperature and Humidity in an Office on Perceived Air Quality, SBS symptoms and performance. Indoor Air, 14(7): 74–81.

[18] Sekhar SC, 2016, Thermal Comfort in Air-Conditioned Buildings in Hot and Humid Climates – Why are We Not Getting it Right? Indoor Air, 26(1): 138–152. http://dx.doi.org/10.1111/ina.12184

[19] Jin M, Liu S, Schiavon S, et al., 2018, Automated Mobile Sensing: Towards High-Granularity agile Indoor Environmental Quality Monitoring. Building and Environment, 127: 268–276.

[20] China Sports Daily, 2017, Interpretation of the National Fitness Guide, General Administration of Sport of China, viewed June 14, 2024. https://www.sport.gov.cn/n315/n331/n405/c819327/content.html