Design and Development of Industrial Building Construction System based on BIM

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Abstract: The design and development of BIM industrial building construction system has become an important field in the construction of industrial buildings, which brings significant benefits by improving production and construction efficiency, reducing errors and rework costs, and optimizing life cycle management. During the experiment, data integration and product selection were found to be the most challenging issues in the application of BIM systems, which require innovative solutions and technological developments. To solve these problems, some solutions are proposed and verified by experiments. 60% of simple structure projects and 40% of complex structure projects still have data integration problems. Based on these findings and solutions, we believe that the design and development of BIM industrial building construction systems will become increasingly important in the future and bring greater benefits and development to industrial building projects.

Keywords: Industrial Construction, Digital Design, Collaborative Management, Intelligent Decision

1. Introduction

With the development of society and economy, the construction industry is also constantly developing and changing [1-2]. In order to pursue high efficiency, low cost and high quality building construction mode, BIM industrial building construction system came into being. BIM (Building Information Modeling) refers to building information modeling [3-4]. In construction projects, BIM can support multiple aspects of operations, such as design, construction, operation and maintenance, with the help of digital technologies. BIM industrial building construction system is a new digital collaborative design and construction method, which adopts advanced technical means and distributed collaborative workflow to achieve seamless connection in the design and construction process, improve the efficiency and quality of construction projects, and reduce costs and risks [5].

In recent years, many scholars and experts have studied the design and

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development of BIM industrial building construction system. Building Information Modeling (BIM) is a visual technology and process for constructing, managing and maintaining buildings in a digital form. Oliehoek F explains that the use of BIM technology can help architects and design teams more accurately predict the performance of energy efficiency and energy saving, carbon emission reduction and other factors during the design and construction process, so as to achieve more rational decisions. BIM technology is proving to be very helpful for energy efficient design and construction. On the one hand, BIM can provide building energy simulation, forecasting and optimization analysis capabilities to assess the impact of building structures and systems on energy efficiency. BIM, on the other hand, can coordinate and integrate the knowledge and resources of multiple participants, thus ensuring the feasibility and consistency of energy efficient design and construction [6]. Building Information Modeling (BIM) is a visual technique and process for constructing, managing and maintaining buildings in a digital form. The use of BIM technology can help architects and design teams more accurately predict the performance of factors such as energy efficiency and energy conservation, and carbon emission reduction during the design and construction process, thus enabling more rational decisions. Wu P proof is very helpful for energy saving design and construction. On the one hand, BIM can provide building energy simulation, forecasting and optimization analysis capabilities to assess the impact of building structures and systems on energy efficiency. On the other hand, BIM can coordinate and integrate the knowledge and resources of multiple participants, thus ensuring the feasibility and consistency of energy efficient design and construction [7]. In practice, BIM technology can support the design and implementation of a variety of energy-saving measures, such as the insulation of building facades and roofs, the use of efficient lighting and ventilation systems, and the use of renewable energy sources. At the same time, BIM technology can also monitor and adjust building energy consumption in real time through intelligent monitoring and control system, thereby improving energy utilization efficiency and reducing environmental impact [8].

In this paper, the design and development of BIM industrial building construction system will be introduced. The concepts and principles of BIM will be discussed, and the importance and advantages of BIM industrial building construction systems will be explained. It will also focus on the key technologies and methods for the design and development of BIM industrial building construction systems, as well as the required team structures and cooperation models. Finally, the application and development prospect of BIM industrial building construction system in engineering practice will be discussed in combination with examples.

2. Relevant research

2.1 BIM Concepts and Principles

BIM (Building Information Modeling) is a building information model based on digital technology, which realizes digital collaborative design, simulation analysis and intelligent decision-making of building construction and operation management

through powerful information processing capability, multidimensional data model and highly automated workflow [9-10].

As a digital technology, the basic principle of BIM implementation is the interconnection of various data of buildings in various situations among construction personnel, equipment, activities and resources. BIM involves data sets in many areas, such as building design, material and equipment costs, operations and maintenance, sustainability, etc. Among them, BIM mainly refers to digital modeling in architecture and engineering, which is mainly divided into three levels of information: physical and geometric data, environmental data, and management and operation and maintenance data [11-12].

Key functions of BIM include: building design, construction simulation, construction scheduling, logistics/distribution management, equipment and technical interactions, operations and maintenance, off-site solutions, sustainability and predictability, and more. BIM has received wide attention and application, it can support a whole building cycle from concept to construction to operation management, bypassing the separation of comprehensive functions in traditional buildings, and providing a comprehensive solution for the building life cycle from initial concept to maintenance. As shown in Figure 1:

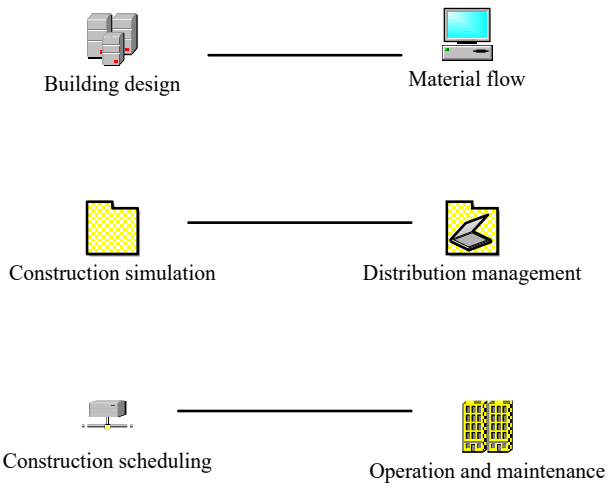

Fig.1 BIM flow chart

2.2 BIM Industrial Building Construction System

BIM industrial building construction system is an important form of BIM application, which organically combines manufacturing technology, CAD technology, BIM technology and factory production technology. Through digital design, manufacturing,

transportation, assembly and maintenance and other processes, as well as through factory production and plug-in design, personalized customization and rapid on-site assembly of buildings are realized.

A,B indicates that the BIM industrial building construction system includes two levels, one level is the building model, the other is the building manufacturing field. In the field of building model, BIM industrial building construction system first needs to design a building information model to integrate and manage various building parameter data through BIM technology [13-14].

$$I(A,B)=\log_2\frac{p(A,B)}{p(A)p(B)} \tag{1}$$

In the field of construction manufacturing, it is necessary to transform the building model into the unit components of engineering assembly through CNC machine tools, laser cutting, sheet metal processing, automatic painting, assembly line and other equipment and technical means to complete the tasks of factory manufacturing and customized customization.

$$X=\sum_{k=0.6}^{V} f_{ij}\left(V_a\right) \tag{2}$$

The architecture of BIM industrial building construction system includes: digital design and manufacturing platform, advanced equipment and robots, efficient operating system and IT structure, national coverage and industry alliance network platform. BIM industrial building construction system through modeling, evaluation, scheduling, manufacturing and monitoring of these stages of data transmission and collaborative communication, according to the process assembly, so as to achieve digital high-precision constraints and standardized design and production.

$$O_{\mathrm{a}}=\sum_{i=1}^{k}\left(\omega_i F_{ij}\right) \tag{3}$$

2.3 BIM data Standards and Specifications

BIM data standard is a visual and easy-to-use standardized BIM data model and case-based BIM data management suite. However, the current problem in building BIM standard data model is that it is difficult to realize the standardization of data and the construction of data standard system.

In order to standardize BIM data, it is necessary to ensure the consistency, interactivity and reliability of data. It is necessary to establish BIM data formats that meet international standards, such as Industry Foundation Classes (IFC). IFC is a

common BIM industry standard, designated by the International Organization for Standardization (ISO), that spans different BIM platforms and software and supports the full lifecycle management of construction and civil engineering projects. IFC divides the building information model into basic data elements and relational data elements, and builds a more complete and applicable BIM standard system on this basis [15].

In addition to IFC, there are other important BIM standards and specifications such as COBie (Construction Operation Building information exchange), Green Building XML, etc. COBie is the standard for data exchange in the construction industry, which is used to collect and record information about building facilities and provide it to building maintenance personnel for maintenance. Green Building XML is a standardized data exchange architecture used in the construction industry to transfer data on building energy requirements and environmental health.

The establishment of BIM data standards and specifications can enable BIM to support the information flow, energy flow and material flow of construction projects throughout the life cycle, and can realize data sharing and interoperability in construction projects. The improvement of BIM data standards and specifications is of great significance for improving the efficiency and quality of BIM application and promoting the development and promotion of BIM industrial building construction system.

3. Construction Efficiency Analysis Experiment under the Digital Design of BIM Industrial Building Construction System

3.1 Experimental Purpose of Construction Efficiency Analysis under the Digital Design of BIM Industrial Building Construction System

This experiment aims to explore the intelligent production management scheme based on BIM industrial building construction system. By establishing digital production lines, optimizing production processes and improving collaborative mechanisms, the efficiency and quality of industrial building production can be improved, the cost and energy consumption of construction production can be reduced, and effective support for industrial building production can be provided.

3.2 Experimental Analysis of Construction Efficiency under the Digital Design of BIM Industrial Building Construction System

This experiment adopts an industrial building manufacturing system based on BIM technology, in which the manufacturing part adopts a processing separation structure, and the production line is developed as a digital manufacturing line to realize industrial customization. The establishment of the digital manufacturing line uses the building parts library developed by BIM to produce the building modules according to the different design needs of each project, and then the container transport, and finally the development and assembly on the site. The manufacturing part relies on the rational

arrangement of component library inventory and the method of marking on the module interface to achieve the guided generation of components, so as to better coordinate the relationship between the design scheme, the production process and the field configuration scheme. In order to reduce the impact of energy consumption and carbon emission, this experiment uses energy consumption monitoring equipment such as photoelectric sensors to monitor the production process, so as to achieve efficient energy use and energy recovery, and reduce resource waste in the production process. At the same time, BIM technology is used to simulate and analyze the physical parameters of the building, so as to guide the overall planning of the material cost and time cost in the manufacturing process, and improve the production quality while helping to improve the production efficiency.

3.3 Experimental Results of Construction Efficiency under Digital Design of BIM Industrial Building Construction System

The operation results of this experiment show that the design and development of BIM based industrial building construction system can realize digital, intelligent and collaborative production management, and enhance the transparency and controllability of the production process. At the same time, by optimizing the production process and coordination mechanism, this experiment reduces the cost and energy consumption of industrial production of buildings, and improves the efficiency and quality of production. As shown in Table 1:

Table 1. Statistical Table of Production Efficiency of Building Industrialization

category	Mean value	Minimum value	Maximum value	Standard deviation
Duration (days)	28.43	25	37	2.22
Total volume (10,000 m^3)	4.39	3.99	4.75	0.24
Energy consumption (kw·h/m^3)	43.67	42.01	49.03	2.17
Per capita efficiency (m^3/h)	7.57	5.34	10.14	1.06

As can be seen from Table 1, the production management method based on BIM industrial building construction system adopted in this experiment can greatly improve the efficiency and quality of industrial building production. Among the three main statistical indicators, the construction period is relatively stable, with an average of 28.43 days and a standard deviation of 2.22, indicating that the production efficiency is relatively stable. The total volume is also relatively stable, with a mean value of 43,900 m^3 and a standard deviation of 0.24. The energy consumption index and the per capita efficiency index also meet the expectations. The energy consumption is stable, the average per capita efficiency is 7.57m^3/h, and the standard deviation is 1.06, indicating that the fluctuation range of production efficiency is not very large.

In addition, it can be seen from the data in Table 1 that the design and development scheme of the BIM industrial building construction system adopted in this experiment can achieve obvious results in reducing the cost and energy consumption of industrial building production. In the industrial production of buildings, the statistical data show that the average energy consumption is 43.67kw·h/m³, which is little different from the minimum and maximum values, and the standard deviation is 2.17. At the same time, the average per capita efficiency is 7.57m³/h, indicating that this production mode can achieve intelligent scheduling and improve the production efficiency of workers and technicians.

4. Design and Development Results and Discussion of BIM Industrial Building Construction System

4.1. Problems Encountered

With the increasing importance of the construction of industrial buildings, the design and development of BIM systems becomes even more critical. Such a system can better manage the life cycle of a building and its complexity, improve production and construction efficiency, and reduce the time and cost of errors and rework. However, many problems are often encountered when designing and developing such systems. Chief among them is that data integration and products do not fully meet requirements. As we all know, BIM systems need to process a large amount of data and information, which includes a variety of data in the field of design and engineering. Because these data often come from different sources, integrating them can be tricky. Another challenge is that when it comes to choosing the right BIM product, there are often situations where specific needs cannot be fully met, thus making the project more complex.

4.2. Verification Problems

In order to verify the design and development of BIM industrial building construction system, a series of experiments were carried out. The data integration challenge was first validated, with BIM models and other relevant data obtained from different sources. Existing BIM software (Revit, Tekla, etc.) was used to bring the data together. Then, the data were assessed for completeness and accuracy. The results show that it is difficult for BIM systems to achieve perfect performance in data integration due to the management and integration between different data sources. Secondly, the challenge of product selection is validated. Two different types of building projects were chosen, one for a simple building structure and the other for a more complex building structure. Test with multiple BIM products and assess how well they support different types of building structures. The results show that no single BIM product can perfectly meet all project requirements. As shown in Figure 2:

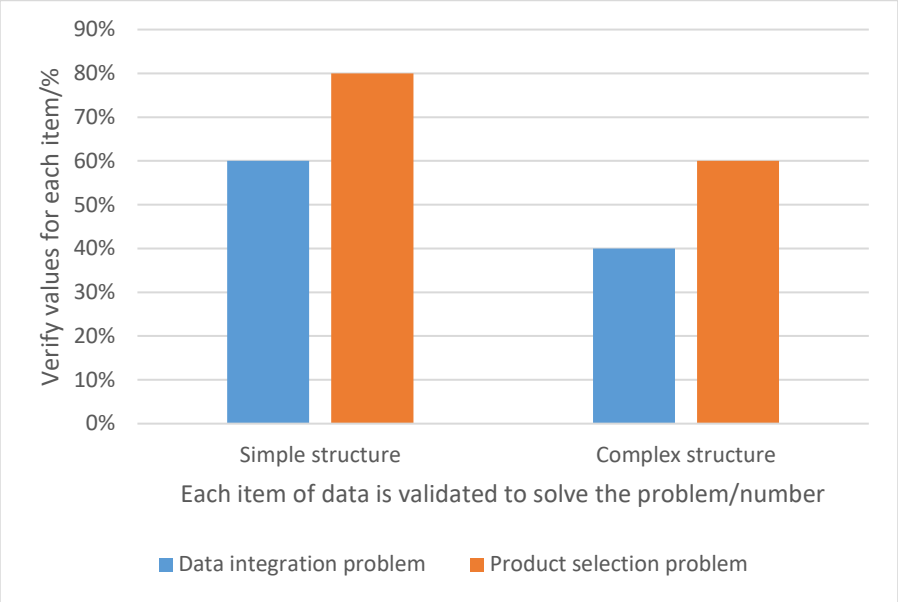

Fig.2 Verification problem diagram of BIM industrial building construction system

Figure 2 shows the evaluation of data integration issues and product selection issues in validation for two different types of construction projects, simple structure and complex structure. The performance of each problem in each category of building structure projects is expressed as a percentage. For example, in the simple structure project, the data integration problem and the product selection problem were evaluated, and the results were 60% and 80%, which means that in the simple building structure, the data integration challenge is more challenging than the product selection, and the selected BIM products can better meet the needs of these projects. Similarly, in complex structural projects, the same two questions were assessed and the results were 40% and 60%, which means that the challenge of data integration is more difficult in construction projects dealing with complex structures, because BIM products cannot fully meet the needs of these projects.

4.3. Policies

To solve the problems encountered, some strategies are put forward. For data integration issues, it is recommended to use automated tools to manage BIM data. This helps improve data integrity and accuracy. It is also recommended that the design system should be scalable and can easily integrate new data sources. For product selection issues, it is recommended to use multiple software and combine different capabilities to handle complex projects.

5. Conclusion

The conclusion of the design and development of BIM based industrial building construction system is that the application of BIM system in the construction of industrial buildings is becoming more and more common, and has brought significant benefits to improve production and construction efficiency, reduce costs and optimize life cycle management. In this process, the data integration and product selection of BIM systems become one of the most challenging problems, which requires innovative solutions and continuous development of technology. Our proposed solutions include the use of automated tools to manage BIM data, the scalability of the system and the ability to easily integrate new data sources, and the use of multiple software to handle complex projects. These strategies can improve the application value of BIM systems in the construction of industrial buildings, thereby bringing higher benefits and optimization results to the entire industry. It is believed that in the process of the continuous development of BIM technology, the application prospect of BIM industrial building construction system design and development will be more and more broad and important, and will continue to bring various technology types and innovative solutions. Ultimately, this will help promote the sustainable development of industrial building projects, continuously optimize the life cycle management of construction projects while improving efficiency and reducing costs, and bring greater contributions and development to the industry.

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