



Research on Key Technologies and Management Strategies in Assembly Building Construction for an EPC Project in Linqing City

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Abstract. In the evolution of the construction sector towards enhanced sustainability and efficiency, prefabricated buildings have come to the fore. Nevertheless, issues such as component handling and construction procedures pose significant hurdles. This research investigates an Engineering, Procurement, and Construction (EPC) project located in Linqing City, focusing on the essential technologies and management strategies employed in the construction of assembly buildings. The project encompasses a variety of structural designs, with certain residential units achieving a notably high rate of prefabrication. To address construction-related challenges, including the delivery and storage of components, installation and connection processes, and joint waterproofing, innovative solutions were adopted. These included the integration of vehicle-crane operations, the utilization of high-precision equipment and testing technologies, and the implementation of advanced waterproofing techniques. Additionally, a comprehensive quality control system was established, encompassing all stages from component production to construction, alongside a scientifically informed schedule management framework. The results indicated significant improvements in both construction efficiency and quality, facilitating the seamless progression of the project and providing valuable insights for the advancement of the assembly building sector.

Keywords: Assembly building; Construction technology; Quality management; Progress control; Safety and security.

1 Introduction

1.1 Background and Significance of the Study

Prefabricated buildings represent a significant avenue for the transformation and enhancement of the construction industry, offering notable benefits in terms of energy efficiency, reduction of emissions, and increased construction productivity. Nonetheless, existing studies seldom comprehensively address the specific challenges in pro-

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jects with diverse structures and high prefabrication rates, like vehicle-crane integration, component connection control, and node waterproofing. Our Linqing City EPC project aims to fill this gap. With multiple structures and high prefabrication in some parts, it's a complex and representative case. Analyzing and solving its problems can offer valuable experience for similar projects, promoting the development of prefabricated building technology and management.

1.2 Overview of the Current Status of Domestic and International Research

Internationally, the development of prefabricated buildings has a long-standing history characterized by mature technologies. European nations have achieved considerable progress in the production of precast concrete components, connection technologies, and standardized design practices. Germany, in particular, is recognized for its leadership in component precision and quality control, supported by an industrialized construction system that promotes efficient building practices^[1]. Similarly, Japan has made substantial investments in the research and development of seismic-resistant prefabricated building technologies, focusing on the creation of connection nodes and damping technologies that enhance the seismic resilience of structures.

In recent years, research pertaining to prefabricated buildings in China has experienced rapid advancement. Fueled by policy initiatives, both scholars and enterprises are actively pursuing technological research and practical applications. In the domain of component production, there has been ongoing optimization of raw material formulations and production processes aimed at improving the strength and durability of components. Furthermore, significant progress has been made in construction technology, particularly concerning the hoisting and connection of prefabricated components. However, there remains potential for enhancement in construction management, particularly in terms of refinement, informatization, and regional adaptability^[2]. This project addresses these challenges and, through the examination of engineering examples, offers targeted solutions to foster the development of prefabricated buildings in China, thereby promoting localized innovation in both technology and management practices.

2 Project Overview

2.1 Basic Information on the Project

The project is situated in the northern region of Linqing City, Liaocheng City, Shandong Province, encompassing a total land area of 18,146 m² (approximately 27.22 acres) and a total construction area of 52,603.09 m². The design incorporates a differentiated structural system, which includes:

- **Frame Structure:** The basement, kindergarten (Building 1), and distribution room (Building 7) utilize a frame structure, facilitating spatial layout flexibility and optimizing seismic performance through modular design.

- **Assembled Monolithic Shear Wall Structure:** Buildings 2 and 6 employ this system, achieving a prefabrication rate of 83.50%, which significantly minimizes on-site wet work .
- **Cast-in-Place Shear Wall Structure:** Buildings 3 and 5 utilize traditional cast-in-place methods as a comparative group to assess the economic viability of assembly technology.

2.2 Assembly Building Design Features

Buildings 2 and 6, above the third floor, incorporate a prefabricated laminated plate combined with a prefabricated staircase system, showcasing the following technical innovations:

- **Optimization of Structural Performance:** The interface shear resistance of the laminated slab is enhanced through the implementation of two-way truss reinforcement, and the width of the cast-in-place strip in the node area is extended to 500 mm to improve structural integrity.
- **Breakthrough in Assembly Rate Indicators:** Non-Masonry Percentage of the Enclosure Wall: 66.01%; Piping Separation Ratio: 100%(Table 1).
- **Integration of Industrialized Decoration:** The implementation of the Skeleton-Infill (SI) system in kitchen and bathroom design facilitates the decoupling of equipment pipelines from the primary structural framework.

Table 1. Pre-evaluation Form for Prefabricated Concrete Structures.

evaluation unit		Application ratio	Evaluation requirements	evaluation mark
Main structure(Q1) (50 points)	Vertical elements such as columns, load bearing walls		20%≤application ratio≤80%	15-30*
	Beams, slabs, stairs and other components	83.50%	70%≤application ratio≤80%	10-20*
Enclosure walls and internal partition walls(Q2)(20 points)	Non-bearing perimeter walls not masonry		Application ratio ≥ 80%	5
	Enclosure wall with insulation and decoration in one Integration	66.01%	50%≤application ratio≤80%	2~5*
	Internal partition walls, non-masonry	55.05%	Application ratio ≥50%	5
	Internal partition wall with piping and decoration Integration	80.5%	50%≤application ratio≤80%	2~5*
Furnishings and equipment Piping (Q3)(25 points)	full renovation	-		5
	Floors and ground surfaces of dry working methods		Application ratio ≥ 60%	5
	integrated kitchen	90.3%	70%≤application ratio≤90%	3~5*

	integrated bathroom	91.1%	70%≤application ratio≤90%	3~5*
	separation of pipelines		50%≤application ratio≤70%	3~5*
	Standardization of floor plans			1
Standardized design Q4(3 points)	Standardization of prefabricated components and parts	-	"one" radical in Chinese characters	1
	Standardization of nodes			1
	Information Technology (Q5) (2 points)	-	-	2

3 Challenges in Assembly Building Construction and Mitigation Strategies

This study examines the construction of prefabricated buildings within an Engineering, Procurement, and Construction (EPC) project located in Linqing City. It identifies key challenges and proposes relevant solutions.

3.1 Issues Related to Component Entry and Storage

The limited space available on the construction site poses challenges for the traditional storage of prefabricated components, often resulting in secondary transportation that escalates costs and quality risks. To address this issue, the project implements an innovative "truck-crane integration" approach, wherein prefabricated components are directly lifted onto transportation vehicles. By precisely planning the hoisting route and coordinating equipment to directly load components onto vehicles, we sought to enhance construction efficiency. For instance, in the case of Building 2, transportation vehicles are strategically positioned on a temporary construction road located on the northern side. Through meticulous planning of the hoisting route and effective collaboration among hoisting equipment, a seamless transition from transportation to installation of components is achieved, thereby reducing the construction timeline and enhancing overall efficiency^[3].

3.2 Technical Challenges in the Installation and Connection of Components

The installation and connection of prefabricated components are critical processes. Two significant technical challenges include the precise reservation of mechanical and electrical points and the quality control of grouting sleeve connections. Any deviations in mechanical and electrical points can adversely affect the installation of subsequent equipment and the overall functionality of the building, while the integrity of grouting sleeve connections is essential for structural stability. To mitigate these issues, the following measures are implemented^[4]:

- Component Production: The introduction of high-precision molds and advanced production equipment facilitates stringent control over dimensional deviations, en-

sureing that the accuracy of reserved mechanical and electrical points aligns with design specifications.

- Installation Phase: Construction personnel receive specialized technical training to enhance their proficiency in the grouting sleeve connection process. Additionally, nondestructive testing technology is employed to monitor the quality of grouting connections in real-time, thereby ensuring their reliability.
- Finished Product Protection: A dedicated team is established to safeguard both installed and in-progress components from surface damage and interference with connection parts.

3.3 Key Issues in Nodal Construction

The joints of prefabricated components in such structures are particularly vulnerable to waterproofing issues, with inadequate treatment potentially leading to water leakage. The project emphasizes quality control at critical nodes^[5]:

- Nodes between Prefabricated Stairs and Prefabricated Slabs: The use of new sealing rubber strips and waterproof mortar for double-layer sealing is implemented to enhance waterproof performance at these junctions (Figure 1).
- Horizontal Joints of Prefabricated Components: The splicing process is refined, incorporating waterproof structural measures such as water-stop steel plates and water-stop belts. Stringent control over joint width and splicing flatness is maintained.
- Nodes between Prefabricated Balcony Slabs, Air-Conditioner Slabs, and Cast-in-Place Structures: Reinforcement anchorage and concrete vibration compaction are intensified to bolster connection strength and waterproof efficacy. Upon completion of construction, rigorous water-holding tests and quality inspections are conducted on these node areas to ensure the absence of leaks, effectively mitigating potential water leakage risks and enhancing the overall quality of the building.

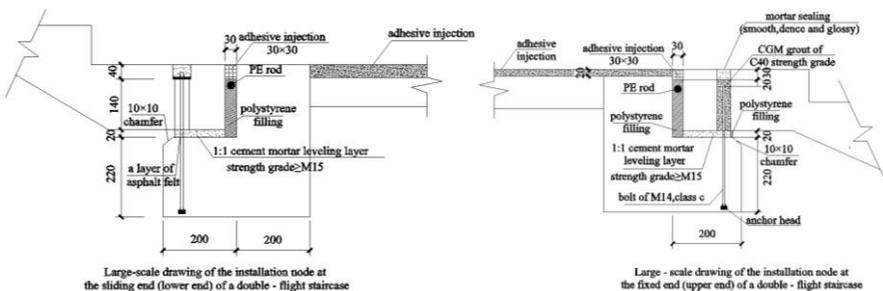


Fig. 1. Details of the Installation Nodes of the Double - Flight Staircase.

4 Assembly Building Construction Quality Control System

4.1 Quality Assurance Mechanism for the Production of Prefabricated Components

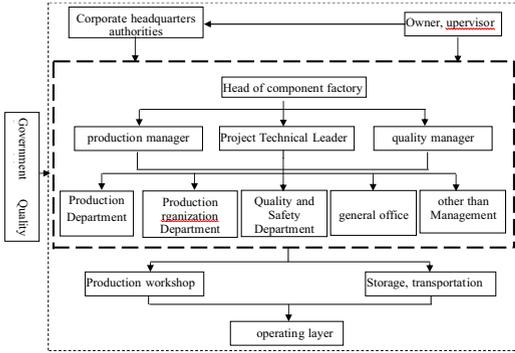


Fig. 2. Quality management organization.



Fig. 3. Quality management system.

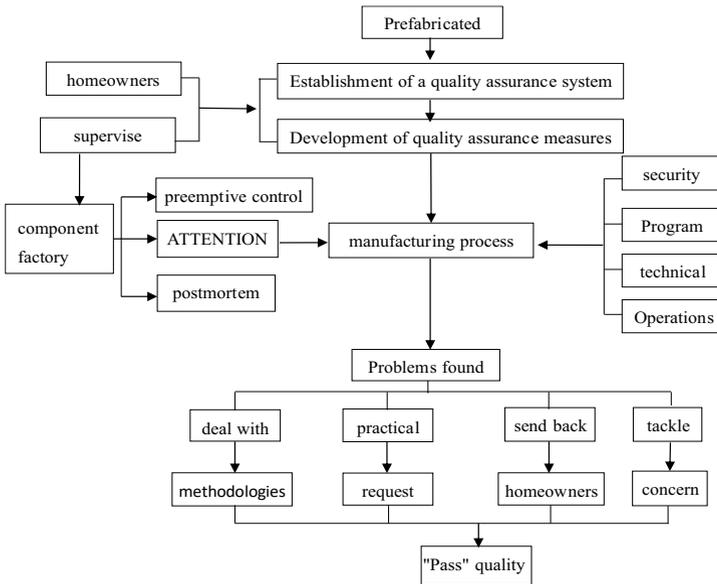


Fig. 4. Quality control procedure.

Within the quality control framework for assembly building construction, the quality assurance mechanism governing the production of prefabricated components is a pivotal element. The component manufacturing facility has established a comprehensive quality management organization (Figure 2) and developed a quality management system encompassing several crucial components (Figure 3). It has also adopted the

Plan-Do-Check-Act (PDCA) cycle (Figure 4) quality management approach. Through systematically collecting and organizing quality records, analyzing product conditions and trends, and formulating targeted improvement strategies, the required quality can be ensured.

4.2 Quality Management of Transportation and Storage of Prefabricated Components

In the domain of quality management pertaining to the transportation and storage of prefabricated components, the project has developed a comprehensive and rigorous management plan aimed at ensuring the quality and safety of these components throughout the transportation and storage processes.

Transportation Management: The project employs specialized vehicles designed for the transportation of finished products, which are equipped with flexible support and fixation devices. These features significantly mitigate the risks associated with vibration and collision during transit^[6]. Transportation routes are meticulously planned, taking into consideration the specific characteristics of the components as well as prevailing road conditions. Routes that involve complex road sections and areas prone to traffic congestion are deliberately avoided to minimize both transportation time and associated risks. During the loading phase, components are positioned and secured in strict adherence to established operational procedures, thereby ensuring the stability of the center of gravity and preventing any potential displacement during transit^[7].

Storage Management: The construction site is organized in a systematic and rational manner. Storage areas are categorized based on the type, size, and installation sequence of the components, with clear identification signage provided. The ground in the designated area for storing laminated boards is meticulously leveled to comply with flatness standards. Laminated boards are stored horizontally on specialized racks, with their positions precisely aligned with the designated lifting points. The number of storage layers is strictly limited to a maximum of six, with an upper height restriction of 1.5 meters, in order to prevent deformation of the components resulting from improper stacking practices.

4.3 Quality Supervision of the Construction Process of Assembled Structures

In the construction of prefabricated structures, a strict quality inspection system is established for the process flow of components such as composite slabs and precast stairs.

During the construction of plywood, the verticality of the uprights and the horizontality of the crossbars are monitored using a level and a theodolite when setting up the formwork support system (Figure 5). Before the installation of plywood, construction personnel need to inspect the components and mark the hoisting sequence. When hoisting to 500mm, precise installation is carried out according to the pre-set lines, and then the position and elevation are adjusted using a crowbar and U-shaped support, while ensuring proper safety precautions.

During the installation of prefabricated stair slabs, construction workers are required to first familiarize themselves with the drawings, number the components, and use total stations, level gauges and other instruments to mark lines and conduct re-checks (Figure 6). In the concrete pouring stage, the concrete mix ratio, slump, and vibration compactness should be strictly controlled. During the hoisting process, keep the hoisting stable and make fine adjustments after reaching the position. After the correction is completed, connect the steel bars in accordance with the requirements and conduct inspections. When pouring the concrete again, control the pouring height and vibration quality to ensure the reliability of the connection joints.

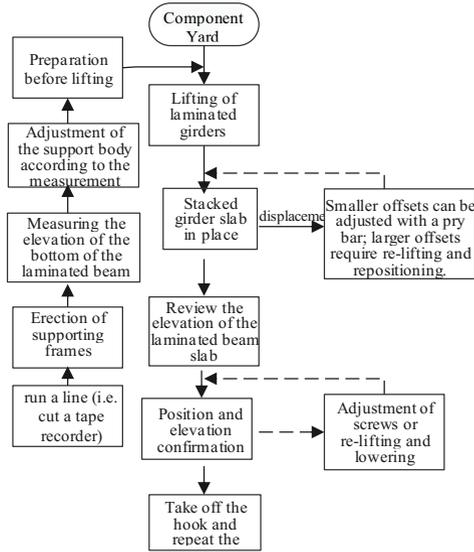
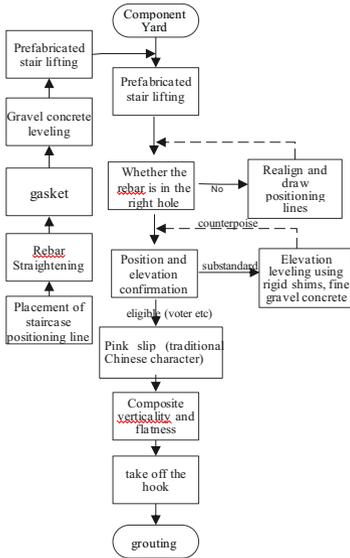


Fig. 5. plywood construction process flow chart. Fig. 6. Construction Process Flowchart of Prefabricated Stairs.

5 Assembly Building Construction Progress Management Methods

5.1 Construction Schedule Preparation and Optimization

The construction project of the assembled integral shear - wall structure commenced on July 20, 2024, and the entire structural construction is scheduled to be completed by the end of December. The construction period for both Building 2 and Building 6 is 120 days each, and the construction of the standard floors is strictly controlled to be completed at a rate of one floor every six days (Table 2). The project adopts a combination of flow construction and parallel construction. For example, while hoisting prefabricated components, the steel bar binding and formwork installation of the cast - in -

place structure in the adjacent area are carried out simultaneously to shorten the construction period. Meanwhile, professional schedule management software is utilized to track and control the progress. By updating the progress data in real - time, potential issues can be promptly identified and resolved, ensuring the smooth progress of the project as planned.

Table 2. Standard Floor Construction Progress Schedule.

No.	Task name	Duration (hours)	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
			am pm					
1	Structural snap - lining, Hoisting steel bars, Reinforcement binding for exterior and interior walls	12	█					
2	Slab wall reinforcement binding, wall and column formwork, steel pipe racking erection	12		█				
3	Installation of wall and column formwork, erection of rows of frames, and construction of floor and beam formwork installation	14			█			
4	Laminated panel installation	16				█		
5	Pre-embedded utility piping and reinforcing steel binding for laminated slabs	12					█	
6	Concrete Pouring	12						█

5.2 Dynamic Adjustment and Optimization of the Schedule

The project implements a flexible mechanism for adjusting the construction schedule to effectively manage various uncertainties that may arise during the construction phase.

- To ensure the timely production and supply of components, a communication framework has been established with manufacturers. An information system is utilized to monitor the production and transportation of components in real-time, allowing for the planning of delivery schedules based on actual conditions to guarantee a consistent supply.
- In response to changes in on-site construction conditions, contingency plans have been developed to address potential challenges such as adverse weather and geological issues. In the event of inclement weather, the construction plan is modified to prioritize indoor work or preparatory activities. When geological changes are detected, experts are assembled to assess and revise the foundation construction plan, thereby minimizing any adverse effects on construction safety and progress^[8].^[9]

5.3 Progress Management Measures and Safeguard Mechanisms

In order to facilitate the effective execution of the progress plan, the project has been optimized in five key aspects to ensure rational resource allocation and enhance construction efficiency. Workforce allocation is strategically managed based on project progress; for instance, during peak periods of prefabricated component hoisting, additional personnel are assigned to maintain high operational efficiency. Long-term partnership agreements are established with reputable suppliers to secure a consistent material supply, thereby mitigating the risks of overstocking or shortages through the

development of procurement plans aligned with project timelines. The selection and positioning of tower cranes and other equipment are informed by construction methodologies and project specifications, with hoisting plans designed to maximize efficiency. A combination of sequential and parallel construction techniques is employed; for example, while hoisting prefabricated components, concurrent activities such as steel bar binding and formwork installation for adjacent cast-in-place structures are undertaken to ensure continuity in construction and reduce overall project duration. Furthermore, a communication framework for stakeholders is instituted, wherein the construction unit enhances collaboration through meetings and technical briefings, fostering close communication with both construction and supervision units to collectively advance the project^[10].

6 Conclusions

In conclusion, the "Truck - Crane Integration" model in the Linqing City EPC project not only reduced secondary transfer costs and risks but also offered a practical example for optimizing component transportation and installation in prefab building, promoting the development of construction logistics management.

The application of advanced waterproofing techniques solved the joint waterproofing problems in prefab buildings, providing technical references for improving structure durability and guiding the innovation of waterproof materials and methods.

The comprehensive quality control system ensured each stage from component production to construction met the standards, contributing to the formulation and improvement of quality management norms in the prefab building field.

The scientific progress plan showed an effective way to manage uncertainties during construction, providing a model for optimizing schedules in other projects and promoting the research and application of advanced project management techniques.

Overall, this project has significantly advanced the knowledge and practice in prefabricated construction. Future research should focus on standardizing prefabricated components, improving connection-node specifications, and strengthening the application of BIM and other technologies.

Acknowledgments

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