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Research on the Application of BIM Technology in Prefabricated Building Design

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Abstract: With the continuous development of building informatization and industrialization, building information model (BIM) technology is more and more widely used in architectural design. Meanwhile prefabricated buildings are also be widely promoted and applied in cities and towns across the country. This paper takes BIM technology and prefabricated buildings as the research objects and introduces the concept and characteristics of BIM. In brief BIM is based on all the information of buildings. It has characteristics of visualization, coordination, simulation, optimization, plotting, integration, parameterization and completeness of information. In addition, the paper studies the application of BIM technology in prefabricated building design through a practical project case--a teacher apartment of Changsha Vocational and Technical College. The application of BIM technology starts from the design stage, containing four aspects: Collaborative Design,. Visual Design, Component Standardized Design and Green Building Design. Compared with traditional architectural design methods, the advantages of BIM based prefabricated building design are discussed, such as saving the time of design and construction phase, reducing the cost of building projects, improving architecture design process, enhancing the effectiveness of comprehensive design. The paper also provides a reference for architectural designers and engineering technicians using BIM tools in the fields of prefabricated building design and research.

Keywords: BIM Technology, Prefabricated Construction, Architecture Design

1. Introduction

The construction industry is one of the pillar industries of our national economy, which has provided strong support for the development of our economy. However, the generation method of the construction industry has been relatively extensive, especially in terms of energy conservation, environmental protection, and there is still a significant gap compared to the requirements of high-quality development. With the continuous progress of society, the concept of building industrialization, digitalization and intelligence has gradually formed, and it is urgent to accelerate the change of construction methods and promote the high-quality development of the construction industry. In 2022, the Ministry of Housing and Urban Rural Development of the People's Republic of China issued the "14th Five Year Plan" for the Science and Technology Development of Housing and Urban Rural Construction, which proposed to strengthen the basic research on the application of information technology in the construction industry, intelligent construction and technological innovation of new building industrialization, vigorously develop Prefabricated building, and accelerate the coordinated development of new generation information technology and building industrialization technology, by increasing the integration and innovative application of new technologies such as Building information modeling (BIM) in the whole process of construction [1]. Many provinces such as Hunan and Guangdong have also issued implementation opinions on promoting the coordinated development of intelligent construction and building industrialization, which all mention the implementation of BIM technology application in the whole process of engineering construction, improving BIM design collaboration ability, and promoting intelligent production technology [2].

The application of BIM technology in the design of prefabricated building is consistent with the existing conditions of our country, and can promote the

transformation and upgrading of the construction industry. BIM technology can guide the prefabricated building design, combined with the advantages of BIM and assembly technology, which is beneficial to solve the problems encountered in the current architectural design. At present, the application of BIM technology in the design of prefabricated building is still in the early stage, which needs continuous research and exploration [3].

2. BIM Overview

2.1. Basic BIM Concepts

BIM, also known as Building information modeling, is based on various relevant information data of the construction project as the model to establish a three-dimensional building model and simulate the real information of the building through digital information simulation. BIM can be applied in various stages of the entire lifecycle of engineering projects, including planning, architectural design, project drawing, construction site management, operation and maintenance, and even renovation. Through the digital and three-dimensional expression of BIM technology, various stages and links of the entire life cycle of buildings are highly coordinated and integrated to form an engineering data system, leveraging the advantages of building informatization and greatly improving the efficiency of building design and construction.

2.2. Characteristics of BIM

2.2.1. Visualization

Visualization is "What you see is what you get". BIM technology can transform two-dimensional components into three-dimensional graphics for display in front of people, which is a visualization that can form interaction and feedback between components. Building a three-dimensional model through BIM can display architectural renderings and roaming animations to all participants involved in the engineering project. And communication, discussion, and decision-making among all participants at each stage of the project design, construction, and operation can be carried out in a visual state [4].

2.2.2. Coordination

In the traditional architectural design process, various professions such as architecture, structure, and equipment are divided into different tasks. Due to inadequate communication between different professions, collisions between various professions often occur. In the past, remedial measures can only be taken by issuing change notices from the design party, which will inevitably affect the construction progress and bring inconvenience to the construction process. By using BIM technology to detect collisions among buildings, structures, and electromechanical models during the design phase, real-time collision detection reports are generated and data is coordinated to identify potential problems during the construction phase and make modifications as soon as possible, which can improve work efficiency.

2.2.3. Simulation

In the design stage, BIM technology can be used to conduct simulation tests, such as energy-saving simulation, sunshine simulation, heat transfer simulation, etc. In the Procurement and construction stage, BIM 4D construction progress simulation (3D model plus project development time) can be carried out, and cost control can be achieved through BIM 5D simulation (3D model plus project time plus project cost). In the later operation and maintenance stage, BIM software can simulate the handling of daily emergency situations, such as earthquake personnel evacuation simulation and fire personnel evacuation simulation.

2.2.4. Optimality

BIM technology can better optimize all stages of the whole life cycle of construction projects, and realize the whole process management such as design, construction, operation and maintenance. BIM models provide a lot of physical information related to buildings, including geometric information, physical information, etc. BIM and various supporting tools provide the possibility of optimizing complex projects, combining project design with investment return analysis, providing owners with the choice of multiple design plans, so that owners can determine which project design plan is more conducive to their needs, and optimize the design and construction scheme, which can also significantly shorten the time of construction period and reduce the cost [5].

2.2.5. Graphic Capability

BIM can easily convert 3D models to 2D drawings. After 3D modeling is completed, common architectural design drawings and component processing drawings can be generated by creating drawings. Through the visual display, coordination, simulation and building optimization, it can also help the owner to generate the optimized comprehensive pipeline diagram, comprehensive structure hole reservation diagram, collision detection report and suggested improvement plan.

2.2.6. Integration

Based on BIM technology, design, construction, operation, and maintenance can be integrated management throughout the whole life cycle of the project. The technical core of BIM is a database formed by a computer model, which not only contains the design information of the building, but also can contain the whole process information from design to construction and occupation, and even the end of the use cycle [6].

2.2.7. Parameterization

BIM technology deconstructs and transforms various information required for the building lifecycle into various information categories and establishes logical relationships between different categories one by one. Based on these information categories, parameterized objects are established to describe the actual building model in details. By changing specific parameters, building components can be adjusted.

Building models created by parameterized objects are not just about component creation but can automatically maintain consistency and rationality of information categories based on engineering characteristics, which traditional building technologies cannot achieve [2].

2.2.8. Information Completeness

BIM is a digital representation of the physical and functional characteristics of facilities, which includes all information of engineering objects, including descriptions of three-dimensional geometric information and topological relationships of engineering objects, as well as a complete description of engineering information. The Completeness of BIM information is mainly reflected in the following four aspects: BIM is a model with complete graphic information; BIM is a complete component object data model; The BIM model includes complete architectural elements; The BIM database complies with the law of data Completeness.

3. Application and Research of BIM in Prefabricated Building Design

3.1. Project Overview

This project is a teacher apartment building of Changsha Vocational and Technical College located in Leifeng Town, Yuelu District, Changsha City, Hunan Province. The site area is 4244.90 square meters, and the total floor area is 3990.40 square meters. The building consists of 6 above-ground floors with a height of 22.05 meters. The design service life is 50 years. It adopts a prefabricated integral frame structure, with a structural safety level of Level II and a seismic design intensity of 6 degrees. The project utilizes prefabricated building design methods, with main prefabricated components including prefabricated external wall panels, prefabricated internal wall panels, prefabricated stairs, composite beams, and composite slabs, achieving a prefabrication rate of 51.43%.

Based on several national standards for prefabricated building design, such as "Technical Standard for Prefabricated Concrete Buildings" (GBT51231-2016), "Design Standard for Prefabricated Residential Buildings" (JGJ/T398-2017), and "Technical Specification for Prefabricated Concrete Structures" (JGJ1-2014), this study examines the application of BIM technology in prefabricated building design through the example of the teacher's apartment project. BIM technology can be utilized to achieve collaborative design, visual design, standardized component design, and green energy-efficient design in prefabricated building construction, aligning with the characteristics offered by BIM technology. The BIM model of the teacher apartment is shown in Figure 1.

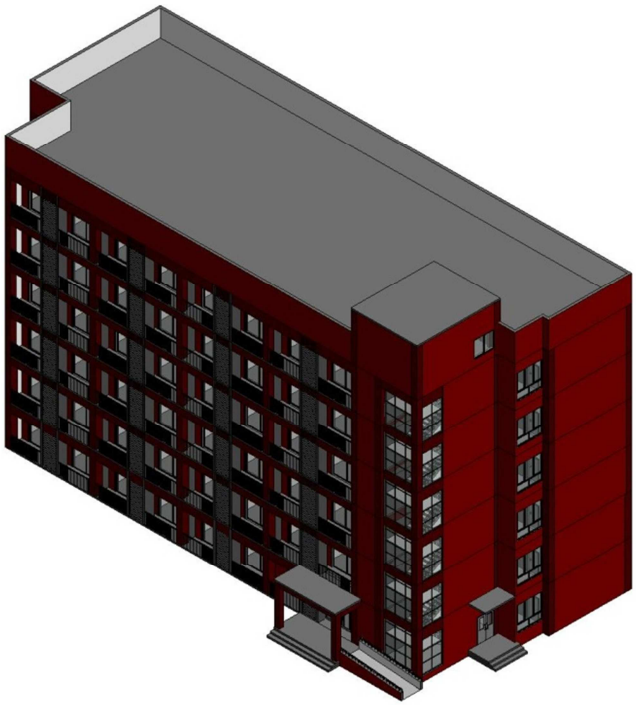

Figure 1. *The teacher apartment model.*

3.2. BIM Collaborative Design

The occurrence of errors, omissions, clashes, and design changes in architectural engineering design is primarily due to the fragmentation of information among different disciplines and stages, leading to isolated islands of information without integration and sharing. The lack of a common collaborative platform results in information closure and transmission errors. In prefabricated building construction, problems discovered during on-site installation of prefabricated components can lead to significant losses. By utilizing BIM technology, architectural, structural, and MEP (mechanical, electrical, plumbing) designs can all share the same BIM model, facilitating collaboration between design, fabrication, and installation. The collaborative platform established using this model enables more intuitive and convenient inspection and resolution of clashes and conflicts between disciplines and stages, thereby enhancing work efficiency. The collaborative design process of prefabricated building based on BIM technology is shown in the Figure 2 [7].

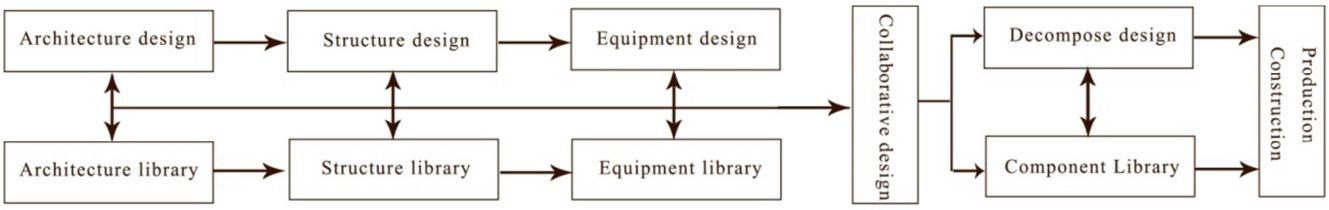

Figure 2. *The collaborative design process.*

3.3. BIM Visual Design

BIM technology enables visual design, promoting user-friendly collaboration and more detailed design. For instance, in the exterior design of the teacher's apartment, BIM can be used to create 3D views, rendered images, and walkthrough animations to showcase the overall spatial layout, form, materials, colors, and other aesthetic effects. It allows for the selection of visually appealing external wall finishes. In the interior decoration design of the teacher's apartment, visualization enables the direct inspection of design effects, ensuring the quality of decorative design. In room layout design, BIM-based design and simulated installation of furniture, fixtures, and sanitary devices facilitate visual communication with clients, simplifying the design process and improving efficiency [7].

3.4. BIM Component Standardized Design

In this project by utilizing BIM technology, a standardized BIM component library corresponding to standardized prefabricated components or parts can be established. In the design process, the architectural scheme is first developed based on the owner's requirements, meeting the functional needs. Then, the overall structural model is decomposed, and standard components are selected from the BIM component library for combined design. Standardized design reduces design intensity and improves component manufacturing efficiency [8]. Additionally, BIM software enables automatic splitting of structural components. For instance, in PKPM-PC, the splitting scheme design parameters consider factors such as the shape, dimensions, weight, construction requirements, and specification drawings of prefabricated components. The splitting of components can be completed based on the actual project conditions, and the original splitting scheme can be adjusted parametrically using splitting modification tools. For components with the same cross-sectional dimensions and reinforcement, the same splitting scheme can be applied. In the BIM model, it only requires selecting the structure component in any view and applying the existing splitting scheme to it, which is more efficient and accurate compared to traditional splitting methods [9].

3.5. BIM Green Building Design

The teacher apartment project adopts the BIM positive green building design method, with reference to the Hunan Province "Green Prefabricated building Evaluation Standard" (DBJ43/T332-2018). The vertical components use high-precision formwork, the floors and stairs are laminated and prefabricated components, the exterior wall is prefabricated components, the interior wall is light slats, and the full decoration mode is adopted. The green building rating is two stars level [10]. The project configuration of construction technology is shown in the table 1.

Table 1. *Configuration of construction technology.*

Configuration of construction technology	Adopted
Prefabricated exterior wall panels	yes
Prefabricated interior wall panels	yes
Prefabricated air-conditioning panels	no
Prefabricated stairs	yes
Integrated interior wall and pipeline	no
High precision formwork	yes
BIM design and construction	yes
Heat preservation and decoration integration	no
Modular coordination of construction	yes
Integral exterior wall assembly	no
No external frame construction	no
Fully furnished	yes
Green star standard	yes
EPC mode	no

3.5.1. Application of Bim Technology in the Early Stage of Green Prefabricated Building Design

In the process of designing the teacher apartment plan, designers need to comprehensively evaluate the terrain and geomorphic characteristics of the area where the project is located, conduct comprehensive research on sunlight and ventilation, and ensure that passive energy-saving design can be better applied. Before carrying out green building design work, two-dimensional design measures are usually adopted, which covers a huge workload. Using BIM technology to carry out building space and architectural design can effectively reduce the design cycle. Based on the actual planning status of the project and the site information of the project, BIM technology is used to simulate sunlight and ventilation of the building. This can ensure that the designed building orientation and building spacing are more reasonable, and thus ensure that the designed building layout is more scientific [11].

3.5.2. Application of Bim Technology in the Architectural Design Stage of Green Prefabricated Building

The parameterization and modular design of BIM were utilized in the teacher apartment project to achieve modeling work. The BIM software includes the parametric design function module, which can accurately describe the building shape by the application of relevant parameters, and can also quickly complete the modeling. At the same time, it can also modify and improve the relevant parameters in the built model. At the same time, the BIM system can automatically keep some unchanged parameters in the original state when carrying out parameter optimization, This ensures that the integrated system has better coordination. In addition, the use of BIM visualization design technology can analyze the design from a differentiated perspective, allowing for perspective and bird's-eye observation of the overall or layout of the building, ensuring that designers have a better understanding of the design effect of building engineering from a comprehensive perspective. Therefore, utilizing BIM technology can effectively enhance the effectiveness of comprehensive design.

3.5.3. Application of Bim Technology in Environmental Analysis of Green Prefabricated Building

The application of BIM technology in the green building design process of this project can effectively improve the internal environment of the building and enhance the stability of the green building structure. Firstly, with full utilization of the natural lighting in the building, designers adopt BIM technology while complying with the natural lighting requirements of green buildings, and improve the corresponding design plans with targeted goals; Secondly, when applying BIM technology to effectively simulate indoor natural ventilation, targeted modifications can be made to the size and location of the building's internal air vents based on the operation of the green building model to ensure indoor air circulation. Moreover, when constructing water and grassland models within buildings, BIM technology is used to select reasonable design parameters and comprehensively improve the layout of green buildings. By adopting BIM technology in a reasonable manner, designers can gain a deeper understanding of the building environment, physical and structural characteristics, in order to improve the efficiency of green design [11].

4. Conclusion

Prefabricated building will promote the upgrading of the construction industry and effectively solve the problem of the shortage of highly skilled labor in the construction industry at this stage. The construction industry will continue to develop in a more economical, environmentally friendly and efficient direction. Prefabricated building will also be widely promoted and applied in cities across the country. With the advancement of industrialization, the application of BIM technology in China's construction industry is gradually expanding [12]. Adopt BIM collaboration mode in Prefabricated building, complete BIM overall planning in the design phase, including overall design, scheme optimization, standardization and finalization, and transfer information to subsequent links; Complete BIM model design and conduct comprehensive pipeline design; Complete the design of BIM PC component library and provide a list of PC components, etc; Complete BIM green building design and conduct parametric environmental simulation analysis. At present, BIM technology in the construction industry is still in the stage of continuous development, and the application of BIM technology in prefabricated building still needs continuous exploration. The application of BIM technology starts from the design stage. With the implementation of information sharing, effective transmission and collaborative work in project design, PC component production and construction, operation and maintenance, the future development of BIM technology plus prefabricated building is promising [13].

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