

Research on Green and Low Carbon Prefabricated Buildings under the Background of Carbon Neutrality

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Abstract. China's building industry is developing rapidly, and the scale of building construction is expanding rapidly. However, at present, the development of the building industry has reached the stage of platform, and the sustainable development of traditional cast-in-place buildings has been unable to balance the relationship between the economic benefits of the building industry and environmental pollution. Prefabricated buildings have the characteristics of high standardization, high construction efficiency and environmental friendliness. In addition, with the development of the computer industry and intelligent technology, prefabricated buildings also have the ability to adapt to intelligent building software, which can improve the industrialization of the building industry and reduce the carbon emissions of the entire process. The Chinese government has issued a series of policies and regulations to encourage and guide the development of prefabricated buildings. With the development trend of prefabricated buildings, its research value is becoming more and more obvious. This paper mainly analyzes the development status of prefabricated buildings in China, summarizes the shortcomings of its development, and puts forward solutions.

Keywords: Carbon neutrality, green and low-carbon, prefabricated buildings, BIM.

1. Introduction

China's building industry has been flourished for decades, it's obviously that the industry gradually became the pillar position of China's national economy, and it has made great contributions to stimulating the national economy [1]. In the past and at the present stage, the industrial characteristics of China's building industry are still labour-intensive, which is no substitute for improving the level of urbanization in China and improving the employment station of migrant workers in towns and villages. Nevertheless, the development mode of China's building industry is mainly extensive, with low levels of industrialization, informatization and intelligence, and there are also problems of large carbon emissions. For instance, in 2020, the total depletion of energy and carbon emissions in all processes of buildings in China were 5.08 billion tons, overtaking 50% of all national carbon emissions [2]. Nowadays, under the background of the vigorous implementation of China's "dual carbon" goal (carbon peaking and carbon neutrality), the building industry actively facilitate intelligent development and low-carbon green development, which is the demand of the whole society for the high-quality and low-carbon development of the building industry, and is significant important to accelerate transform and upgrade the industry.

The difference of construction methods is the main reason that prefabricated buildings differ from traditional cast-in-place building. Common traditional cast-in-place buildings need to transport the raw materials required for construction to the site for construction operations, which is inefficient and generates serious dust pollution to the environment. But in the prefabricated structure, components would need to be cast-in-place are first mass-produced in a manufacturing plant according to standards, and then transported to the site for reliable connection [3]. Contract with traditional cast-in-place structures, the whole process is easier to control the quality of components, reduce resource consumption, shorten the construction period, and reduce construction noise and dust. Obviously, prefabricated buildings are the important point to promote the reform and upgrading of the building industry and realize the industrial and even digital and intelligent development [4]. In the context background of China's proposal to develop intelligent construction, the combination of Building

Information Modelling (BIM) technology and prefabricated buildings has become a development trend, which is conducive to improving the intelligent and low-carbon development in all processes of prefabricated buildings [5]. This paper discusses how to achieve green and low-carbon development of prefabricated buildings under the background of "dual carbon" goal, and promote the industrialization, digitalization and intelligent development of China's building industry.

2. The Development of Prefabricated Buildings

2.1. Development Process and Current Situation

Prefabricated buildings were first used in Western countries (e.g., France, the United States, Denmark, Sweden, etc.) and Japan [6]. Due to its fast construction speed, low construction cost and high degree of standardization of prefabricated buildings, prefabricated buildings have been widely used and promoted by countries around the world since their inception. Today, prefabricated technology is becoming more and more mature in many countries in Europe, Asia and North America. By 2021, the penetration rate of prefabricated buildings in the United States and Japan is as high as 90%, France and Denmark have also reached more than 80%, and Singapore is slightly lower than these four countries, but the figure is about twice that of China, as shown in Fig. 1. Contrast the achievements of developed countries in this field, the development of prefabricated buildings in China not only starts slowly, but also has a low industry penetration rate. This is because the research and practical application of prefabricated buildings started late in China, and it is still in the initial stage of development, as shown in Table 1.

Prefabricated buildings in China didn't develop smoothly, it first experienced a period of stagnation, then slowly into the right track with the development of the economy. China began to study the prefabricated building in the 1950s, and introduced the "big board" structure from the former Soviet Union in the 1970s, which improved the speed and quality of construction in China to a certain extent. However, there are some problems of "big plate" structure, such as insufficient floor stiffness, poor thermal insulation and sound insulation performance, poor earthquake resistance, have seriously reduced people's trust in "big plate" structure [8]. By the 1990s, with the rapid development and wide application of cast-in-place concrete structures, prefabricated buildings once fell into a cold period of development. After 2015, the Chinese government issued a series of policies to encourage the development of prefabricated buildings. In September of 2016, The General Office of the State Council promulgated the *Guiding Opinions of The General Office of the State Council on Vigorously Developing prefabricated Buildings*, clearly pointing out that the development of prefabricated buildings is a significant change in the construction method and an important measure to promote supply-side structural reform and new-type urbanization development, and must vigorously develop prefabricated buildings [9]. The *"14th Five-Year" Building industry Development Plan* issued in 2022 proposed that one of the long-range goals of the building industry in 2035 is that the proportion of prefabricated buildings in new buildings should reach more than 30% [10].

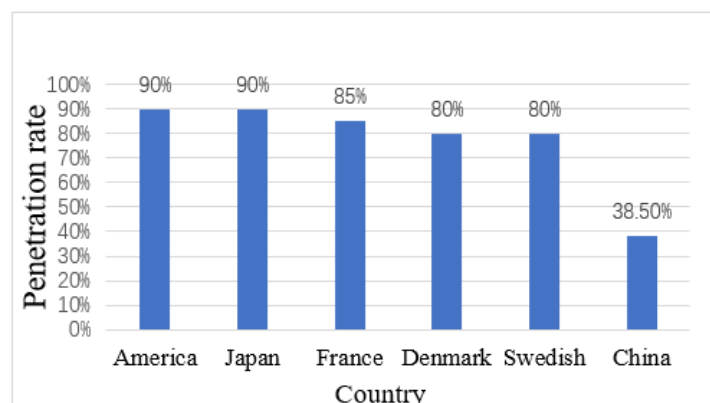


Fig. 1 Penetration rate of prefabricated buildings in various countries in 2021 [6].

Table 1. Development of prefabricated buildings in various countries [7]

Country	Industry achievements	Building system
United States	High level of commercialization and generalization, high degree of mechanized production of components	Concrete and steel prefabricated structural systems
Japan	The first to mass-produce residential buildings in factories	Multi-rise residential system buildings with reinforced concrete frames
France	One of the earliest countries to promote prefabricated buildings, high degree of industrialization standardization	Prestressed prefabricated and frame structure systems
Denmark	The first country to achieve modular in prefabricated buildings, pursuit of standards at the same time to meet diversified needs	Based on the system of product diary design as the standard
Sweden	One of the first countries to house assemble	Based on the housing system of general components
China	Started later, but with the improvement of the national economic level and the transformation of the traditional building industry, prefabricated buildings have entered a phrase of rapid growth.	Multi-purpose prefabricated concrete frame structure and prefabricated steel structure

As the Chinese government continues to increase its support for prefabricated building policies, new prefabricated buildings have reached to a peak period of development. In addition, prefabricated buildings not only accurately solve the pain points of high carbon emissions, low industrialization level and high labor cost in the current building industry. Therefore, the market scale of prefabricated buildings continues to expand, accelerating the transformation and upgrading of the building industry, as shown in Fig. 2.

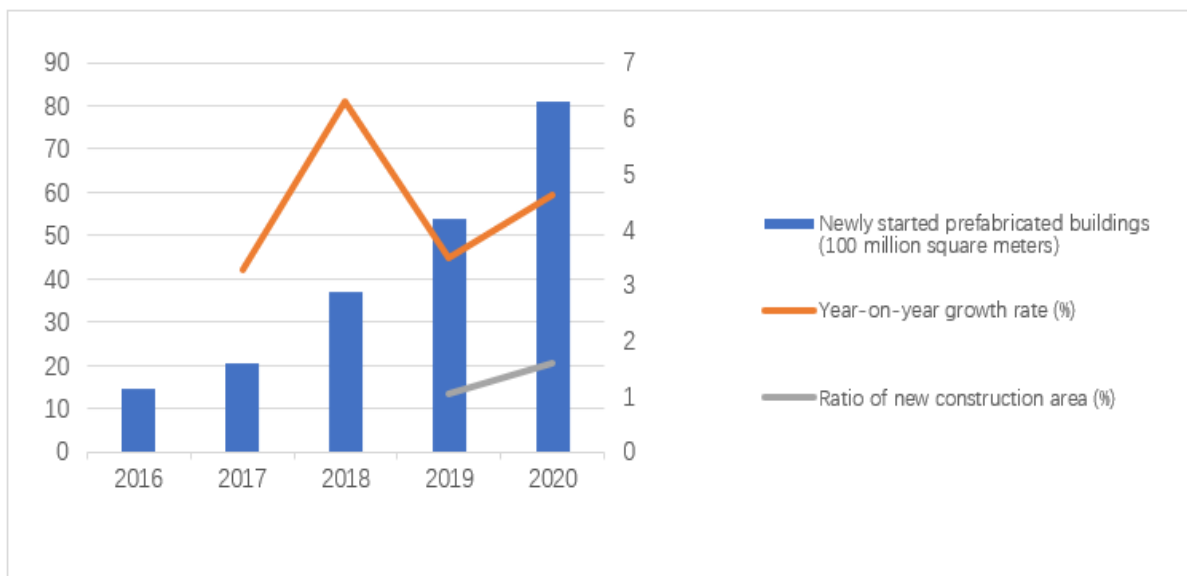


Fig 2. China's Newly Started Prefabricated building Area and Growth Rate in Recent Years [11].

2.2. Advantages of Prefabricated Buildings

At present, the core of prefabricated building in China is prefabricated concrete components. Among all kinds of prefabricated structures, concrete structures account for 67%. If the prefabricated structure wants to develop rapidly in the market dominated by cast-in-place buildings and improve market recognition, it must have unique advantages. First of all, the most intuitive advantage of prefabricated buildings is the construction aspect. The components needed in prefabricated buildings are prefabricated in special factories. The production process can ensure the size of the components, the positioning of the steel bars, the quality of the concrete forming, the thickness of the protective

layer and the accuracy of the reserved embedded positioning [12]. The factory performs mass production of components of the same size according to construction requirements. It will not be affected by rain and snow atmosphere. After maintenance and quality testing, the components can be quickly connected in the site. Compared with the traditional cast-in-place building, the industrialized production process and mechanized construction operation of the prefabricated building can greatly improve the construction efficiency, avoid the error caused by artificial pouring and form removal as much as possible, and reduce the dependence on manual. In addition, the prefabricated building can change the high energy consumption of the building industry. When concrete is poured in site during construction, it will cause noise and dust. The components of prefabricated buildings are produced in factories, which reduces damage to the land. Since the number of components has been planned in advance, blind construction can be avoided, energy saving and environmental protection can be achieved, which is conducive to the low-carbon development of the building industry. Table 2 is the comparison between the two building modes about energy consumption.

Table 2. Comparison between PC prefabricated buildings and cast-in-place buildings [13]

Item	PC prefabricated buildings	Cast-in-place buildings	Savings and improvements
Floor construction period (days)	140-180	250-280	Over 30%
Number of site builders required (people)	40-50	150-160	60%-75%
Water consumption (cubic/square meter)	0.040-0.054	0.084-0.088	35%-50%
Energy consumption (KWH/m ²)	6.5-6.9	8.7-8.9	20%-25%
Amount of building waste disposal (kg/m ²)	6.32-6.75	22.75-23.50	65%-75%
Dust level (PM10) (mg/cubic)	50-69	80-90	20%-40%

2.3. The Predicament of Prefabricated Building in China

In the past decade, although China has made great breakthroughs in theoretical research and specific application of prefabricated buildings, there are still many fundamental problems obstructing its development. The following are the problems that still need to be improved in the field of prefabricated building in China.

(1) The synergy of upstream and downstream industrial chains is poor. Compared with the traditional building industry chain, the production and construction of the whole industry chain of prefabricated buildings have higher requirements for integration and collaboration. At present, the integration and collaborative development of China's prefabricated building industry is low, the production and construction of upstream and downstream enterprises lack organization and coordination, and the exchange of information is insufficient, resulting in inaccurate resource allocation among various links, which improves the operation of the industry [4]. For example, upstream design units pay attention to the safety of building structures and the optimization of details in the process of drawing design. They do not fully consider the difficulties of subsequent factory production of prefabricated components and on-site construction.

(2) The talent reserve insufficient. Because the construction in China in the previous decades was dominated by cast-in-place concrete structures, the number of professional prefabricated building technicians was not high, and the theoretical research and practical application of prefabricated buildings were also insufficient. The development of prefabricated building is the key to the industrialization and intelligence of China's building industry. The labour personnel needed are no longer ordinary construction workers, but technicians with professional knowledge reserves are required to be responsible for the design drawings, on-site hoisting, construction management and other links. Therefore, personnel training must keep up with the speed of change in the building industry in order to maintain the healthy development of the industry.

(3) The level of intelligence needs to be improved. China proposed to develop intelligent construction in 2022, so China's prefabricated buildings still maintain in the exploration stage of intelligent development. The fault tolerance rate in the construction process of prefabricated buildings is lower than that of cast-in-place buildings. It is because the pre-design scheme of prefabricated buildings must be highly matched with the later components production and on-site construction [14]. Once the size of a batch of prefabricated components is not up to standard or the pre-embedded positioning is inaccurate, it must be reworked. It will definitely result in construction delay and cost increase. According to the above analysis, the prefabricated building needs to introduce BIM technology to optimize the defects existing in the whole process of production, construction and management, and realize the intelligence of the whole life cycle.

3. Promoting Measures for Green and Low Carbon Development of Prefabricated Buildings

Based on the shortcomings of prefabricated buildings at the present stage, making full use of the advantages of BIM technology is one of the measures to achieve its green and low-carbon development, and it is also the focus of the current building industry. BIM is a modern building technology based on 3D digital technology, with the characteristics of visualization, coordination and simulation [15]. BIM technology can integrate the relevant information of all aspects of the building, facilitate the information sharing and collaborative management among various departments. This method not only effectively improves the efficiency of design and construction, but also lower the cost and carbon emissions. Applying BIM technology in the whole process of the prefabricated building cycle can make it achieve the goals of reasonable structural design, standardized component production, efficient construction process and intelligent construction management. The application value of BIM technology in the whole process of prefabricated building is reflected in the following aspects. Information interaction

In order to realize the transformation and upgrading of prefabricated buildings to industrialization and intelligence, it is necessary to realize standardization in the initial scheme design [16]. In the past structural design process, more two-dimensional design was carried out, such as CAD computer-aided design. At present, CAD is still the design software adopted by most construction enterprises in China, which is expressed through two-dimensional drawings such as plane, elevation and section view. When a drawing modifies part of the content, others does not change at the same time, then causing a delay in information. BIM technology, on the other hand, can realize 3D model of buildings and parametric design of building components, which has strong information interaction ability and enables teams to cooperate in drawing design [17].

(2) Live simulation

Based on the visual characteristics of BIM technology. Therefore, before assembly construction, BIM technology can be relied on to simulate the construction process of the structure and the application of loads. Prefabricated buildings have high requirements for the precision of the connection of components, and excessive errors will cause poor quality of the connection of components, which will affect the safety of the whole building. The application of BIM technology can realize the visual real simulation of prefabricated building construction. In the process of simulation, the structural designer analyses the parameters provided by BIM technology to investigate and modify the hidden dangers of safety, so as to avoid the hidden dangers caused by unreasonable structural design in advance and ensure the construction safety.

(3) Cost management

BIM technology can dynamically simulate the whole process of input resources. With the help of the digital, precise and concrete characteristics of BIM technology, unnecessary material consumption can be reduced. It can avoid the waste of steel bars, columns, beams, floors and other components, and promote low-carbon and green development.

4. Conclusion

This paper mainly studies the development of prefabricated buildings in China and how to make the prefabricated buildings achieve green and low-carbon development. In summary, in recent years, China's theoretical research and practical application of prefabricated buildings are gradually mature, but there is still a huge disparity with developed countries, and problems such as high energy consumption, industrial integration and personnel training need to be solved. The integration of BIM technology into all processes of prefabricated buildings can effectively solve problems above, promote the low-carbon and green development of prefabricated buildings. Finally realize the industrialization and intelligence of the whole industry on this basis. In the future, the great integration of prefabricated buildings and BIM technology in China is a trend, and the combination of BIM with cloud platform, block chain and artificial intelligence is also a good way for the industry to intelligent development. In short, the reasonable use of BIM technology can provide new development ideas for prefabricated buildings, meet the needs of the current low-carbon and green development of the industry, and bring greater economic value and clearer development prospects for prefabricated buildings.

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