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Current Status and Future Prospects of Prefabricated Buildings

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Abstract: *This paper provides a systematic review of the development history and technical characteristics of prefabricated buildings, with a focus on analyzing the current state of development both internationally and in China. It highlights the advantages of prefabricated buildings in terms of standardized design, factory prefabrication, on-site assembly, and information-based management. The article discusses the challenges currently faced by prefabricated buildings in China, including an incomplete standard system, cost pressures, shortages of technology and talent, and insufficient industrial collaboration. It proposes strategies to address these issues, including strengthening technological innovation, improving policy support, promoting smart manufacturing and the application of green building materials, and establishing a diversified and collaborative industrial chain. The study concludes that prefabricated buildings, as an important pathway to achieving building industrialization and green and low-carbon transformation, will play a key role in driving the high-quality development of the construction industry in the future.*

Keywords: *Prefabricated Buildings, Standardized Design, Technological Innovation, Industrial Collaboration*

1. Introduction

At present, due to policy promotion, prefabricated buildings are accelerating their popularization. Through standardized design, factory production, and assembly construction, they significantly improve construction efficiency and reduce resource consumption. Technological upgrades focus on intelligence and greenness, integrating innovative methods such as BIM and robotic construction. In terms of development prospects, the collaboration of the industrial chain is increasingly deepening, and the application fields expand from residential buildings to public buildings and industrial construction, promoting the transformation of the construction industry towards low-carbon, efficient, and sustainable directions. This article will discuss five aspects: the development of prefabricated buildings, the characteristics of prefabricated building construction technology, the development prospects of prefabricated buildings, the existing problems of prefabricated buildings, and the challenges and countermeasures faced by prefabricated buildings.

2. Manuscript Preparation

2.1 The Development of Prefabricated Buildings

As a key manifestation of construction industrialization, the development of prefabricated buildings is closely intertwined with the technological evolution and the overall transformation of the construction industry.[1] Currently, with the continuous integration of information technology, green and low-carbon concepts, and smart manufacturing, prefabricated buildings are entering a new phase of high-quality development.

2.1.1 International Development

Prefabricated buildings originated in Western Europe during the late Industrial Revolution and were widely applied in post-war reconstruction in the 1950s. Countries such as Germany, Sweden, Japan, and Singapore have led the way in this field, with their development characterized by the following features:

Germany: Emphasizing the integration of structure and performance, Germany has developed a

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high-standard, strictly regulated prefabricated concrete building system, prioritizing energy efficiency and sustainability. Japan: Focusing on residential industrialization, it has established mature systems such as SE housing and PC factory systems, emphasizing seismic performance and user experience. Singapore: The government has strongly promoted the use of mandatory quota systems to encourage construction companies to adopt PPVC (prefabricated pre-enclosed volume modules) technology, significantly improving construction quality and efficiency. In these countries, the adoption rate of prefabricated construction generally ranges between 40% and 70%, with well-established industrial chains, technical systems, and policy support mechanisms.

2.1.2 Development in China

The development of prefabricated buildings in China can be roughly divided into three stages:

Initial Exploration Stage (1950s–1980s): Represented by the standard panel system assisted by the Soviet Union, pilot applications were concentrated in major cities like Beijing, but technical capabilities and management levels were limited, resulting in slow development.[2]

Technological Transformation Stage (1990s–2010): With the development of the commercial housing market and the advancement of urbanization, some residential development projects began to experiment with prefabricated composite slabs and prefabricated staircases, but the overall proportion remained low, and no large-scale development was achieved.

Rapid Development Stage (2016–present): In 2016, the State Council issued the "Guiding Opinions on Vigorous Development of Prefabricated Buildings," clearly stating the development goal of "prefabricated buildings accounting for more than 30% of new buildings by 2025."[3] Various regions have successively introduced supportive policies, built PC factories, cultivated industrial bases, and promoted the integration and coordination of design, construction, and component production.

According to data from the Ministry of Housing and Urban-Rural Development, in 2022, the total floor area of newly started prefabricated buildings nationwide was approximately 640 million square meters, accounting for about 27% of the total floor area of newly constructed buildings. Among these, the proportion of residential projects has been increasing year by year, showing a positive development trend.

2.2 Technical Characteristics of Prefabricated Building Construction

The construction process of prefabricated buildings differs from the traditional "on-site casting and on-site processing" model, adopting an industrialized construction approach of "factory prefabrication on-site assembly." This technical system encompasses multiple stages, including design, production, transportation, lifting, connection, and overall construction. Its core technical characteristics are specifically manifested as follows:

2.2.1 Standardized Design and Modular Components

Prefabricated buildings emphasize "design-led" principles, with components designed to be highly standardized and modular. Through unified modular coordination, architects can design spatial and structural layouts based on component dimensions, effectively enhancing design efficiency and component versatility. Additionally, parametric modeling and BIM (Building Information Modeling) technology enable precise component design, quantity calculation, and layout optimization, ensuring seamless integration with subsequent manufacturing and installation processes.

2.2.2 Component Factory Prefabrication, Controllable Quality

Components primarily include prefabricated columns, beams, floor slabs, wall panels, and staircases, all of which are manufactured on standardized production lines in factories. Factory production enables mechanized control of processes such as concrete pouring, rebar tying, embedded part placement, and steam curing, significantly improving component geometric accuracy and intrinsic quality while mitigating the variability of on-site construction.

2.2.3 Dry construction methods, efficient and convenient on-site assembly

Assembled buildings primarily use dry construction methods on-site, mainly employing lifting and assembly techniques, thereby avoiding large-scale on-site concrete pouring and significantly reducing wet construction operations. Prefabricated components are assembled using connection methods such as Plug-in type, mortise and tenon style, and frout sleeve, which offer high connection node strength and convenient construction, facilitating rapid construction and parallel work by multiple trades.

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2.2.4 Mature connection technology ensures structural performance

Currently, prefabricated buildings generally adopt hybrid structural systems, such as prefabricated frame-shear wall structures, prefabricated steel structures, and prefabricated concrete structures. In terms of connection technology, critical nodes typically use cast-in-place connections, bolted connections, welding, or grout sleeves to ensure structural continuity and integrity, meeting seismic and fire resistance standards. Some connection components, such as rebar sleeves and grouted socket connections, have been localized and standardized, with mature and stable technology.

2.2.5 Transportation and lifting processes are coordinated and complementary

Due to the large size and heavy weight of prefabricated components, prefabricated buildings impose high requirements on transportation and lifting. During transportation, routes and component stacking methods must be reasonably planned to prevent component deformation and damage. On-site lifting requires the use of large-scale lifting machinery, following the "lifting → positioning → alignment → connection" process flow, and coordinating with civil engineering, electrical, and plumbing professionals to improve workflow efficiency.

2.2.6 Integration of Information Technology and Intelligent Construction

Prefabricated buildings heavily rely on information technology support,[4] enabling full-process digital management from design modeling to component production, transportation, and installation. Through BIM platforms, construction companies can conduct construction simulations, node optimization, progress modeling, and quality tracking, achieving "visualization + controllability" in construction. Combined with IoT devices and smart terminals, real-time monitoring of component status, lifting accuracy, and construction environment can be achieved, enabling smart construction.

2.3 The Future Prospects of Prefabricated Buildings

As China's construction industrialization process continues to advance, prefabricated buildings have emerged as a key pathway to achieving high-quality development and a green, low-carbon transition in the construction sector, offering vast future prospects. In the coming years, the technical framework, policy environment, and market mechanisms supporting prefabricated buildings will continue to evolve, laying a solid foundation for their large-scale development. This is primarily reflected in the following two aspects:

2.3.1 Technological Innovation in Construction Drives Quality Improvement and Efficiency Gains in Prefabricated Buildings

The sustained development of prefabricated buildings relies on continuous breakthroughs and integration in construction technology. As the concept of smart construction is deeply implemented, technological innovation has become the core driving force for industry upgrading.

BIM and Smart Construction Integration: The widespread application of Building Information Modeling (BIM) technology in prefabricated buildings enables digital integration and management across design, production, transportation, and construction processes. Through 3D visualization design, component layout optimization, and construction simulation, design accuracy and construction efficiency can be significantly improved, while reducing error rates and rework rates. Additionally, the data accumulation on BIM platforms will further support building lifecycle management.

Smart factories and industrialized production upgrades: Component prefabrication factories are moving toward automation, digitization, and flexibility, introducing robotic processing, intelligent maintenance, and automated transportation equipment to effectively improve production efficiency and component quality. As the collaborative capabilities of the industrial chain strengthen, the standardization and interchangeability of components will significantly improve.

Development of new connection technologies and green building materials: The maturation of new prefabrication technologies such as dry connection technology and multifunctional integrated wall systems has enhanced construction convenience and overall building performance. The research, development, and promotion of green building materials, such as recyclable concrete and lightweight high-strength materials, will further reduce resource consumption and carbon emissions, contributing to the achievement of the "dual carbon" strategic goals.

Smart construction equipment enhances on-site assembly efficiency: The widespread application of construction equipment such as tower crane intelligent positioning systems, automatic grouting

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equipment, and precise lifting auxiliary devices makes on-site construction safer, more precise, and faster, effectively ensuring the quality and efficiency of prefabricated buildings.

Continuous technological advancements are driving the development of prefabricated buildings from "component assembly" to "system integration," gradually achieving a balance between industrialized construction, intelligent management, and green sustainability.

2.3.2 Policy Support and Market Demand Drive Industry Development

Policy guidance and market mechanisms jointly constitute the dual driving forces behind the development of prefabricated buildings.

The policy environment continues to improve: The central government has introduced multiple policies to support the development of prefabricated buildings. Documents such as the "14th Five-Year Plan for the Development of the Construction Industry," "Guiding Opinions on Vigorous Development of Prefabricated Buildings," and "Action Plan for Green Building Creation" clearly outline development goals and supportive measures. Local governments have also successively introduced incentive policies, including fiscal subsidies, land preferences, streamlined approvals, and tax reductions, to accelerate the construction of component factories and the implementation of pilot projects.

Accelerated implementation of the "dual carbon" goals in the construction sector: The carbon peaking and carbon neutrality strategy requires the construction industry to significantly reduce energy consumption and carbon emissions. Prefabricated buildings,[5] with their energy-saving and environmentally friendly characteristics, have become an important pathway for promoting green construction. Under policy guidance, the proportion of prefabricated buildings in government-invested projects, public buildings, and green buildings will continue to rise in the future.

Market demand continues to expand: With the structural transformation of the real estate market and the upgrading of residential needs, homebuyers are placing higher demands on residential quality, energy efficiency, and comfort. Prefabricated buildings have obvious advantages in terms of construction precision, structural performance, energy efficiency, environmental protection, and living experience, making them better suited to diverse needs such as mid-to-high-end residential buildings, affordable housing, industrial parks, and prefabricated public buildings. Additionally, urbanization, renovation of old residential areas, and new rural construction provide extensive application opportunities for prefabricated buildings.

Active corporate participation and supply chain integration: An increasing number of large construction companies, real estate developers, and component manufacturers are joining the prefabricated building supply chain, driving collaboration and technology sharing across the industry. Cluster effects are gradually emerging, forming an integrated development model encompassing design, production, construction, and operations.

2.4 Issues in China's Prefabricated Building Industry

With the growing popularity of green construction concepts and strong government support, prefabricated buildings have seen rapid development in China. However, in practical implementation, this model still faces a series of deep-seated issues, primarily in four areas: standardization systems, cost control, technology and talent, and coordination mechanisms and industrialization levels.

2.4.1 Standardization Systems and Technical Specifications Still Need to Be Unified and Improved

Currently, China has not established a systematic and comprehensive national standard system for prefabricated buildings. Significant differences exist across regions and companies in terms of component modularization, interface forms, and connection processes, with a lack of unified technical standards, which hinders component interchangeability and efficient resource utilization. Additionally, current regulations provide limited support for emerging technologies such as BIM and smart manufacturing, failing to meet the technical requirements of prefabricated buildings across multiple structural systems. This weakens the replicability and universality of their promotion.

2.4.2 Cost pressures and economic challenges coexist

Although prefabricated buildings offer advantages in construction efficiency and quality control, their initial construction costs are generally 10%–15% higher than those of traditional buildings.[6] The primary reasons include high mold development costs, complex transportation processes, high levels of

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component customization, and increased on-site management requirements. Additionally, the industry has not yet achieved stable economies of scale, making it difficult to effectively reduce unit costs. These factors are particularly pronounced in third- and fourth-tier cities or mid-to-low-end residential projects, constraining the market competitiveness of prefabricated buildings.

2.4.3 Lack of Technical Support Systems and Composite Talent

Prefabricated construction involves multiple stages such as design refinement, factory prefabrication, on-site installation, and operations management, placing higher demands on composite technical talent. However, current university and vocational education curricula in this field are not yet systematic, and enterprises lack personnel with comprehensive knowledge structures and collaborative capabilities. Design firms lack a deep understanding of prefabricated component design, construction firms have insufficient technical reserves, and component factories vary widely in management quality, leading to difficulties in ensuring project progress efficiency and engineering quality.

2.4.4 Inadequate Collaborative Mechanisms and Low Industrialization Levels

Prefabricated construction requires strong collaboration throughout the entire process, but most current projects still follow traditional construction models, with BIM and other information tools failing to be effectively integrated into the design-production-construction-operation and maintenance phases. Poor communication between component factories and construction companies often leads to rework and project delays, while supply chain management issues such as untimely transportation and insufficient storage space further impact overall project efficiency. Additionally, the standardization and universalization of building components in China remain low, with components primarily customized for individual projects. PC factories generally suffer from outdated technical equipment and loosely managed production processes, making it difficult to support true industrial-scale mass production.

2.5 Challenges and Countermeasures for Prefabricated Buildings

With policy encouragement and market demand, prefabricated buildings are gradually becoming an important direction for the transformation and upgrading of China's construction industry. However, in the actual implementation process, its development still faces a series of deep-seated issues, which urgently require a comprehensive response from multiple aspects such as institutional mechanisms, technical support, and industrial ecology.

Firstly, the current technical system for prefabricated buildings is still immature, with disconnects between design, production, and construction. Due to low standardization levels, there are no unified standards for component dimensions, connection methods, and installation processes across different regions and enterprises, hindering the large-scale and systematic advancement of the industry. Additionally, some projects fail to adequately implement assembly rates and precision control, leading to a trend of prioritizing form over substance, thereby weakening the inherent technical advantages of prefabricated construction.[7] Therefore, it is necessary to expedite the establishment of an integrated technical standards system covering the entire design-manufacturing-construction process, and leverage intelligent construction technologies such as BIM and AI to enhance overall construction precision and collaborative efficiency, thereby optimizing construction quality and process integration from the source.

Second, the development of prefabricated buildings cannot be separated from the efficient coordination of all links in the industrial chain. However, at present, component factories are unevenly distributed, production capacities vary greatly, and their coverage capabilities are limited, making it difficult to meet the dual requirements of component quality and timeliness for large-scale projects. At the same time, the lack of professional talent has become a bottleneck constraining industry development, particularly in key areas such as prefabricated design, on-site installation management, and BIM technology application, where significant shortcomings exist. To address this issue, it is not only necessary to strengthen the layout of regional industrial bases and establish a component supply system that radiates to surrounding areas, but also to establish and improve talent cultivation mechanisms for prefabricated buildings, promote collaboration between universities, research institutions, and enterprises in talent cultivation, and enhance the industry's human resource safeguard capacity.[8]

Additionally, the promotion of prefabricated buildings still faces dual pressures of cost and public perception. Due to high initial investment in component molds, transportation and installation costs, and a lengthy return on investment cycle, developers have concerns about economic viability.

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Additionally, some consumers remain skeptical about the comfort and safety of prefabricated housing, which affects market acceptance. To overcome this challenge, it is essential to reduce unit costs through design optimization and the promotion of standardized molds. Policy incentives, such as fiscal subsidies, expedited approval processes, and bidding preferences, should also be utilized to encourage corporate participation. At the same time, efforts should be made to strengthen the construction of model demonstration projects and industry promotion to guide the public in correctly understanding the advantages of prefabricated buildings and create a favorable market environment.

3. Conclusions

As an important direction for promoting construction industrialization and green development, prefabricated buildings are currently in a critical stage of rapid development and technological upgrading. Although China has made significant progress in policy support, market demand, and technological innovation, issues such as an incomplete standards system, significant cost pressures, shortages of technology and talent, and insufficient industrial collaboration continue to hinder its large-scale and high-quality development. In the future, efforts should be made to strengthen top-level design and standards development, promote the application of smart construction technologies, improve industrial chain collaboration mechanisms, and enhance talent cultivation to achieve the sustainable development and industry transformation goals of prefabricated buildings.

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