

# Research on Prefabricated Building Construction Technology: Current Status, Challenges, and Solutions

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**Abstract:** Prefabrication is the main carrier of the construction industry's industrialization development; the improvement of construction technology will promote the transformation and upgrading of construction methods. This paper analyzes the application status of prefabricated construction technology at home, discusses its development features from the point of view of implementation of the structure system, implementation of the building procedure, and quality management, and points out major problems in the industry, including inconsistent technical specifications, poor efficiency of construction coordination, and low professional level. Based on the intelligent building development trend, this article puts forward some improvement measures from standard optimization, process optimization, and management improvement, which provide a reference basis for the healthy development of prefabricated construction technology.

**Keywords:** Prefabricated construction; Construction technology; Quality control; Intelligent construction

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## 1. Introduction

In the context of the greening and upgrading of the building industry, prefabrication is becoming the most common paradigm since it provides a better energetic performance, lower materials consumption, more effective construction methods, and better controllability for quality control. The innovation and utilization of construction techniques are important means to promote the development of the construction industry. In recent decades, China has made great achievements in the prefabricated construction technology of structure system, construction methods, and equipment utilization. Prefabricated concrete and steel structures reach a high maturity level, and BIM or Internet of Things technology is applied in all stages of construction. But, compared with the demands of industrialized construction, prefabricated building practices are still plagued by several practical issues, such as consistency of technology application with the field construction environment, comprehensiveness of the whole process quality control, etc. Analyzing the current construction methods and limitations, and developing scientific countermeasures, has important practical implications to promote the comprehensive and high-quality development of the prefabricated building industry.

## **2. Current application status of prefabricated building construction technology**

### **2.1. Practical application of multi-structure system construction technology**

A multi-variety and comprehensive technical system of China's prefabricated building includes the following: Prefabricated concrete structure, steel structure, wood structure and composite system. Among them, the application range of prefabricated concrete structures is the most extensive, having become popularly applied to houses and buildings, with a relatively mature construction process for the installation and assembly of parts, such as composite slab and precast shear wall. The steel building prefab is suitable for big space halls and factories, where factory manufacturing and field rapid construction dramatically reduce the project duration and allow for greater flexibility. While lumber and mixed-use systems are still emerging, their use has been gradually increasing in cultural tourism architecture and low-rise housing construction. Combined with the development of eco-friendly building materials, their building techniques are becoming more environmentally friendly and accurate. The individualized evolution of such technological structures is also being adjusted to various types of architecture, supporting a diverse, coexisting ecosystem of applications.

### **2.2. Implementation level of core construction processes for prefabricated components**

Prefabricated component hoisting, installation, and grouting is the key link in the construction of prefabricated buildings. The top construction companies at home have formed a mature, uniform lifting technology, using mobile or tower crane equipment to correctly and precisely lift the prefabricated beams, floor plates, columns, etc. The continuous updating of smart facilities is constantly improving hoisting efficiency. Grouting technology has formed a standardization process based on technologies such as the sleeve grouting method and grout anchor splicing method, while the development and use of special grout materials have greatly improved the durability of component connections. The use of auxiliary processes, such as sealing and waterproofing for prefabricated components, has also been greatly improved. In order to solve problems existing in engineering practice, such as leakage joints in prefabricated buildings, the sealing materials and waterproof layer material adaptability is improved, by standardization process procedures, construction firms decreased human errors and gradually increased the rate at which their key process outputs met standards. But, the process application still has significant differences between various areas, as well as among enterprises of different qualification levels, while small and mid-size construction companies continue to need more uniformity in their processes.

### **2.3. Integrated application of digital technologies in construction processes**

BIM becomes the mainstream digitalization tool of prefab. The major features are 3D modeling, collision checking, and parameterized modeling, to reconstruct the whole building structure in an early stage of the construction process so that spatial conflicts as well as dimensional deviation between components can be detected early to optimize assembly plans at the source, significantly reducing on-site rework rates and material waste. Leading construction firms have further achieved real-time integration between BIM models and construction progress, cost, and quality data, tightly integrating model data and construction schedule for visual workflow planning and dynamic resource assignment, thus greatly improving the informatization and precision control over the whole building construction process; while the application of IoT is based on intelligent sensors placed in the prefabricated parts and building machines to realize real-time data collection, tracking and tracing through its full life-cycle (i.e., from manufacturing and transport to construction site installation and assembly). It precisely identifies parts' location, status and construction machine conditions, thus avoiding wrong installation and machine breakdowns as well as providing accuracy and security during the whole building process<sup>[1]</sup>. On the other hand, the integrated application of technologies such as big data and artificial intelligence in prefabricated construction is becoming increasingly sophisticated. Through the integration, systematic analysis, and deep exploration of multidimensional data, including personnel, material, machine, schedule, and quality produced during the course of construction, to facilitate early detection of safety risks, reasonable arrangement of construction resources, and the intelligence optimization of construction procedures. Some intelligent building sites have even used intelligent facilities

such as drone inspection, smart vibration devices, and welding robots that replace human workforces for dangerous and repetitive jobs, pushing forward the automation and intelligentization of building processes. In general, integration of digital technologies with prefabricated construction techniques is gradually breaking down traditional information barriers, transforming construction management models and on-site operations, and being used to improve the productivity, quality, etc., of prefab.

### **3. The core issues in the development of prefabricated building construction technology**

#### **3.1. Regionalization and fragmentation of the construction technical standards system**

Although the technical standards of prefabricated building construction in China have already been preliminarily established, there is still a great gap between regions. Each province or city has also formed different construction technical specifications based on their own local development needs, leading to the absence of national standards on the size specifications, connecting methods and acceptance rules of prefabricated parts, which brings great inconvenience to the large-scale project cooperation between regions and is not conducive to the mass production and supply of prefabricated parts throughout the country. Further, the updating speed of some building standards is not in line with the development of the industry; there are no general technical specifications and acceptance criteria for new prefab parts or smart construction machinery, leaving professionals with little direction on how to apply such developments in practice. As a result, certain companies remain committed to conventional building practices, diminish technological innovation, and reduce the efficiency of prefabricated building techniques. While lack of good coordination between construction technical requirements among various structures, and the lack of construction standards for hybrid structural prefabricated buildings.

#### **3.2. Process and efficiency shortcomings in prefabricated component construction coordination**

A myriad of technical issues plagues each step along the process chain: from the production of components in a factory to the construction site where they are assembled. Poor anchoring and shielding can lead to damage whilst transporting them, deformation and so on, affecting the precision of installation. Some construction units do not have special transport route planning and methods, which further increases the possibility for components to be damaged. During in situ assembly, the precision of placement and alignment is still insufficient; many small and medium enterprises still rely on manual measuring means, which results in a large deviation affecting the stability of the whole structure; Low overall construction efficiency, with lack of coordination between the arrival acceptance of components, their storage at site and their lifting and assembly operation: long lags between these steps and suboptimal use of construction means are responsible for delays.

Meanwhile, methods of connection between precast and monolithic parts remain unperfected, which creates major difficulties in the creation of joints, which not only hinders construction efficiency, but it also creates potential quality risks, and is also a significant factor limiting improvement in the productivity of prefabricated construction.

#### **3.3. Insufficient precision in quality control throughout the entire construction process**

The quality of prefabricated buildings is controlled at various stages from the production of their parts through transport, design, manufacturing, on-site installation and final acceptance. Nevertheless, the existing QC system is still dispersed without good communication across each phase of the life cycle or timely sharing of information between the manufacturer for components and the contractor for construction, which means that defects at the production stage cannot be discovered promptly, not maintaining the site work standards. Construction inspection is usually concentrated only on key activities and not on other supporting activities, making small flaws more probable. There are a few technical methods of quality assurance: most companies still mostly use visual inspection and field measurement, not having access to sophisticated smart test instruments that allow the quality of key hidden work features (e.g., bond at joints, fullness of grout) to be determined with confidence, which makes accurate quality control difficult<sup>[2]</sup>.

Meanwhile, the system of quality control responsibility is still insufficient. For some construction enterprises, quality control becomes just a show, and workers' low-quality consciousness and lack of compliance with production procedures exacerbate QC accuracy and efficacy problems.

## **4. Analysis of the causes of technical issues in prefabricated building construction**

### **4.1. Insufficient synergy between technological R&D and engineering practice**

The development of prefabrication construction technology mainly depends on the university and scientific research institute, and major construction material companies, whose research is largely focused on basic research and new technology development. Yet, these developments are usually not closely related to the practical needs of engineering work. While some scientific findings do relate to technological development, their application in practical engineering projects is limited due to problems such as site constraints or economic concerns, resulting in a disconnect between technological advancement and its actual application by engineers on projects. Construction firms are the primary end-users for such technologies; they have little incentive to invest in R&D. The vast majority of small- and medium-sized construction companies lack internal R&D capability, and instead use existing technologies passively, rather than addressing the actual challenges encountered during fielding. This precludes technology fixes for important operating constraints. Further, the mechanism system for the transformation of scientific research results is not yet perfect; there are no dedicated science and technology service institutions or platforms. From laboratory research to engineering construction takes a long time, which greatly restricts the speed of updating and upgrading technologies.

### **4.2. Lagging progress in enhancing the compatibility of construction equipment and processes**

The level of intelligence and the degree of specialization of prefabrication construction facilities are relatively low at present. Most domestic construction firms use conventional general-purpose equipment in their primary activities, such as hoisting, grouting, positioning, and inspection. Lack of special intelligent equipment that are specially designed for the features and needs of prefabrication construction, resulting in a small share of the marketplace. Several high-end smart building systems are still dependent on foreign vendors, resulting in high purchase and maintenance costs, which are out of reach for many small- to mid-size companies. Thus, there is a significant gap between existing construction equipment and high precision requirements for prefabrication construction techniques; the speed of upgrading the construction process far lagged behind that of equipment and component development, while the field application of new prefabricated components and smart equipment requires parallel improvement of construction techniques. Many enterprises still use the old method of prefabrication, and do not timely adjust their process and construction methods based on the performance parameters of the facilities and components, so the performance advantage of intelligent devices is not fully utilized, and the quality of construction for newly added facilities cannot be guaranteed<sup>[3]</sup>.

Meanwhile, the standardized and regulated training system for construction techniques remains inadequate, and construction workers lack sufficient proficiency in new techniques and methods, further compromising the compatibility between construction equipment and processes.

### **4.3. Weak professional construction teams and management system development**

Prefabrication is highly demanding in terms of skills and expertise of the professionals involved; it needs qualified workers capable of performing key operations like assembly, connecting and grouting prefabricated parts, but also specialized managers able to operate on digital equipment, manage all links of the construction process, coordination between many construction processes. But at present China's professional prefabricated construction team is far behind the pace of development, most of these people were transferred from traditional construction personnel, no systematic, lack of relevant education and experience regarding the production of prefabricated components or use of computerized technology, leading to a lower level of expertise; lack of matured project management system for precast/prestressed concrete

structures; conventional extensive management models from traditional construction are not able to fulfill completely the precision, digitalization, and prefabricated project standardization requirements. Most construction enterprises do not have a department for prefabricated construction management, no professional staff, with unstandardized procedures, undefined management criteria, and insufficient capacity to effectively coordinate the monitoring of construction schedules, prices, cost, and quality.

At the same time, there are no standardized professional standards and a systematic training system in the industrial field of prefabricated construction management staff, which leads to different professional skills and management abilities of prefabricated building management staff, making it difficult to realize accurate and full-process control over the whole construction process, which seriously affects the application of building technology in practice.

## **5. Optimization strategies for assembly building construction technology**

### **5.1. Establish a nationally unified construction technical standard system**

considering the particularities in terms of construction features and demands related to the use of different structural systems for prefabricated buildings, such as precast concrete, steel, and wood buildings, to harmonize manufacturing of the building products (prefabs), design plans, core quality acceptance criteria, and safety operating procedures. This will eliminate regional standard differences, achieve nationalized uniform production and effective distribution of prefab parts, and dramatically lower coordination costs for inter-provincial construction projects. At the same time, establish a flexible standard revision process in order to adapt to the development of technology within the industry. In relation to the on-site use of new types of precast elements, intelligent construction equipment, and digital management technologies, relevant professionals and top companies need to formulate corresponding construction technology specifications and quality acceptance standards as soon as possible to fill the blanks left by the current industry standards and give technical instructions for the implementation of new technologies and new equipment<sup>[4]</sup>. Improve the effective connection between construction technical standards of various types of structures, and (c) special attention to the improvement of standards related to hybrid structure types of prefabricated buildings to achieve a national standard system that covers all structural systems, construction phases, and quality dimensions.

At the same time, strengthen the implementation and oversight of standards to guarantee that all construction companies fully comply with national regulations throughout the building process.

### **5.2. Promoting the integrated innovation of construction technologies and intelligent equipment**

Equipment manufacturers via collaborative university-industry-research partnerships. Focus on fundamental construction activities, such as lifting, grouting, alignment, and quality control. to develop flexible, cost-effective, user-friendly intelligent machines that will significantly reduce reliance on imported technology and increase the use of smart systems by smaller contractors and subcontractors. At the same time, promote the intelligence transformation and upgrade of conventional construction machinery, adding intelligent sensors and automatic control devices for greater accuracy and degree of automation; based on large-scale use of intelligent equipment, promote concurrent optimization and innovation of building technology. Based on the operation mode and performance advantage of various intelligent appliances, lead manufacturers need to define standard work procedures, operation instructions, etc., in order to reach the best possible match of machine and process, fully exploiting the technological advantages of smart technologies.

Enhance R&D and the broad use of new construction technologies. Solving industry problems like connections between pre-fabricated parts, hidden engineering implementation technology, anti-water/anti-seepage technology, research and application of advanced, excellent and economical new processes and techniques, such as new sleeve grouting technology, overall assembled water-proof closure technology, etc., to improve the science and operability of the whole construction process.

### **5.3. Improve the refined management system for the entire construction process**

Develop an integrated, information-based management platform covering the entire prefabricated construction process. By integrating digital technologies such as BIM, IoT, big data, and artificial intelligence, this platform eliminates information barriers across all stages, from prefabricated component production, transportation, and storage to on-site construction, project completion acceptance, and operational maintenance. It enables real-time data sharing and coordination among all phases, allowing continuous monitoring of construction progress, quality, costs, and safety metrics. The platform facilitates dynamic and rational allocation of construction resources and early risk alerts, fundamentally breaking down fragmented quality control practices and significantly enhancing management precision and efficiency. A comprehensive quality control system spans the entire construction lifecycle, establishing a clear accountability traceability mechanism covering “component production – on-site construction – project completion acceptance.” This defines the quality responsibilities of all stakeholders, including component manufacturers, construction contractors, and supervision firms, and strengthens quality inspections for critical processes such as grouting, connections, and waterproofing. Advanced intelligent inspection equipment, including grouting fullness detectors, component connection density testers, and 3D laser scanning systems, is widely adopted to improve detection accuracy and scientific rigor. Additionally, optimized management workflows reduce procedural delays, ensure seamless coordination across construction phases, and maximize overall efficiency while effectively controlling project costs.

## **6. Conclusion**

Prefabrication is at the heart of building industrialization. The development level represents a phased outcome of China’s construction industry transformation, while current standards, construction methods, and management problems are all important bottlenecks to solve if we want this field’s mass production. To resolve such technical problems, it is essential to ground our work on practical situations of the industry: reaching a technical agreement with common standards, driving improvement in building methods and techniques, driving quality assurance improvements, and emphasizing the training of professional construction talents and the coordination between industrial chains.

Through comprehensive innovation in various aspects (technology, process, management), etc., we can constantly improve the technological level of the prefab industry and promote the whole building industry towards a high-quality, green and intelligent development. In addition, developing prefabricated building technology is a systematic project that needs the joint efforts of governments, enterprises and research institutes to strengthen scientific and technological development and application. This approach would fully leverage the role that prefabrication can play in upgrading and transforming our construction industry, thus contributing towards achieving China’s overall goals on industrialised construction.

## **Disclosure statement**

The authors declare no conflict of interest.

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