Analysis And Prospects on The Construction of High-Rise Green Buildings

Boyu Yuan*

Houston International Institute, Dalian Maritime University, Dalian, China

* Corresponding Author Email: yby001105@dlmu.edu.cn

Abstract. Green building basically refers to environmentally friendly building. At present, green buildings still make up a small share of the global construction industry. At the same time, high-rise buildings are growing in densely populated places, but these buildings consume a lot of energy and resources. Therefore, the green high-rise building is very important. Based on relevant researches, this paper analyzes the design and construction of high-rise green buildings from the aspects of technology, material and economy, taking Shanghai Tower as an example. This paper also argues that advanced computer technology will appear more and more in the future construction projects. High-rise green buildings should minimize the impact on the environment, but also pay attention to the impact of the environment on the building. In addition, adequate investigation and analysis should be carried out to ensure that green technologies are suitable for local climate and resource characteristics. In order to create a good environment for the development of green building, it is necessary for all relevant departments of society to cooperate and reduce the cost of green building. The future development of green buildings still depends on the development of relevant technology, research and education. While ensuring the performance of the building, it is necessary to find more environmentally friendly and cheaper structures and materials as a solution.

Keywords: Green building; high-rise building; green building design; building construction; green building technologies.

1. Introduction

Green building is a continuously changing concept. The meaning varies among districts and countries due to the difference of climate, culture, history, economic condition, etc. [1]. However, it is for certain that green building basically refers to a kind of constructions that is less harmful to the environment and has a better resource conservation ability. According to relevant researches, the total resource consumption of the buildings in China occupies approximately 30% of the gross domestic resource consumption [2]. Definitely, the building industry is a giant of resource consumption. As the rapid development of global construction industry and the increasing of environmental problems, in the coming future, green buildings will have a high possibility of becoming a focus of the industry. It has been proved that green buildings are beneficial to environmental protection and resource conservation, and also have positive social influence. In US and other countries, green buildings with Leadership in Energy and Environmental Design (LEED) certification show a 25% reduction of energy consumption and a 21% reduction of water consumption [1]. Nowadays, although some countries have published green building certification standards and incentive policies, generally speaking, green building still occupies a limited part of the global construction [1].

High-rise buildings, according to China's current code for fire protection design of buildings, refer to residential buildings with a height of 27m or more, as well as non-single-floor workshops, warehouses and other civil buildings with a height of 24m or more, in which those with more than 100m height are called super high-rise buildings [3]. From the perspective of current global building situation, high-rise buildings will continuously develop in the places with high population density in the future. High-rise buildings increase the utilization rate of urban land, and promote relevant technologies development as well. However, high-rise buildings also have some inevitable drawbacks, and the most important one is the large consumption of energy and resources. Therefore, in the current time when environmental protection requirements become stricter, the greening of high-rise buildings is particularly important.

Since the 21st century, more attention has been paid to green buildings, especially to high-rise green building (HRGB). The researches and analysis of this kind of buildings are necessary. This article, from the perspectives of technology, material, as well as economy, analyzes the design and construction of HRGBs with some relevant researches and the case study of Shanghai Tower. Based on this, this paper puts forward the prospects and suggestions for the future development of HRGB industry and related researches.

2. Case Study of Shanghai Tower

There are many HRGB cases, in which one of the most representative cases is the Shanghai Tower project. Shanghai Tower, located in the core area of Lujiazui business zone in Shanghai, is a super HRGB integrating offices, a hotel, and sightseeing places, etc. It is also one of Shanghai's landmark buildings. With a height of 632m and 119 floors, the building adopts a number of advanced green building technologies, and has been awarded the China three-star green building Designation as well as the US LEED Certification. According to the environmental impact report of Shanghai Tower, the comprehensive energy saving rate of the building is more than 60% [4].

2.1. Construction and Material

Shanghai Tower adopts the design of double-layer glass curtain walls (as shown in Fig. 1). 25% colored glazed glass is used for the exterior curtain wall and low-radiation insulating glass is used for the inner curtain wall. A temperature buffer between the inner and exterior walls is formed, which has the function of heat preservation and insulation. In terms of foundation construction, the building adopts a cylindrical, none-inner support, deep foundation pit with an 123m outer diameter and 31m depth, reducing the environmental pollution caused by the demolition of the enclosure structures. Large-diameter filling piles with a diameter of 1m and a depth of 56m are used to avoid the squeezing effect of precast piles and reduce the environmental impact. The application of post-grouting technology not only increases the pile carrying capacity by 50%, but also reduces the material consumption [5].

At the top of Shanghai Tower, 54 vertical turbine wind generating sets are placed for the top landscape lighting, which alleviates the pressure of public power supply [5]. The Tuned Mass Damper (TMD) system of the building is a highlight. On the basis of the traditional viscous damping TMD system, Shanghai Tower innovatively applies the magnetic eddy current technology to it, which not only reduces the abrasion of the entire system as well as the mass of the dampers, but also reduces the cost, providing a new solution to the shock absorption problem for the future HRGB projects [5].



Fig. 1 The structure of Shanghai Tower's double-layer glass curtain walls [5]

2.2. Design and Technologies

In terms of building design, the Building Information Modeling (BIM) technology is adopted to the architectural design of Shanghai Tower. This technology integrates project information with computers, which can realize information sharing among different departments. If problems occur during the construction process, relevant staffs can find and deal with them in time [4]. During the construction process, six data collection stations are set up to the overall structure to realize real-time monitoring of vertical deformation, lateral deformation, wind load, etc., which ensure the quality of each construction detail [5].

Shanghai Tower applies the wind resistance technologies based on aerodynamics. The exterior wall irregularly distorts 1° every time the height is raised by 1 floor, resulting in the unique external shape of the building (as shown in Fig. 2). This also reduces the overall building wind load by about 25% compared with buildings of the same height [4]. The CO2 monitoring system is used as well, which is able to regulating the air flow rate of the primary air system depending on the real-time monitoring of the number of people in the building. The internal energy consumption monitoring system is capable of real-time monitoring of equipment condition and warn when energy consumption exceeds the standard as well [4].



Fig. 2 The external shape of Shanghai Tower (Photo credit: Original)

3. Prospects

Although only one HRGB case cannot fully reflect the current situation of the whole green building industry and more researches are still needed, it is almost certain that the Shanghai Tower project is worthy of reference and a beacon of the future HRGB development. Shanghai Tower use innovative technologies in several aspects of design and construction, achieving the goal of saving materials and costs. According to the results of this building project, it is concluded that the HRGB project can achieve higher resource conservation and environmental protection requirements by implementing the green building concept in many aspects. Specifically, in the process of HRGB design and construction, the green building concept can be applied to the exterior walls, interior spaces and so on.

3.1. Industry Development

Obviously, in the future HRGB projects, especially super HRGB projects, the application conditions and frequency of BIM and other advanced computer technologies will become more and more. Through adopting these technologies, problems can be found and solved in time, saving manpower and resources. The design and construction of HRGB is a comprehensive consideration of many aspects. In fact, the green building concept can even be applied to the initial site selection. It is

necessary to investigate the surrounding environment of the building, thoroughly consider the local climatic and geological conditions, then select the best location, height, etc., in order to reduce energy consumption and make full use of local natural resources, such as sun light and rain, maximizing the building benefits [6]. Meanwhile, just like utilization of wind energy of Shanghai Tower, the recycling, purification and reuse of natural resources are also the important aspects that should be taken into consideration in HRGB projects.

High-rise buildings, especially super high-rise buildings, have a great impact on regional wind environment, and this impact is more significant in high-rise and super high-rise building groups [4]. Therefore, HRGBs should minimize their impact on regional environment, such as the influence to wind environment, light pollution, and light blocking. It is worth mentioning that the impact of environment on buildings should be paid attention to as well. According to a study by Dalian University of Technology, the climate of coastal cities in cold regions dramatically increases the cost of implementing water-saving technologies [7]. Dalian is a typical coastal city in the cold area of China. Although Dalian is rich in rainwater and sea water resources, the cost of obtaining water resources is high [7]. Table 1. shows the cost of some green building technologies and materials of the public buildings in Dalian. As a result, how to realize the greening of high-rise buildings while fits local conditions at the same time, not only needs the thinking of the people working in the industry, but also needs the policy and economic support from the government and financial institutions.

Table 1. The Cost of Some Green Technologies and Materials of the Public Buildings in Dalian [7]

Type	Name	Cost	Applying Area (m^2)	Incremental cost (US\$/m^2)
Land Saving	Grass-planting brick	7 US\$/m^2	19,500	7.00
	Soil radon detection	42 US\$/m^2	40,497	42.00
Energy Saving	Solar water heating system	252 US\$/m^2	408,877	0.769
	Heat recovery system	1.4 US\$/($m^3 \cdot$ h)	432,053	1.656
	Energy-saving elevator	28000 US\$/set	306,090	1.386
Water Saving	Reclaimed water system	49000 US\$/set	299,820	0.406
	Rainwater reuse system	28000 US\$/set	256,849	0.444
Indoor	Indoor air monitoring	630 US\$/unit	519,953	0.644

Relevant researches have shown that the cost of green buildings and the availability of green building incentive measures are the fundamental barriers to green building development, especially in developing countries. Compared with traditional buildings, the integration of green systems increases the cost by 10.77% [8]. Therefore, the current representative green buildings are mostly the regional landmark buildings. Such buildings have a high cost, which challenges the ability of the investors. In addition, investors' expectation is a strong motivation factor of their investment in green buildings. There is also a significant positive correlation between green building tax preference as well as life-cycle cost saving, and the green building development [8]. As a result, people working in the industry are supposed to consider about how to reduce the overall cost of HRGBs to enhance confidence of the investors. Policy makers, financial institution managers, as well as other people in relevant industries should also think about how to set up green building incentive measures. In brief, all related sectors of the society are supposed cooperate to create a better environment for green building development.

3.2. Future Researches

Since the infrastructure of a building usually accounts for most of the resource consumption of a construction project, in the future, relevant researchers can carry out more research on the infrastructure section, such as the design and construction of the foundation, as well as the key parts of large structural components. In order to find better solutions with green building concepts to meet the performance requirements, more researches about the aspects such as bearing capacity and seismic ductility test, are needed. Only in this way can the achievement of a greater degree of resource conservation and more economic benefits be realized. As mentioned above, it is of great significance that researchers should conduct thorough investigation and analysis of the technologies used in green building projects, making sure that they are suitable for not only the local climate condition, but also the local resource characteristics.

In terms of building materials, the green building concepts are mainly reflected through two aspects: raw materials and material properties. In terms of raw materials, it is obvious that using industrial waste to produce building materials not only improves the utilization rate of the resources, but also effectively reduces the cost, but whether the performance of this kind of materials can meet the requirements of high-rise buildings, especially super high-rise buildings, more researches and experiments are still needed to demonstrate. In terms of material performance, some building materials with good performance have appeared in the market, which have less negative impact on the environment as well. However, the common disadvantage of such materials is a high price, which reduces the enthusiasm of contractors using such materials, blocking the development of green building [9]. Therefore, researchers can carry out researches from this perspective in the future, finding a way to guarantee the material properties while effectively reducing the cost.

At present, the development of green building still faces with many obstacles, in which the information deficiency, including relevant researches and education is considered as one of the major barriers [10]. In addition, a study by the University of Melbourne shows that there is a high correlation between the success of green building projects and the development of related technologies, indicating that the development of technology restricts the development of green building, indicating that the development of technology restricts the development of green building as well [11]. That is, the future of green building will still depend on the development of technology, researches, and education.

4. Conclusion

In conclusion, the design and construction of HRGB is a comprehensive consideration of many aspects. During the initial project site selection, it is necessary to investigate the surrounding environment of the building, and consider the local climatic and geological conditions. The recycling, purification and reusing of natural resources are supposed be emphasized as well. In the future HRGB industry, the application conditions and frequency of advanced computer technologies will become more and more. Besides, HRGB should minimize the impact on the regional environment, while the impact of local environment on buildings should be paid attention to as well. The greening of high-rise buildings according to local conditions not only needs the thinking of the industry, but also needs the policy and economic support from the government and financial institutions. The success of HRGB projects also requires the support of investors, whose expectations for green building projects are influenced by the cost of green building and the availability of green building incentives. Therefore, how to reduce the overall cost of HRGB and enhance the confidence of the investors, should be a question for those in the construction industry to think about, as well as for the policy makers and financial institution managers. All related sectors of society should cooperate to create a better development environment for green buildings.

In the future, researchers can carry out more studies on basic structures of buildings and try to find better solutions. Meanwhile, it is necessary to carry out in-depth investigation and analysis of the technology used in the green building projects, making them fit the local climate and resource

characteristics. More researches and experiments are needed to prove whether the building materials produced from industrial wastes can meet the performance requirements of high-rise buildings as well. Most environmentally friendly building materials with good performance are expensive, so future researchers should strive to find ways to effectively reduce the cost while ensuring the material performance. At present, information barrier, with relevant research and education involved, is one of the most important factors hindering the development of green building. The development of technology also restricts the development of green building. As a result, the future of green building depends on the continuous development of technology, researches, and education.

It can be believed that through the cooperation of all relevant sectors of society, as well as the continuous development of researches and education, green buildings, especially HRGB, will certainly have a better development environment and achieve more remarkable results in the future. As a result, the contradiction between the resource problems and environmental protection will be effectively alleviated.

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