Industry Science and Engineering Vol. 2 No. 9, 2025

Research on Quality Control and Efficiency Improvement of Prefabricated Concrete Structures in High-Rise Building Construction

Chen Xingui, Jiang Yan
Xinjiang Production and Construction Corps Xingxin Vocational and Technical College, China

Abstract: The use of prefabricated concrete structures in high-rise buildings has become a primary method in building industrialization. This imposes strict requirements on verticality, component connection reliability, and construction efficiency during the construction process of high-rise buildings, necessitating research on prefabricated construction techniques. Starting from key stages such as the production of prefabricated components, transportation, on-site installation, and joint connections, the main factors affecting construction accuracy and efficiency are analyzed. Emphasis is placed on technical aspects such as high-precision positioning, cumulative control of installation deviations, and joint connection processes like sleeve grouting. By optimizing construction workflows and improving connection technologies, the construction process and overall structural stability of high-rise prefabricated buildings can be enhanced.

Keywords: High-Rise Buildings; Prefabricated Concrete; Construction Accuracy; Construction Efficiency; Joint Connections; Construction Efficiency Node Connection

1. Introduction

In recent years, prefabricated concrete structures have been widely adopted in high-rise buildings due to advantages such as standardized design, factory production, and on-site assembly. High-rise structures are tall and complex in load-bearing, making them sensitive to dimensional deviations and cumulative errors during construction. How to ensure rapid and accurate on-site installation while maintaining the precision of prefabricated components and guaranteeing the reliability of numerous connection nodes remains a challenge in high-rise prefabricated construction. Therefore, in-depth research on key process control points across construction stages and exploration of collaborative approaches to improve efficiency hold practical significance for advancing the efficient development of prefabricated technology in high-rise buildings.

2. Construction Characteristics of Prefabricated Structures in High-rise Buildings

High-rise building structures, with their numerous floors and considerable height, exhibit distinct characteristics in prefabricated construction. The considerable lifting height of components and limited working radius impose high demands on the performance and coordinated operation of large machinery such as tower cranes. Secondly, the requirement for overall verticality in high-rise structures far exceeds that of multi-story buildings, as installation deviations accumulate layer by layer, affecting the positioning of the upper sections of the structure. The wide variety of components complicates the coordination of transportation, storage, and installation sequences. Additionally, the numerous connection nodes between vertical load-bearing components require reliable connection techniques, which are essential for ensuring the safety and stability of high-rise structures under complex loads [1].

3. Key Points of Prefabricated Component Production and Transportation

3.1 Control of Mold Dimensional Accuracy

The dimensional accuracy of prefabricated components serves as the foundation for subsequent installation work. Molds, as the carriers for component shaping, must have their geometric dimensions, flatness, and rigidity strictly controlled. In the design and manufacturing of molds, potential deformations during concrete pouring, vibration, and curing should be taken into account. Steel mold seams must be tightly sealed to prevent grout leakage. For molds reused multiple times, a regular inspection and maintenance system should be established to promptly repair worn or deformed parts. For special-shaped components or those with complex openings, positioning ribs and limiters in the molds must be stable and reliable to ensure consistency across batches of the same component type.

3.2 Positioning of Embedded Parts and Reserved Holes

Embedded parts (such as lifting rings and connecting reinforcement bars) and reserved holes (such as sleeve holes and pipeline holes) in prefabricated components are critical elements for achieving structural connections and functional requirements. Their spatial positioning demands not only accurate planar placement but also three-dimensional precision in controlling elevation, depth, and verticality. Even minor spatial deviations in embedded reinforcement bars or sleeves can cause difficulties during on-site installation and alignment, affecting the anchorage length of the reinforcement bars and the mechanical load transfer path. If the position or size of reserved holes deviates, on-site secondary chiseling becomes necessary. Such destructive adjustments compromise the integrity of the components and impact the installation of pipeline systems [2].

3.3 Optimization of Component Transportation and Stacking

The transportation and on-site storage of components from the production plant to the construction site are critical phases that impact efficiency and ensure the integrity of the components. High-rise buildings require a large quantity of components, making it essential to develop a rational transportation plan to align component supply with the on-site lifting schedule and prevent excessive accumulation of components at the site. During transportation, custom supports should be designed according to the type of components to ensure even stress distribution and prevent cracks or damage caused by road shocks or improper stacking. The on-site storage area should be level and solid, with component labels facing outward for easy identification. The stacking arrangement should take into account the sequence of lifting, optimize the process of secondary handling, and minimize unnecessary repeated movements of the tower crane.

4. On-Site Installation Precision Control and Efficiency Coordination

4.1 Measurement, Layout and Positioning Reference

The accuracy of on-site installation relies heavily on precise measurement and setting-out. In high-rise buildings, high-precision total stations or laser plummets should be used to establish a site-wide control network. The baseline for positioning the first-floor structure serves as the reference for subsequent floor installations, requiring millimeter-level accuracy. As the building height increases, control points must be transferred upward floor by floor. The internal control method is employed during this transfer process, which involves vertically projecting control points from the base floor to the working level through reserved floor openings, thereby reducing measurement errors caused by external factors such as wind and sunlight. Installation control lines on the working level should be marked and carefully verified before component lifting.

4.2 Component Hoisting and Temporary Fixation

Component lifting is central to the efficiency of prefabricated construction. High-rise buildings are subject to significant wind loads, requiring lifting operations to be conducted within specified wind speed limits. Before lifting, the operation path of the tower crane should be optimized to ensure a smooth process during hoisting, rotation, and descent, preventing collisions with already installed components or support systems. During component positioning, slow and precise alignment with the installation control lines is essential. Once initially positioned, components must be temporarily fixed immediately. Particularly for exterior wall panels and precast columns, adjustable diagonal bracing should be used for temporary support. The stiffness of the bracing and the reliability of its connections are critical, as they facilitate subsequent fine-tuning adjustments [3].

4.3 Install Verticality Deviation Control

Vertical alignment is a key control metric in high-rise prefabricated structures. The cumulative effect of installation deviations is particularly pronounced in tall buildings. The essential approach to controlling verticality is "calibration floor by floor, timely deviation correction." After the installation of prefabricated walls or columns on each floor, their vertical alignment must be verified using a laser plummet based on the control points from the base floor, while the components are still temporarily fixed. If deviations are detected, fine adjustments should be made using adjustable braces or jacks. Under no circumstances should upper-level components be installed while deviations persist. For exterior wall panels, the flatness of the façade must also be ensured. Through layer-by-layer measurement and adjustment, construction tolerances can be kept within acceptable limits.

4.4 High-Precision Installation and Calibration Technology

Traditional calibration methods relying on crowbars and plumb bobs often struggle to meet the millimeter-level installation accuracy required for high-rise buildings, due to human factors and interference from wind loads at elevated heights. As a result, high-precision calibration technology has evolved into a system based on active adjustment and real-time feedback. By installing fine-tuning devices integrated with multi-directional hydraulic jacks at the base of prefabricated columns or wall panels, these systems enable remote-controlled adjustments after temporary component fixation. This allows for precise corrections of horizontal displacement, elevation, and verticality with an accuracy of up to 1mm. This active adjustment approach replaces the traditional passive methods of hammering or prying, significantly improving both the controllability of calibration and operational efficiency.

5. Node Connection Technology and Process Optimization

5.1 Fullness of Sleeve Grouting Connection

Sleeve grouting is a critical technique for connecting reinforcing bars in vertical components of high-rise prefabricated structures. The fullness of the grouting directly affects the anchorage performance of the rebars and the load-bearing capacity of the joints. It is essential to use specialized grouting materials with high fluidity, slight expansion, and high strength. Before grouting, the sleeves and component connection areas must be thoroughly cleaned, and the grout outlet vents must be unobstructed. During grouting, pressurized grouting should be applied with stable pressure maintained until uniform, bubble-free grout flows from the outlet vents. After grouting, the components should not be disturbed. Techniques such as endoscopic sampling or ultrasonic testing can effectively verify the fullness of the sleeve grouting.

5.2 Construction of Grouting Anchor Lap Joints

Another method for vertical connection of precast wall panels is grouted sleeve splicing. This technique involves using U-shaped reinforcing bar grooves reserved at the bottom of the wall panel, into which U-shaped rebars are inserted and lapped with the exposed rebars of the lower wall panel. The connection is then achieved by grouting with high-strength, non-shrink mortar. The key to construction lies in controlling the accuracy of the rebar lap length and position. During mortar grouting, it is essential to ensure the compactness of the mortar and avoid voids in the lapped area. Since this joint is located inside the wall, making post-construction inspection difficult, process control is particularly critical. Special formwork is used to seal the grouting port, and light vibration is applied to ensure the mortar fully envelops the lapped rebars, forming a reliable anchorage.

5.3 Horizontal Component Connection Process

Horizontal connections between precast beams and columns, as well as between precast floor slabs and beams, are crucial for ensuring the integrity of the structural floor system. Common connection methods include cast-in-place concrete with reserved reinforcing bars, keyway connections, and bolt connections. For horizontal connections using cast-in-place concrete, such as the core zones of beam-column joints, careful attention must be paid to the arrangement of reinforcing bars to avoid excessive density that could hinder proper concrete flow. The cast-in-place concrete should be made of micro-expansive, early-strength materials with the same grade as the precast components. The arrangement and removal timing of the support system for composite slabs must be precisely calculated. The composite slabs should remain supported until the cast-in-place concrete layer reaches the required design strength to prevent surface cracking.

6. Conclusion

The construction of prefabricated concrete structures in high-rise buildings is a complex systematic project composed of multiple highly interconnected stages, including production, transportation, installation, and connection. Improvements in construction efficiency and the control of construction accuracy mutually reinforce each other. The precision of prefabricated component manufacturing serves as the foundation, on-site measurement and positioning provide the benchmark, and layer-by-layer installation deviation control governs the process. The reliability of joint connections, particularly those of vertical components, is essential for ensuring the overall stability of high-rise structures. In-depth analysis and continuous improvement of each key process, along with the ongoing enhancement of construction techniques and collaborative operations, represent the inevitable direction for achieving efficient and high-precision construction of high-rise prefabricated buildings.

References

[1]Zhao Z ,Mao J ,Liu J , et al.Low-carbon electric curing of alkali-activated slag precast concrete: Advancing efficiency, energy savings, and carbon reduction[J].Journal of Building Engineering,2025,114114350-114350.

[2]Sun Z ,Cheng X ,Liu L , et al.Pullout behavior investigation of connecting rebars in mortise-tenon joints for precast concrete shear walls[J].Engineering Structures,2026,346(PA):121630-121630.

[3]Wang S ,Cui N ,Yang D , et al.Mixed-integer programming and constraint programming approaches for precast concrete flowshop scheduling with multiple production lines[J].Automation in Construction,2026,181(PA):106621-106621.

[4]Sachchithananthan M ,Thayaparan M .A framework to select suitable sustainable materials for high-rise buildings in Sri Lanka[J].International Journal of Construction Management,2025,25(9):1072-1086..

[5]Azarij L ,Jingjing Y ,Irina T .Features of construction control in the construction of high-rise buildings[J].E3S Web of Conferences,2024,53303011-03011.DOI:10.1051/E3SCONF/202453303011.