Application and analysis of the suitability of green building technologies for school in hot summer and cold winter region: A case study from Zhejiang Province

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Abstract. With the rapid development of school buildings in China during recent years, the preferential selection of appropriate technologies has important guiding significance for the high-quality development of green school buildings. This study took Zhejiang Province as a case example, which was in hot summer and cold winter region. The quantity and type characteristics of green schools were analyzed. The application of green building technology for schools in Zhejiang Province was then analyzed and finally, based on the maturity of technology application and star application, the appropriate green school building technology for different situations was summarized and proposed. The results can provide technical guidance for the design of green schools in hot summer and cold winter region.

Keywords: Green school; Suitability; Green building technology; Zhejiang.

1. Introduction

At the end of 2018, the urbanization rate of China's resident population reached 60%, and the nation's urbanization process entered a new stage of people-oriented scale and quality. The current growth model of China's urban and rural construction, however, is still dominated by crude growth in which the quality of development is not high, and building life cycles demand high resource consumption where energy-saving functions still require improvement. It is important, therefore, to promote green and low-carbon development in construction for the transformation and upgrading of the industry. Green building refers to a construction type that meets the Green Building Evaluation Standard (GB/T 50378-2006). It maximizes energy savings, land-use savings, water savings, and material savings for the whole life cycle of the building, while protecting the environment and reducing pollution in its construction, and providing people with a healthy, suitable, and efficient space that enables them to live in harmony with nature.

In related studies on green building technology, Wu et al. [1] found that the development of green building technology (GBT) has occurred differentially among the cities of Zhejiang Province, but the overall incremental cost shows a downward trend. Darko et al. [2] interviewed 33 green building experts through a questionnaire survey and found that the most critical obstacles to the promotion of GBT were a resistance to change, a lack of knowledge and/or awareness, and higher costs. Ge et al. [3] evaluated 37 common GBTs based on 43 green housing certification cases to provide clear guidelines for the selection of GBT for affordable housing." Dwaikat et al. [4] pointed out that the incremental cost of more than 90% of green building technologies is between -0.4% and 21%, and the overall cost of green building is lower than that of traditional building. Qian et al. [5] concluded that the main obstacle to the development of the green building market is transaction cost, where unreliable developers and technologies will lead to a reduction of income.

In the context of the large-scale expansion of school buildings, green buildings are of major significance to high-quality development. Not only does the green and low-carbon development of school buildings effectively ensure the satisfaction of teachers, students and school efficiency, it also reduces the energy consumption in running the school. Climatic variation produces considerable differences in the application of technologies for green school buildings in different regions, so it is necessary to summarize the existing experiences of green school building development to provide references for its future design and development.

2. Methods

The study takes Zhejiang Province as an example to analyze the characteristics of green school development: the region is hot during summer and cold during winter. The application of green school building technologies in the region is counted and analyzed, and recommendations are proposed based on the maturity of the technology application.

The study collected information on all 72 green building projects in Zhejiang Province from 2008 to 2019, which included the following two aspects: 1) basic information on green buildings including certification time, certification star, location, etc., and 2) the application of green building technology. Taking 18 green schools from the province as examples, the application of green building technology was counted, and the statistical information was divided into six areas of technology utilization based on the green building evaluation standards [6]: land-use savings, water savings, energy savings, material savings, indoor environmental quality, and operation management. Construction was excluded in this study.

3. Results & Discussion

3.1 General situation

At the end of 2019, a total of 72 school building projects in Zhejiang Province had received the logo certification (Figure 1). In terms of total number and time, only 25 school buildings in received logo certification from 2008 to 2016. During this time, the development of green buildings was in the initial stage marked by a slow growth rate. After 2015, the annual increment of school-type green building projects kept expanding, and especially so during 2017, when the increment reached 22 schools. In terms of stars, the total number of one-star, two-star, and three-star green buildings are 25, 37, and 10, respectively (Figure 2). The total number of two-star buildings is the largest, the total number of one-star buildings is the second largest, and the total number of three-star buildings is the least, forming less than 13.9% of the total.

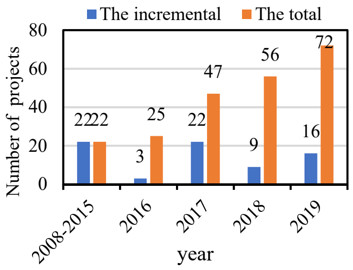


Figure 1. Development of green schools in Zhejiang Province

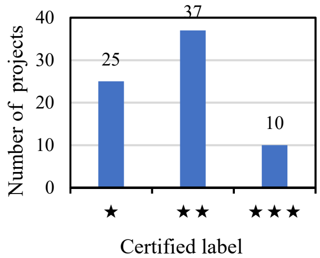


Figure 2. Star distribution of green schools in Zhejiang Province

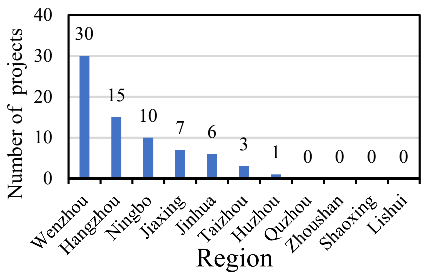


Figure 3. Geographical distribution of green schools in Zhejiang Province

In terms of geographical distribution, seven out of 11 cities in Zhejiang Province have green school building projects, but there is a wide gap in the development rate among different regions (see Figure 3). Wenzhou, Hangzhou, and Ningbo all have more than 10 green school projects, accounting for 76.4% of the total number in Zhejiang Province. Among these cities, Wenzhou has 30 green school projects, accounting for 41.7% of the total in Zhejiang. Jiaxing, Jinhua, Huzhou, and Taizhou are the other four prefecture-level cities with green school buildings, but the cumulative number for these cities is small. Lishui, Quzhou, Shaoxing, and Zhoushan do not even have school-based green building projects. The statistical results show that there is an imbalance in the development of school-based green buildings in Zhejiang, and green buildings are mainly concentrated in relatively developed areas, which indicates that there is still great potential for development in Zhejiang.

3.2 Application of green building technology for schools

Statistical analysis of the detailed technical application data obtained from 18 green school projects in Zhejiang Province was undertaken in reference to seven categories based on the GB/T50378-2014 Green building evaluation standard, as shown in Figure 4: land-use savings, energy savings, water savings, material savings, indoor environment quality, and operation.

In terms of land-use savings, the application of noise-reducing permeable pavement and compound greening among projects is high, at 50% and 94%, respectively. Of the selected projects, 28% have adopted vertical greening and rooftop greening, while the use rate of underground space is less than 30%.

In terms of energy savings, all sample buildings adopt energy-saving lighting and high-efficiency equipment technologies, while solar hot-water technology, openable curtain walls, and sub-metering management have a high use rate of over 70% among projects. The use rate of solar photovoltaic power generation, ground-source heat pumps, air-source heat pumps, retaining structure performance, and heat recovery practices are all low.

In terms of water savings, purpose-built appliances, water supply and drainage design, and graded metering water meters have a use rate of 100%, while rainwater recycling systems have a use rate of 94%, basically achieving complete application.

In terms of material savings, the decrease of shape coefficient of building, ready-mixed concrete, high-strength steel application, and integrated design and construction practices were recorded for more than 88% of the projects, while the adoption rate of recyclable materials and usable space was relatively low.

In terms of indoor environmental quality, the use of natural lighting and ventilation, wall insulation technology, noise and vibration reduction, and barrier-free equipment have been recorded for more than 90% of projects. There is only 44% usage in air purification and monitoring equipment, while the use rate of adjustable external shading is low, at 11%.

In terms of operation management, the use rate of intelligent systems, efficient maintenance, and operation of equipment systems and sub-metering in residential buildings is high. By contrast, the use rate of monitoring equipment, good management systems, and building information modeling (BIM) technology is less than 30%.

The use rate of individual technologies forms the basis for further analysis. A higher adoption rate, as determined by percentage, means that the promotion, maturity, and suitability of the technology is greater. For further analysis, the scoring item technical elements are divided into basic technology (BT), reinforced technology (RT), and improved technology (IT).

The green building technologies with a use rate of more than 75% were defined as a basic technology. The proportion of these is very high, and the technologies have strong applicability to different characteristics of school buildings. Reinforced technology refers to the green building technology with a selection ratio greater than or equal to 50%, but less than 75%, totaling two examples. Improved technology is more mature and refers to green building technologies with a use rate of less than 50%, of which there are 14 examples. The use rate of such technologies is low, and the technologies and products may have limitations or be costly in the design, construction, and/or introduction into school buildings. The actual use rate of each technology, measured as 'basic', 'reinforced' and 'improved' for each of the 18 projects, was calculated and classified according to its star rating. The results are shown in Figure 5.

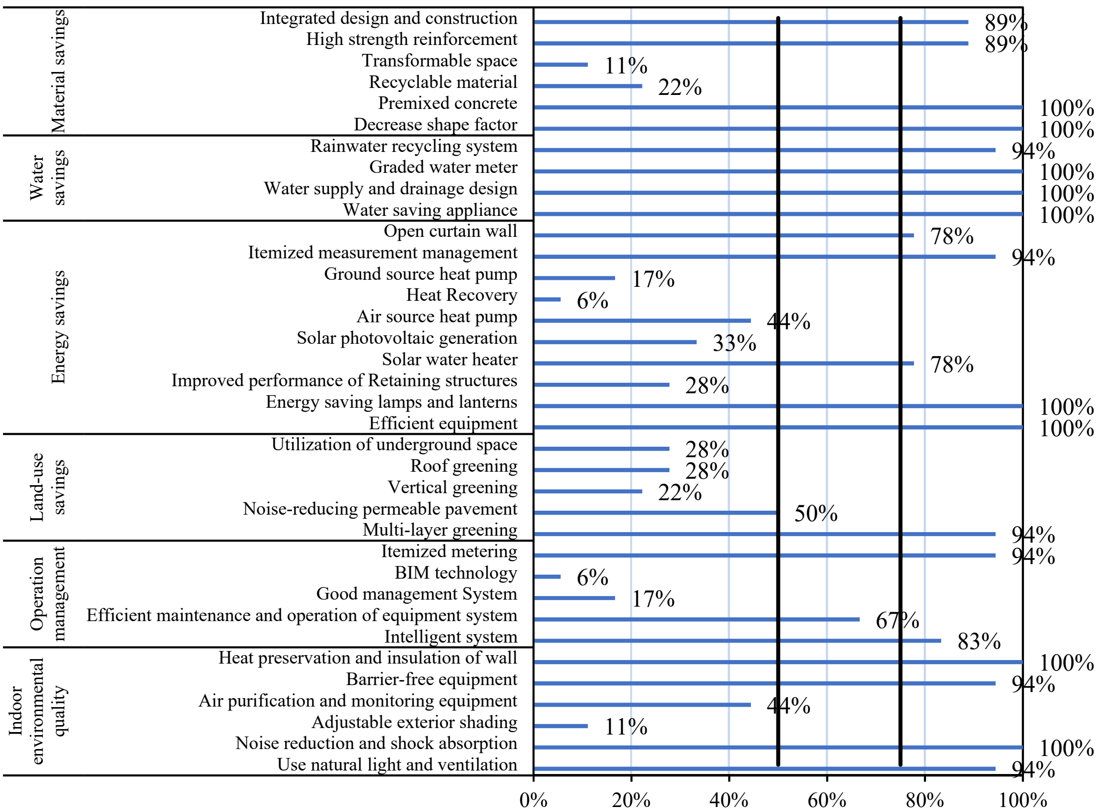
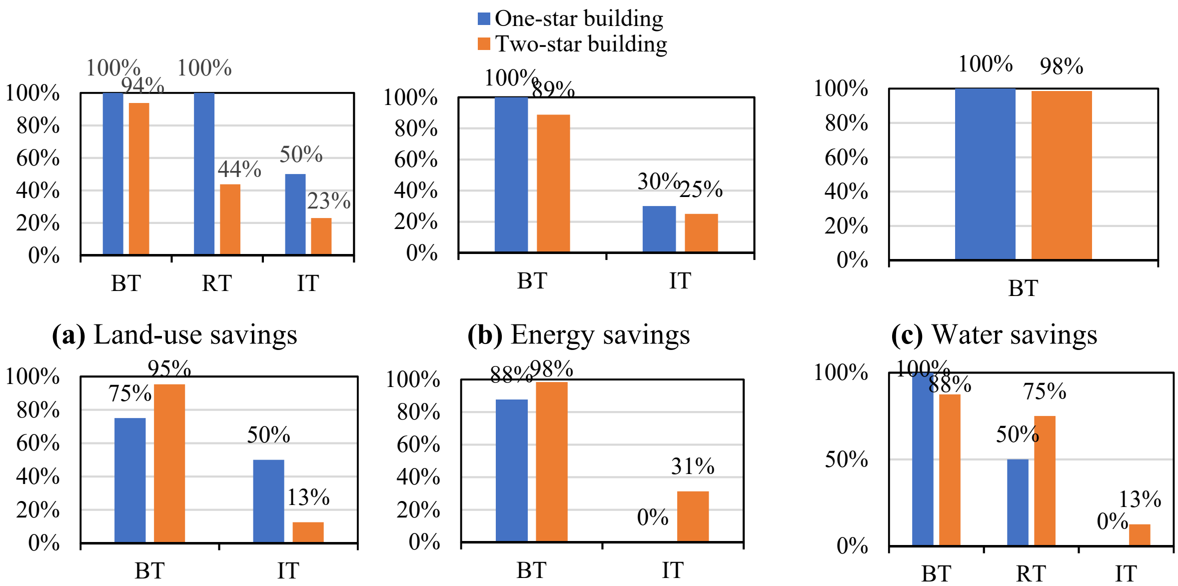


Figure 4. The use rate of green school building technologies in Zhejiang Province according to GB/T50378-2014 categories



(a) Land-use savings **(b)** Energy savings **(c)** Water savings

(d) Material savings **(e)** Indoor environmental quality **(f)** Operation management

Figure 5. Comparison of green building technology adoption in star-certified buildings (BT: basic technology; RT: reinforced technology; IT: improved technology)

Figure 5 shows the use rate results for green building technologies in star-certified buildings. Among the basic technologies, the proportion of technical measures used in each green building category for both one-star and two-star schools is higher than 75%. For reinforced technologies, the proportion of technical measures used in the operation and management category of two-star green buildings is significantly higher than for one-star green buildings. But in the category of land savings, the proportion of technologies used in two areas is higher for one-star buildings than for two-star buildings. As for the improved technologies, the proportion of one-star green buildings using land and material savings is higher than that for two-star green buildings. And there is not much difference between the two in the proportion of energy-saving technologies, while none of the selected one-star green buildings use appropriate technologies for indoor environmental quality and operation management.

4. Conclusions

This study analysed the quantity and type characteristics of green school development in Zhejiang Province as an example. Following this, the application of green school building technology for the province was counted and analysed. Based on the maturity of technology application and the star certification, the suitable technology type for schools was summarized.

The number of green school projects in Zhejiang Province has steadily increased over the past few years, but examples are still mainly one- and two-star projects, while there are fewer three-star projects. In terms of geographical distribution, examples are mainly concentrated in relatively developed area. In general, basic technologies have a high degree of universality and maturity, with a use rate of over 85% among both one- and two-star buildings, while the use rate of reinforced and improved technologies increases with an increase in the star rating of the green building. In constructing green school buildings for hot summer and cold winter region, the selection of relevant technologies should be made according to star rating, with one-star buildings targeting the use of basic technologies with high technical maturity, and if there are requirements for two-star or higher buildings, reinforced and improved technologies should be considered.

Acknowledgments

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References

[1] Wu, J., Weng, J.T., Teng, F.S., et al. (2021). The state of green building development and technology application in Zhejiang Province. Science & Technology Review, 39(15): 117-123. (In Chinese)

[2] Darko, A., Chan, A.P.C., Ameyaw, E.E. et al. (2017). Examining Issues Influencing Green Building Technologies Adoption: The United States Green Building Experts' Perspectives, Energy and Buildings, 144: 320-332.

[3] Ge, J., Zhao, Y.J., Luo, X.Y. et al. (2020). Study on the suitability of green building technology for affordable housing: A case study on Zhejiang Province, China. Journal of Cleaner Production, 275: 122685.

[4] Dwaikat, L.N., Ali, K.N. (2016). Green buildings cost premium: A review of empirical evidence. Energy and Buildings, 110: 396–403.

[5] Qian, Q.K., Chan, E.H.W., Visscher, H., et al. (2015). Modeling the green building (GB) investment decisions of developers and end-users with transaction costs (TCs) considerations. Journal of Cleaner Production, 109: 315–325.

[6] Ministry of Housing and Urban-Rural Development of the People's Republic of China, General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, (2014). Assessment standard for green building GB/T 50378— 2014, Beijing, China building industry press. (In Chinese).