Intelligent Analysis and Construction Coordination of Prefabricated Building Structure Design

Huachun Sheng

Bengbu Architectural Design and Research Institute Group Co., Ltd., Bengbu, Anhui, 233000, China

Keywords: Prefabricated buildings; Structural design; Intelligent analysis; Construction collaboration; Digital technology

Abstract: As a new construction mode, prefabricated buildings are a key path to promote the development of building industrialization, with significant advantages such as improving production efficiency, ensuring engineering quality, reducing environmental pollution, and saving labor costs. Prefabricated concrete buildings have many advantages, such as low pollution, high on-site construction efficiency, and can be reused many times. Assembled building engineering mainly involves production, construction, design, decoration, supervision and other links. The introduction of building information modeling (BIM) technology provides more powerful support for the industrialization of prefabricated buildings. From the actual situation, BIM technology plays an increasingly obvious role in the design process of prefabricated buildings, and has been widely used. The application of intelligent construction equipment in the installation process of prefabricated components further improves the level of construction automation and promotes the transformation of construction methods. This paper studies the intelligent analysis method in the structural design of prefabricated buildings, and how to integrate BIM technology into the whole process of structural design.

1. Introduction

In the contemporary construction industry, with the continuous advancement of technology and the increasing demand for building quality, construction efficiency, and sustainable development, prefabricated buildings, as a new type of intensive, industrialized, and intelligent construction method, are gradually becoming an important direction for the transformation and upgrading of the construction industry [1]. Compared to traditional cast-in-place concrete structures, prefabricated buildings achieve standardization, modularization, and refinement of the construction process through an integrated process of "design factory prefabrication logistics transportation on-site assembly", significantly improving construction efficiency, engineering quality, and resource utilization level [2]. Against the backdrop of the "dual carbon" goal and the construction of new urbanization, the development of prefabricated buildings has become a key path to promote high-quality development of the construction industry [3]. In the whole life cycle of prefabricated buildings, the design and manufacturing processes are very important stages. The three-dimensional space model established by BIM software represents the design results. However, all kinds of architectural drawings and 3D animations of horizontal, vertical and sectional spaces can be completed at will according to the model, which provides designers with more convenient tools [4].

By introducing advanced technologies such as BIM, parametric design and intelligent algorithm, accurate modeling of components, intelligent analysis of structural performance and automatic output of production data can be realized [5]. The application of intelligent manufacturing equipment in the production of prefabricated components has further promoted the development of building industrialization [6]. Prefabricated architecture is essentially an architectural model that separates design, production and assembly in time and space. There is a time and space span between each stage. Changes in the design stage can sometimes be difficult to transfer to the production and construction stages in time. This may lead to component mismatch, installation conflict and project delay [7]. In recent years, the application of BIM technology in the field of architecture has been deepening, but most of the research still focuses on basic modeling and visual display, lacking

  DOI: 10.25236/icacel.2025.125

systematic exploration of multi-stage and multi-disciplinary cooperation mechanism [8]. Based on different angles, the research and exploration are carried out, mainly focusing on the analysis of costs and their influencing factors in each stage, the establishment of relevant forecasting models and so on. These studies have gradually extended to the fields of construction management, schedule simulation and so on, but they are still insufficient in the optimization of construction site layout and visual coordination of assembly process.

BIM technology has powerful three-dimensional modeling ability, information integration characteristics and multi-dimensional simulation function. These characteristics provide an effective way to solve the above problems. BIM modeling tools no longer provide low-level geometric drawing tools, and the operating objects are no longer simple geometric relationships such as points, lines and diagrams, but building components such as walls, doors and windows. From this point of view, it is not a bunch of unrelated points and lines that are established and modified, but the whole building composed of interrelated building components. More importantly, BIM platforms can achieve information sharing and efficient collaboration among multiple stakeholders such as design, production, and construction, breaking the "information island" and promoting the development of project management towards intelligence and integration. Based on this, this article proposes a visual design method for prefabricated building structure construction site layout based on BIM technology, aiming to scientifically plan and dynamically simulate the construction site through digital twin and 3D simulation technology, and improve the intelligence and refinement level of site management.

2. Construction Process and Application Points of Prefabricated Buildings Based on BIM

2.1. Construction Process

In the digital design and construction process of prefabricated buildings, BIM technology plays a crucial role as the core supporting means, and is a key technical guarantee for improving the integration level of building design, production, and construction [9]. In the scheme design stage, the design unit needs to communicate fully with the construction unit, clarify the functional requirements, assembly rate requirements, and technical standards of the project, and carry out preliminary scheme design based on this [10]. Compared with the traditional architectural design structure, BIM technology has more three-dimensional intuitive characteristics, which can better let people know the structural image. Especially the assembled building, its structural design needs to be more reasonable and perfect. The model provides a data basis for further design, component disassembly and production. In order to ensure high efficiency in the construction process, BIM technology is integrated into the whole life cycle management of prefabricated components. The designer refines the structural system according to the preliminary scheme, extracts the information of standardized prefabricated components, and constructs a complete BIM model of prefabricated buildings.

From the perspective of engineering practice, it is necessary to realize reasonable cooperation and perfect consultation. Relevant managers also need to formulate feasible construction measures according to specific structural models, which is also an ideal goal that traditional design schemes cannot achieve. In the plane layout design, the principles of regular layout and reasonable column network should be followed to optimize the efficiency of functional space utilization and streamline organization. In the construction stage, BIM model is used to guide the production, transportation and site hoisting of prefabricated components. Through accurate size control and installation positioning, the construction quality of components is ensured. BIM technology enables different professionals to communicate and carry out corresponding work on the same platform, and complete the combined tasks of various information, building components, electromechanical components, etc. in building engineering. The construction process of assembled building based on BIM is shown in Figure 1.

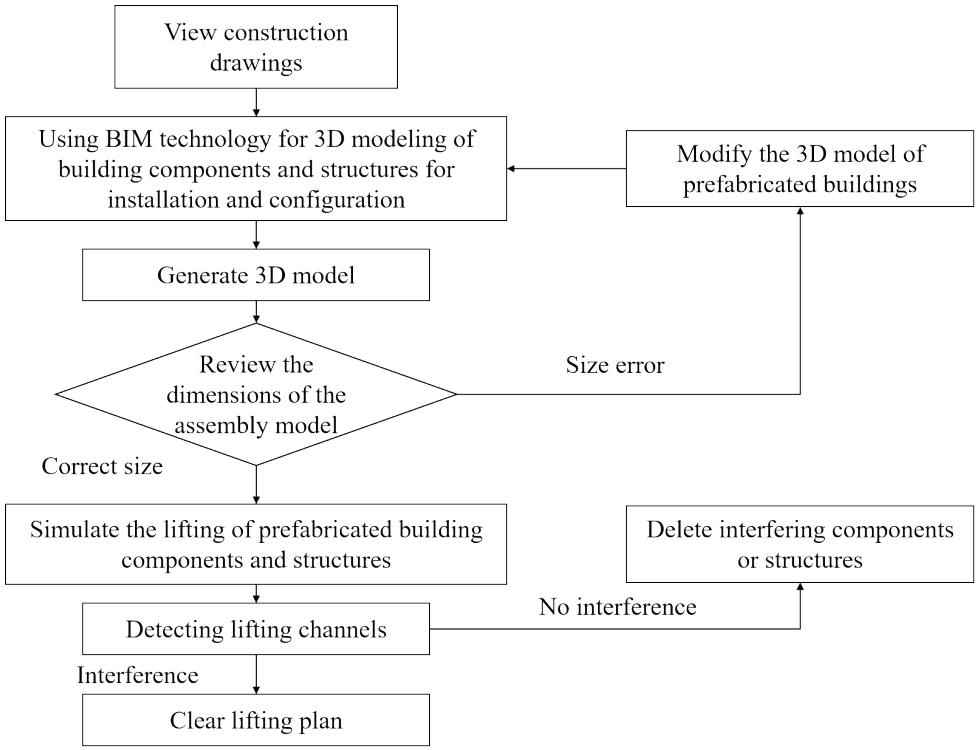

Figure 1 Construction process

2.2. Application Points

In the process of assembly building construction, the application of BIM technology can improve the fine and intelligent level of construction management. With the help of BIM modeling software such as Revit, three-dimensional visual modeling and spatial simulation can be carried out on the construction site. Assembled building is a building system integrating production, construction, decoration and design. This type of building has very obvious integration characteristics. For BIM technical scheme, it is necessary to clarify various main elements. BIM model based on construction drawing can be used for digital pre-assembly and deviation detection of prefabricated components, and accurately identify the differences between actual components and design models in dimensions, positions and connection nodes. Through the application of BIM technology, three-dimensional simulation test can be completed by establishing a model to ensure the integrity and reliability of the data itself.

BIM technology plays a key role in hoisting construction simulation. Information cooperation method can be used to complete visual assembly, inspection and simulation work needs to be completed at interactive nodes to ensure the efficiency of daily data integration, realize dynamic supervision and management, and avoid repeated design problems. By combining the comparison of various hoisting schemes and collision detection, BIM can detect the spatial conflict among equipment, structures and components in advance and evaluate the feasibility and safety of each scheme. At work, the staff of relevant departments can obtain accurate and complete information from the building information model, effectively sort out the information, and achieve the purpose of effectively controlling data redundancy and errors in architectural design. BIM technology also supports the implementation of green building concept. By using its energy consumption analysis, sunlight simulation, ventilation evaluation and other functions, the building envelope, material selection and energy system configuration can be optimized in the design stage to help the project meet the evaluation standards of green buildings.

3. Design of Visual Layout Method

3.1. Basic Framework Establishment

A visual design method for the layout of prefabricated building structures based on BIM

technology has been developed, which integrates design, production, and construction into a digital collaborative work framework. The purpose is to achieve efficient management of the whole construction process. The core of this method is to create a three-dimensional digital model by using BIM technology and realize the collaborative work among disciplines in the design stage. Through three-dimensional visualization technology, potential space conflicts, structural defects and installation difficulties can be identified before construction, and design changes and on-site rework can be reduced. This method emphasizes the collaborative management of the whole process of "design, production and assembly", including three levels: first, the collaboration between design and manufacturing, and the direct output of parts processing drawings and numerical control instructions through BIM model. The second is the coordination of design and construction assembly, and BIM is used for construction simulation and process optimization. The third is the cooperation between manufacturing and construction assembly, and the accurate matching of component production schedule, transportation plan and site hoisting rhythm is realized by using model information.

In the construction of fabricated steel structures, BIM technology further integrates the Internet of Things (IoT) and the network information sharing platform, integrates the component information, construction progress, quality data, etc. in the whole life cycle of the building into a unified model, and realizes the dynamic visual display of the construction site layout. Managers can use this model to grasp the information of key nodes in real time and scientifically plan the site layout, transportation route and mechanical equipment location. By using BIM technology reasonably, the problems existing in profile and two-dimensional expression can be eliminated. When matching prefabricated component models, BIM can reflect its own integration characteristics and help to create standardized prefabricated building components. In addition, it is necessary to simulate the number of components in BIM construction to ensure the richness of its types and specifications. Through the advanced robot control system and algorithm, the precise control of motion parameters is realized, and the machining accuracy and production efficiency are improved. The basic framework of construction visual layout based on BIM technology is shown in Figure 2.

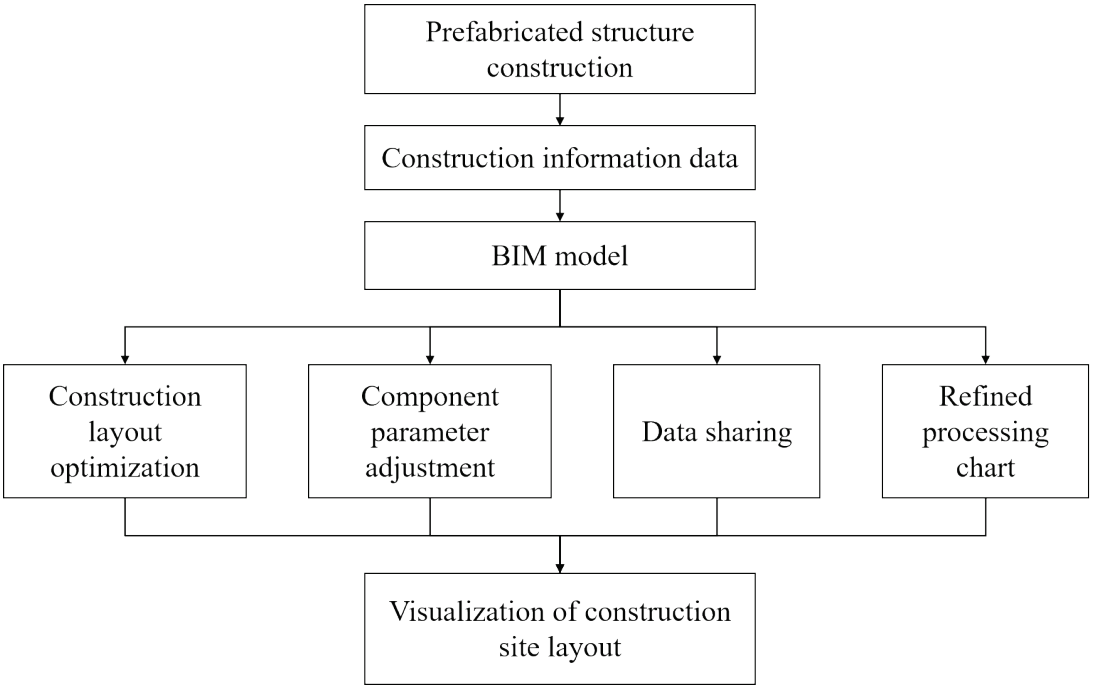

Figure 2 Basic framework

3.2. Collaborative Sharing and Visual Design

In the process of assembly building design, it is necessary to ensure the rationality of BIM technology and pay attention to key links. After visual treatment of specific parts, the number of

prefabricated external walls and corresponding components can be adjusted. With the help of three-dimensional modeling, visual display and dynamic roaming functions of BIM technology, the complex construction site layout is transformed into an intuitive virtual model. With the help of visual expression, designers can clearly grasp the key elements such as component layout, construction access and working scope of lifting equipment. The introduction of digital twin technology further improves the design accuracy, realizes the high-fidelity mapping from the actual design scheme to the virtual environment, and fully shows the geometric characteristics and structural details of the building structure. If abnormalities are found, they need to be corrected and improved according to actual needs. In the process of simulating complex building nodes, it is necessary to combine BIM technology to make a vivid interpretation of various complicated parts and important construction nodes in advance, control the site reasonably and ensure the reasonable treatment method. This high-precision virtual model enables the design team to predict the construction difficulties in the early stage, reduce the design changes in the later stage and reduce the rework cost.

Combined with virtual reality (VR) technology, designers can simulate the assembly, production process and construction technology of components in an immersive way. Prefabricated buildings involve many disciplines and departments such as design, production, transportation and construction. A 4D construction schedule management system based on BIM combines the three-dimensional model with the time dimension, and integrates with project management software to realize the dynamic simulation and visual deduction of construction schedule. No matter in the scheme stage or the design stage, opinions and parameters of all parties need to be fully integrated into the same model. Combined with the monitoring equipment of the Internet of Things, the system can collect key parameters in real time and warn the abnormal situation in time. With the help of the information sharing mechanism of BIM platform, all parties involved can simultaneously check the construction progress and optimization scheme, and participate in the decision-making of key nodes together.

4. Conclusions

This article proposes a visualization design method for prefabricated building structure construction site layout based on BIM technology. By integrating digital twin and 3D simulation technology, it achieves scientific planning, dynamic simulation, and full process visualization management of the construction site. This method can not only optimize component stacking, transportation routes, and mechanical equipment layout, but also effectively identify spatial conflicts and organizational bottlenecks during the construction process, significantly improving the intelligence and refinement level of on-site management. Research has shown that introducing intelligent construction equipment in prefabricated building construction not only improves construction efficiency and precision, but also enhances the safety and controllability of the construction process, which is of great significance for improving the overall construction quality. With the continuous innovation of digital technology and the continuous improvement of industry standard systems, BIM, IoT, technologies such as intelligent construction will play a more profound role in prefabricated buildings. In the future, through the integration of multiple technologies and full process collaboration, it is expected to achieve higher levels of engineering quality, construction efficiency, and cost control, further promoting the industrialization process of construction and injecting strong impetus into the sustainable development of prefabricated buildings.

References

[1] Wang Xiaogang, Han Xueying, Liu Zhao, et al. Research on the Evaluation of Coordination between Prefabricated Building Design, Production, and Construction[J]. Railway Standard Design, 2023, 67 (10): 208-213.

[2] Mei Hao. Analysis of Key Points in the Design of Prefabricated Building Structures[J]. Engineering Technology Research, 2024, 9 (04): 200-202.

[3] Xu Dong, Han Hongxiang. Application analysis of digital technology in the design and construction process of prefabricated buildings[J]. China Building Metal Structures, 2025, 24 (02): 144-146.

[4] Sun Runyu, Chen Sheng, Gan Jingyang, et al. Application of BIM technology in the construction of prefabricated building structures[J]. Sichuan Building Materials, 2024, 50 (12): 142-143+146.

[5] Xu Bin, Li Jiahao, Zhang Guoxing, et al. Research on Fine Construction Management of Prefabricated Buildings under Digital Construction Technology[J]. Journal of Hebei University of Architecture and Technology, 2023, 41 (01): 163-169.

[6] Li Qingzhong. Thoughts and Applications on Digital Design and Intelligent Manufacturing of Prefabricated Buildings[J]. Development Direction of Building Materials, 2024, 22 (20): 43-45.

[7] Wang Guolin, Wu Yunlong, Gong Lizhi, et al. Research on the Application of BIM Technology in the Design Practice of a Prefabricated Energy saving Building[J]. Adhesive, 2023, 50 (02): 180-183.

[8] Ge Hongliang. The Application of BIM Technology in the Design of Prefabricated Building Structures[J]. China Building Metal Structures, 2023, 22 (07): 123-125.

[9] Hu Xiujun, Fang Lubing, Wei, Jinjin. Application analysis of BIM technology in the deepening design and construction of a high-rise prefabricated building[J]. Engineering and Construction, 2022, 36 (05): 1450-1453.

[10] Chen Guang, Ma Yunfei, Liu Jichao, et al. Thoughts and Applications on Digital Design and Intelligent Manufacturing of Prefabricated Buildings[J]. Civil and Architectural Engineering Information Technology, 2022, 14 (04): 121-127.