

Prefabricated Buildings: A Review of Benefits, Challenges, and Future Directions

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ABSTRACT

Prefabricated buildings have gained popularity in recent years due to their potential to transform the construction industry. This paper reviews the benefits, challenges, and future directions of prefabricated buildings, highlighting their advantages in terms of sustainability, cost-effectiveness, and quality control. We explore various types of prefabricated buildings, including modular, panelized, and hybrid structures, and discuss their applications in residential, commercial, and industrial sectors. Our analysis reveals that prefabricated buildings offer significant environmental benefits, reduced construction times, and improved building performance. However, challenges persist, including regulatory barriers, transportation limitations, and public perception. We recommend further research, standardization, and policy support to fully harness the potential of prefabricated buildings.

The traditional methods of construction industry have made the appropriate initiative to make a paradigm shift in the prefabrication construction in order to achieve a higher standard and to adapt to the global business trend.

Prefabricated building technology has the characteristics of resource intensive, green environmental protection and high technical content, which perfectly meets the requirements of the development of the times. In the development of the times, prefabricated buildings gradually appear in people's sight, and are widely recognized by the public because of their green environmental protection, resource intensive and high technical content. Based on this, this paper mainly studies the prefabricated building technology under the current background of review benefits and futuristic approach of prefabricated buildings.

Keywords :

prefabricated buildings, sustainability, cost-effectiveness, quality control, modular construction, panelized construction, hybrid construction, Industrialized Building System (IBS), Modern Method of construction (MMC), Off-site Manufacturing (OSM).

1. INTRODUCTION

Prefabricated buildings are constructed off-site in a factory and assembled on-site, offering a innovative approach to traditional construction methods. The building sector has yet to undergo a complete phase of industrialization. Yet, if a car was produced the way a building is delivered, very few people would be able to own one; if a computer was produced the way a building is delivered, it would cost a fortune (Richard, 2005). This demand can be met by means of the advanced technology used in the Industrialized Building System (IBS) or prefabrication system.

Since the 21st century, with the rapid development of China's construction industry, the scale of the construction industry has continued to expand, and a large number of laborers transferred from rural areas have joined the construction industry. The rapid development of the construction industry has contributed to the development of society and the construction of the economy. And the improvement of people's livelihood has made important contributions. However, it should be noted that the rapid development of the construction industry consumes huge natural resources and has also caused certain damage to China's environment. The rapid development of the construction industry has caused the air quality to continue to decline, affecting people's daily life and health. Based on the current situation, the concept of realizing the green and sustainable development of the construction industry has gradually become popular. The development of prefabricated buildings is still in its infancy. As are presentative of building industrialization, we can see from the policies of the State Council and local governments that it is the national development goal to make "house components "flow on the assembly line and form the process of "building blocks" to build houses. As an efficient construction mode, The production mode of prefabricated buildings represents the development direction of construction industry in the future. Assembly-type building is different from the previous building forms. Instead of completing the components in the construction site, it adopts prefabricated form, which is designed and constructed in advance, and then transported to the construction site after completion. The construction site only needs to complete the relevant assembly work. This way realizes the streamlined production of building construction, greatly improves the work efficiency of construction personnel, and at the same time reduces their workload and effectively reduces the construction cost. The application of low-carbon concept makes prefabricated building technology more energy-saving and environment-friendly, and becomes the main development direction of modern building construction.

Traditional building forms are all the components needed to complete the construction project at the

construction site, but the prefabricated building is different. It refers to the use of the form of appointment to produce the components. After the production is completed, it is transported to the construction site and then assembled according to the procedure. Components, and then realize the construction of the entire building. In terms of advantages, prefabricated buildings prefer the construction form of flow production, which is not only conducive to the improvement of the work efficiency of constructors, but also effectively reduce the resource cost of construction. In terms of environmental protection, it also minimizes the damage of construction projects to the environment, thus avoiding the problem of pollution to the environment, effectively implements the concept of green low carbon environmental protection, and further promotes the development of prefabricated buildings in a more green and environmental protection direction.

2. Application of Low Carbon and Environmental Protection in Assembly Building Design

2.1 Advantages and disadvantages of prefabricated buildings

Advantages:

Prefabricated buildings are formed by mechanized production of prefabricated components in factories and installation on site. Because standardized production is adopted, prefabricated components can be processed by flow process, which can not only ensure the production speed, but also effectively ensure the continuity of supply. Moreover, prefabricated members only need to command the construction of structural nodes when they faint, which reduces the construction difficulty and work load to a certain extent, and reduces the waste of components generated onsite. Prefabricated building construction adopts factory centralized production and unified transportation, so that the concrete mix ratio, cement mortar mix ratio and the number of steel bars are controlled more accurately, and the pollution caused by concrete is reduced. As the prefabricated building uses integrated, integrated and integrated precast concrete components, the wet operation of the form work on site can reduce various pollution phenomena that often occur in traditional building construction to a certain extent, and can reduce To a certain extent, the cement mortar operation is saved, and the cleanliness of the construction site is effectively improved. Prefabricated buildings can effectively reduce material stacking, loading and unloading, so as to reduce the impact of dust on the surrounding environment. Prefabricated buildings convert most of the on-site construction to factory processing, which can help reduce the discharge of solid waste and sewage, reduced us and noise pollution, and be conducive to environmental protection.

Disadvantages:

At present, there is a lack of some targeted laws and regulations at the national level, while some binding policies and legal norms have little impact on promoting the development of prefabricated buildings. Because the building industrialization is still in the primary stage, the government has not issued specific incentive policies, which restricts the development of large enterprises and the progress of building industrialization. In order to improve the construction efficiency of prefabricated components, it is necessary to have stronger substitutability and universality, and government departments and research institutes at all levels also need to increase the research on standardization, modularization and serialization of components. Due to the large one-time investment in the construction of the prefabricated component factory, and the small market demand at this stage, the component amortization cost is high. The current construction industry management system and talent training mechanism cannot meet the needs of this aspect. Basically, universities and colleges across the country have not set up "prefabricated component" majors, nor have they opened up channels for training skilled workers.

Compared with traditional buildings, the production mode of prefabricated buildings has various obvious advantages, such as building safety and quality, personnel, construction period, environmental protection, etc. see Table 1 for details.

Table1 Comparison of production methods of prefabricated buildings and traditional building production methods

Compare Content	Traditional Building	Prefabricated Building
Engineering quality and construction safety	The open-air construction environment has greatly restricted the improvement of the quality of engineering projects, and the characteristics of high-altitude operations will increase the incidence of safety accidents	The parts and components are uniformly mass-produced in advance in the factory, which can more conveniently and effectively control quality problems, reduce high-altitude operations, greatly reduce safety benefits, and ensure construction safety
Construction period	The construction period is long, and it is greatly affected by the external environment such as natural environment, and cross-operations cannot be realized between various majors	A large number of parts and components are prefabricated in the factory, which is not affected by weather and temperature; various professional constructions can achieve three-dimensional crossover operations, which greatly reduces the construction period

Construction staff	The number of workers required is large, the stability of personnel is poor, and the professional level is different, which increases the difficulty of management	The high degree of mechanized operation has greatly reduced the number of workers required, but the requirements for the professionalization of workers have increased
Labor productivity	Low labor productivity: using traditional wet methods	High production efficiency: parts and components are prefabricated by the factory in batches, and on-site mechanized construction
Energy saving and environmental protection		The construction site is clean and tidy, produces less construction waste, and has a higher recovery rate. The semi-closed production environment of the factory can effectively reduce noise, dust and other pollution phenomena
Building quality	There is a lot of construction waste at the construction site, and water resources and noise pollution are serious. Material consumption is high, and it is easy to produce waste	The prefabricated production of parts and components mainly relies on the mechanized numerical control equipment in the factory, which can ensure the accuracy of the components, thereby greatly improving the quality of the building. And the parts produced are better in terms of impermeability, etc.

2.2 Embodiment of low carbon environmental protection in prefabricated building design

The prefabricated building technology based on the concept of low-carbon and environmental protection requires comprehensive consideration at the beginning of the design. First of all, through scientific design, the building takes away indoor heat through the flow of natural wind, instead of artificial means such as air conditioners and electric fans, so as to create a comfortable indoor environment. Figure 1 shows the design of green, ecological and environmentally friendly buildings.

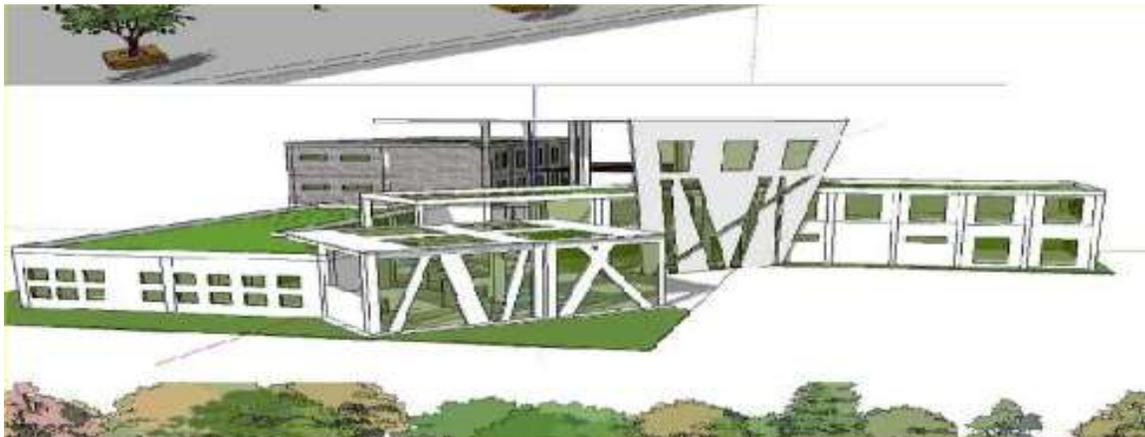
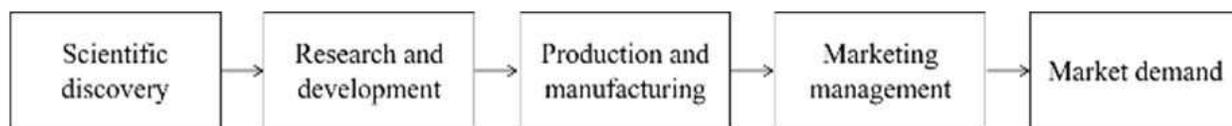


Figure1 Green ecological and environmental protection building design

Secondly, water resources in construction projects can also be reduced by reasonable water supply and drainage design, and solar energy can be used for water heating and power generation. Finally, the energy utilization in the construction project can be replaced by new clean energy, so as to effectively control green house gas emissions. Unreasonable design of prefabricated buildings will lead to poor indoor air circulation, resulting in indoor air pollution, and long-term living will be harmful to the body. Ideally, a permeable north-south indoor layout will make the indoor air unblocked. However, the current city has a small amount of land and it is difficult to achieve such an indoor layout. In this case, the indoor walls and spaces can be rationally laid out. Enhance the circulation of indoor air and the entry of light. For example, designing a ceiling in the interior can appropriately reduce the indoor space, thereby effectively reducing the consumption of resources, and at the same time increasing the indoor thermal insulation efficiency.

Different scholars have different views on the theory of technological innovation process. Many scholars at home and abroad have put forward many models about technological innovation process and technology promotion model from different angles. This model points out that technological innovation mainly covers several stages, such as research and development, production and marketing. Technological innovation begins with scientific R & D and technological creation, and finally the market through the continuous development of enterprise technology. The realization of technological innovation is inseparable from the application of innovative achievements such as new technologies and new products developed by enterprises in the laboratory.

In other words, the market receives the enterprise's new technology, and the customer is the passive recipient. Only by investing enough factor resources in the innovation process, the enterprise will have more opportunities to carry out technological innovation, and the possibility of innovation success will be greater. The model is shown in Fig. 2.

**Fig.2** Technology promotion model

3. Prefabricated building technology based on Green low carbon environmental protection

3.1 Dynamic scheduling in prefabricated buildings

In the process of assembly construction, if the useful information needed by construction scheduling can not be fed back to the scheduling system in time, it will lead to the scheduling system failing to make timely and accurate response according to the actual construction state and produce errors. A complete assembly construction process should involve three links, namely, construction preparation, construction scheduling and construction execution, in which construction data are continuously generated and exchanged. As shown in Fig. 3.

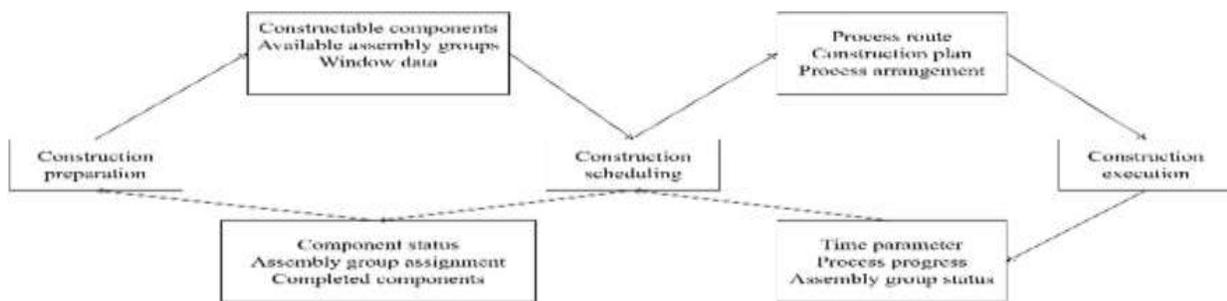


Fig.3. Data flow chart

The construction process of prefabricated buildings involves multiple building components and multiple processes, and multiple assembly groups are required to complete the construction at the same time. Therefore, it is necessary to coordinate the building components, assembly processes, and assembly groups, and optimize the optimization goals by rationally arranging the resources between each component. The mathematical model of prefabricated building schedule optimization can be described as: suppose there are a total of n building components, and each component has k assembly procedures. These k procedures are constructed by an assembly group of m different components composed of several people. The rear ex types of groups, and each type contains different assembly groups. The objective function of the schedule optimization problem is to find the shortest time required to complete all the processes of all building components.

According to the construction characteristics of prefabricated buildings, the main constraints of the schedule optimization of prefabricated buildings are shown as follows:

$$P_{ij} + T_{ij}^a \leq C_{ij} \quad (1)$$

$$C_{ij} \leq P_{i(j+1)} \quad C_{ij} \leq P_{i(j+1)} \quad (2)$$

$$P_{ij} + T_{ij}^a \times W_{ijfg}^a \leq P_{fg} + T_{fg}^a \times (1 - W_{ijfg}^a) \quad (3)$$

Among them, formula (1) and formula (2) represent the front and rear constraints of the process in the same component. The start time and the construction time of a process shall not be greater than its construction completion time, and the construction completion time of any process of the same component shall not be greater than the start time of its next process. Formula (3) indicates the sequence constraint between different component processes in the same assembly group, and the completion time of a component process in the assembly group should not be greater than the start time of another component process in the assembly group. The purpose of this paper is to use scheduling strategies to optimize the construction schedule of the project and minimize the maximum completion time. Therefore, for the evaluation of the pros and cons of the scheduling strategy of prefabricated buildings, this paper will take the minimization of the maximum completion time as the goal and establish an objective function. The function expression is:

$$C = \min \left(\max_{l \leq l \leq n, l \leq j \leq k} C_{ij} \right) C = \min \left(\max_{l \leq l \leq n, l \leq j \leq k} C_{ij} \right) \quad (4)$$

Among them, $\max_{l \leq l \leq n, l \leq j \leq k} C_{ij}$ represents the largest one of the time when all components complete the last process.

• **3.2 The main features of Green low carbon environmental protection in prefabricated buildings**

In terms of prefabricated buildings, the opinions on promoting the sustainable and healthy development of the construction industry issued by the general office of the State Council on February 17, 2017 clearly proposed to promote prefabricated buildings, adhere to standardized design, industrialized production, prefabricated construction, information management and intelligent application, promote the innovation of construction methods and vigorously develop prefabricated concrete buildings, Strive to increase the proportion of prefabricated buildings in new buildings to 30% within 10 years.

According to the statistics of the Ministry of Housing and Urban-Rural Development, as shown in Table 2, in 2015, the newly-built prefabricated building area in China was 73.7 million square meters, accounting for 2.9% of the newly-built urban building area. In 2016, the newly built prefabricated building area was 125 million square meters, accounting for 5.2% of the newly built urban building area, an increase of 57% compared with 2015. From January to October, 2017, about 130 million square meters of prefabricated buildings have been built nationwide.

Table2 Analysis of the development of prefabricated buildings from 2015 to October 2017

Time	Newly built prefabricated building area (ten thousand square meters)	Growth rate of newly built prefabricated building area (%)	Percentage of newly built building area (%)
2015	7370	—	2.9
2016	12500	62	5.2
January- October 2017	13000	—	

In November 2017, the Ministry of Housing and Urban- Rural Development announced the first batch of prefabricated building demonstration cities and industrial bases for prefabricated buildings. As shown in Table 3, 30 cities including Beijing and Hangzhou were identified as the first batch of prefabricated building demonstration cities. 195 companies including Beijing Zhuzong Group Co., Ltd. and Hangxiao Steel Structure Co., Ltd. are the first batch of prefabricated building demonstration industrial bases.

Table3 Fabricated building industry development analysis table

Time	Newly built assembly- type demonstration cities (one)	Assembled construction industrial base (one)	Demonstration project of prefabricated buildings (one)
November 2017	40	195	—
2020	70	59	510
Completion rate (%)	60	98.2	—

Different from previous buildings, the exterior wall design of prefabricated buildings can better meet the requirements of residents. According to different changes in region, climate and temperature, the exterior wall of prefabricated buildings can not only retain personalization, but also have energy-saving effect better than traditional buildings. In the roof structure design of prefabricated buildings, the commonly used structural types are waterproof panel, thermal insulation panel, etc. load materials such as thermal insulation roof board and cement composite board are the main construction materials of roof structure. Use information software for spatial modeling to improve the fineness of interior design. As shown in Figure 4.



Figure4. Prefabricated building design

In addition to the wall surface, the exterior windows of prefabricated buildings have also changed. In the construction of exterior windows, we can no longer rely solely on the traditional single-layer glass, and we need to choose double-layer hollow plastic-steel window glass to satisfy the use of exterior windows of prefabricated buildings and achieve better thermal insulation effect. At the same time, the floor treatment of prefabricated buildings is quite different from that of previous buildings, and it is necessary to consider the suitable materials needed for different floor thicknesses in the selection of materials. The operation and management process of green buildings touches on many aspects of building envelope, water supply and drainage, HVAC, electrical, renewable energy, environmental greening, garbage disposal, traffic safety, etc. The following two points are mainly used for renewable energy and measurement and testing equipment. There are many differences with traditional buildings, and more standardized requirements are put forward for operation and management. Therefore, these two requirements are listed as special items. The technical content includes the operation and maintenance of renewable energy and measurement and testing equipment, optimization, and data collection and analysis of testing equipment.

4. Conclusions

In the current social development, the advancement of urbanization requires people to have more and more demand for buildings. They not only need buildings to have more functions, but also pay more attention to green energy conservation and environmental protection. Prefabricated building is an important product that more conforms to the development of the concept of green, low- carbon and environmental protection in the

current era. The building method based on prefabricated components and assembly can not only effectively reduce the loss of energy and the waste of construction cost, but also reduce the generation of construction waste. The use of green, low-carbon and energy-saving building materials further realizes the protection of the environment. Assembly-type green building is a relatively environmentally friendly, systematic and integrated way. In order to protect the environmental resources we have now, we must adopt green, reasonable and feasible construction methods. At the same time, in order to meet the standards of building environmental protection, green construction technical measures should also be taken to ensure the quality, quantity and timely completion of the project.

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