Research on Modular Construction Scheme of Assembled Building Based on BIM

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Abstract: At present, China's construction industry is facing technological innovation, transformation and upgrading. With the emergence of new technologies, prefabricated buildings have become an important way to promote the transformation and upgrading of traditional construction methods, which is of great significance to the rapid development of China's economy. The modular design method based on BIM is adopted in the design of prefabricated housing, which combines the construction drawing design and split deepening design process in the traditional housing industry, optimizes the design process and improves the design efficiency. Through the detailed investigation of the design, production and construction enterprises of prefabricated components and the analysis and research on the application of modular BIM, a modular design method based on BIM suitable for prefabricated buildings is proposed. Therefore, this article proposes to introduce the information capabilities of BIM technology into refined construction management and establish a refined construction management model based on BIM. The modeling standards, naming and coding standards of PC components are specified to form a standardized BIM component library. Finally, a case is used to prove that the modular pricing method of prefabricated building based on BIM is feasible in the measurement and pricing. The research results of this paper can play a certain reference role in the optimization process of the pricing method of prefabricated concrete buildings.

1. Introduction

In recent years, as the country began to implement the concept of low-carbon economy and sustainable development. Construction industrialization has gradually become a new hot spot in the development of the construction industry. Compared with the traditional cast-in-place building, the prefabricated building has less wet working surface, higher mechanization, less manpower and faster construction speed, which can well meet the requirements of "four festivals and one environmental protection" [1]. At present, three-dimensional digital collaborative design is not a strange word, especially in the manufacturing design industry, and information, parametric design and manufacturing have been greatly popularized. However, in the construction industry, it is still in the design stage, which is mainly based on the traditional flat two-dimensional expression and supplemented by three-dimensional expression. In the design process, designers mainly meet the design requirements with a single major, and on this premise, simple multi-professional coordination is carried out, and the information contained in the design is very small, and the information expression is incomplete [2].

In recent years, due to the continuous progress of prefabricated construction technology and management level, the manufacturing accuracy and quality of prefabricated components have been improved. Therefore, pre prefabrication and on-site assembly of components have become an inevitable construction method for the development of the construction industry [3]. The emergence of prefabricated building just changes this dilemma. prefabricated building are characterized by factory production, high level of mechanization, and good construction quality. The development of prefabricated building can guide the construction industry towards the direction of refinement, informatization, and industrialization, provide the overall benefits of prefabricated building, and promote the development of the construction industry [4]. In 2017, the Ministry of Housing and Urban Rural Development issued the "13th Five Year Plan" prefabricated building action plan,

which clearly pointed out that it is expected that by 2020, more than 15% of the regions will be able to actively implement prefabricated buildings, and the number of buildings will account for more than 15% [5]. The Consumption Quota of prefabricated building issued by the Ministry of Housing and Urban Rural Development shows that the construction cost of low rise prefabricated concrete buildings is about 2150 yuan/m2, and that of high-rise prefabricated concrete buildings is about 2420 yuan/m2. Compared with the construction cost of cast-in-place concrete buildings estimated by the Ministry of Housing and Urban Rural Development to be 2000 yuan/m2, the construction cost of prefabricated concrete buildings is higher than that of cast-in-place concrete buildings [6]. BIM technology is the representative of building informatization. The emergence of BIM technology has ushered in a new research hotspot in the field of prefabricated building. With its high level of information integration, BIM technology makes the management of prefabricated building more convenient and construction more coordinated; Therefore, for prefabricated building, the emergence of BIM information model is a new technological revolution [7].

The research goal of this paper is to put forward a modular design method based on BIM for prefabricated buildings through detailed investigation of prefabricated component design, production and construction enterprises and analysis of modular BIM application, and to provide an application case for modular design method in prefabricated buildings in China. At the same time, it injects new vitality into the fine construction management, makes it more operable and accurate, and provides effective support for the development of fine construction management in China's construction industry.

2. A summary of the research on modular construction scheme of prefabricated buildings

2.1. Related theories of prefabricated buildings

Prefabricated building refers to a building that completes the production of some or all components of the building in the prefabrication factory, then transports the prefabricated components to the site, and assembles the components by reliable splicing [8]. Prefabricated building fully embodies the development concept of system and integration. The design, production, transportation, construction and other processes of prefabricated building are interrelated, and also a collection of different related disciplines. In the entire industrial chain, assembly construction requires the coordination of various aspects such as development, design, production, and construction, which can drive the progress of various types of related units. The rise of prefabricated building has led to a fundamental change in the construction methods of traditional concrete buildings. prefabricated building, according to the needs of the current industry development, have uniformly formulated the standards for prefabricated components, constantly improved the construction process, and optimized the rational allocation of resources [9]. For a prefabricated project, a large number of prefabricated components poses high requirements for node connection. If scientific node connection methods are not adopted, the construction process and overall performance of the building will be affected. This requires more attention to the connection methods and construction process design between components in prefabricated concrete buildings [10].

The technical level of the joints between components also has a direct impact on the seismic and mechanical properties of the prefabricated concrete building itself. Generally speaking, the overall performance of the cast-in-place concrete building is better than that of the prefabricated concrete building in theory. In addition, because the construction process of prefabricated concrete buildings is very different from that of traditional cast-in-place concrete buildings, when the components are transported from the component factory to the construction site, a lot of mechanical assembly is needed. This splicing method is relatively direct, which greatly improves the efficiency of prefabricated construction, so it puts forward higher requirements for the technical level of mechanical construction, and also puts forward higher technical requirements for assemblers. This assembly construction method replaces a lot of manual consumption, which greatly reduces labor costs and environmental pollution. The cost of traditional cast-in-place concrete structure is

composed of direct cost, indirect cost, profit and tax. Among these four items, the direct cost is the sum of the expenses directly generated in the construction process, and the direct cost mainly includes the direct engineering cost and the measures cost. The direct engineering cost is composed of labor cost, material cost and mechanical shift cost, which is the reference base for other expenses. The fees and taxes included in the indirect fees are paid according to the requirements of relevant government departments, and they need to be charged according to relevant standards, which are non-competitive fees that must be turned over. The cost composition of traditional cast-in-place concrete construction is shown in Figure 1.

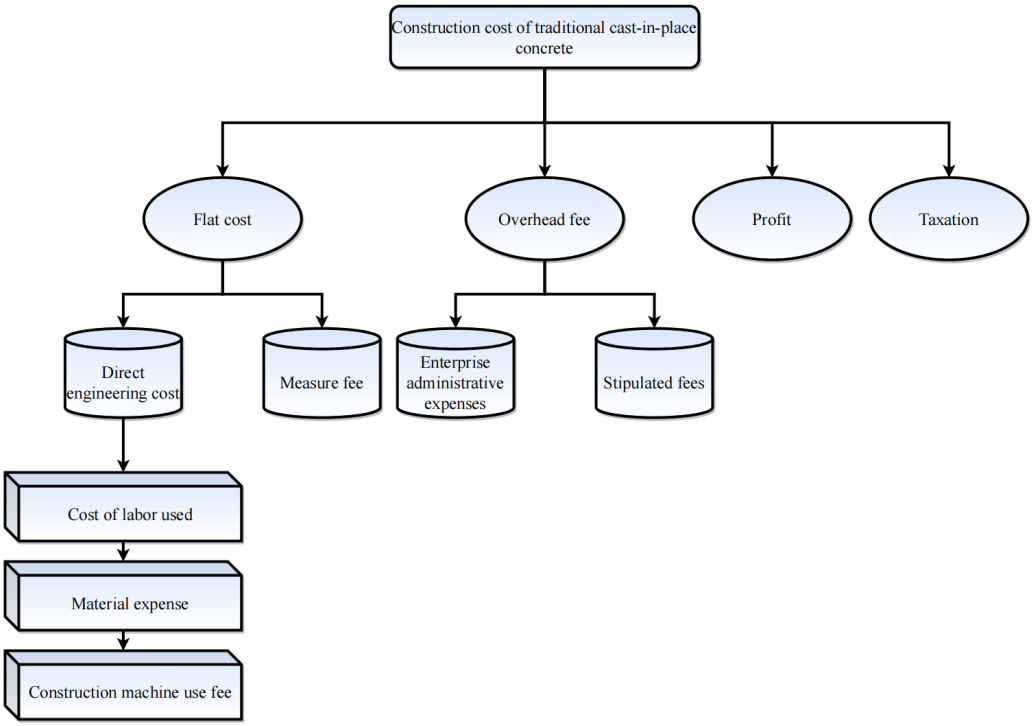

Figure 1 Cost Composition of Traditional Cast-in-place Concrete Building

First of all, prefabricated building need standardization of design and refinement of management process in the design phase. According to the design drawings provided by the design institute, the construction party also needs to split the PC components, and further refine the design of the split drawings of PC components to make the PC components more standardized, which increases the workload in the design phase and the corresponding costs; Secondly, prefabricated building need to add sleeves and grouting materials at the connection of the lap joint. At the reinforcement lap joint, the shear wall connection sleeve and the area connecting the mortar anchor, the densified stirrups will increase the amount of reinforcement, and at the same time the corresponding embedded parts will also increase, resulting in an increase in cost.

2.2. Analysis of the present situation of prefabricated building schedule management

Nowadays, information technology and parametric technology have been popularized in China, especially in the industrial design industry, 3D digital collaborative design technology has been widely used. For us, collaborative design based on 3D digitalization is no longer strange, but in today's construction industry in China, the design process is still in the stage of traditional 2D plane expression and 3D aided design. In collaborative design projects, designers carry out their own design work according to Party A's requirements, and designers of various professions focus on meeting their own professional design requirements. In most cases, there is only simple collaboration between professions, and then coordination among professions is carried out. However, due to the limited component information contained in two-dimensional design, the information expression is not complete and specific enough, resulting in low efficiency. In the foundation construction stage, the project is used to prepare the specific construction schedule.

Because there are many uncontrollable factors on the site, the actual progress often deviates from the planned progress. When adjusting the plan in the project, it is difficult to find out which process is lagging behind to cause the total construction period delay, and it is also difficult to intuitively see the specific time of this process delay. In the early planning stage, the overall project plan, flow construction plan, contract signing plan, and material preparation plan are completed. And it is necessary to divide the entire project into different flow construction sections, with different tower cranes responsible for different construction sections. Therefore, it is necessary to draw a standard construction period bar chart for prefabricated structures.

For the owner, in the project design stage, the key to the application of BIM is to formulate the overall goal of BIM application in combination with the specific characteristics of the project, and at the same time coordinate the information communication between teams, so as to achieve the overall goal of management and control. In order to carry out the project effectively, the owner also needs to stipulate the BIM application ability of all contractors in the form of contract, so that all contractors can look at the problem from the owner's standpoint and promote the application of BIM. The design stage includes scheme design stage, preliminary design stage, construction drawing design stage and deepening design stage, in which the scheme design and preliminary design stage need preliminary architectural scheme design, which involves the establishment of component library, modular design of apartment type, economic feasibility analysis and so on. In the construction drawing design stage, it mainly involves the split design content; The contents of collision and optimization analysis and component deepening design are carried out in the deepening design stage. In the design stage, the components are divided and designed in depth to meet the limited needs of all participants, improve the accuracy of components and meet the requirements of production and construction. The application of BIM in fine construction management provides accurate and true data support for fine management, which makes the work detailed and the assessment quantitative based, and is no longer divided by experience. It makes the refined management no longer an empty regulation, but a well-founded one, which enhances the operability of refined management.

3. Research on Modular Construction Scheme of Assembled Building Based on BIM

3.1. Application of BIM technology in the analysis of prefabricated buildings

BIM technology has the characteristics of visualization, coordination, simulation, optimization and plotting. Combining BIM technology with the current design method of prefabricated buildings can form a modular design method based on BIM that is suitable for prefabricated buildings. The method can realize the three-dimensional model of complex precast member nodes, which is convenient for production and construction personnel to read the design drawings and realize the complete transmission of information between design, production and construction. It can realize the information coordination between upstream and downstream enterprises and various professions, and also carry out the design coordination between various professional components to complete the seamless combination between components; It can make technicians simulate the construction according to the construction organization plan, improve the construction organization plan and realize the feasibility of the plan. Therefore, the modular design method of prefabricated buildings based on BIM can solve some problems in the current design method of prefabricated buildings and promote the development of construction industrialization. In short, designers need to complete the division of functional areas within the unit, the arrangement of load-bearing components, and collision free coordination of equipment. The design of interior units is the foundation of modular design for shear wall systems, and it is the most labor-intensive part of the modular design process. A standardized and serialized unit library can improve the efficiency of collaborative design and lay the foundation for the precise implementation of modular design. In the initial stage, the construction general contractor, component factory, and logistics unit provide their own suggestions and opinions on component splitting, and explain their respective limiting factors, namely the problems that often occur during component production, transportation, and construction. After

listening to the opinions of the construction general contractor and the component factory, the design unit conducts a preliminary disassembly of prefabricated components. After the disassembly is completed, it is submitted to the owner for review, and the estimated cost of the preliminary disassembly plan is reported to the owner. After approval by the owner, the preliminary construction drawing design split plan will be sent to the construction general contractor, component factory, and logistics unit. After receiving the construction drawing model, the construction general contractor needs to conduct a construction constraint analysis of the component split plan, the component factory needs to conduct a production constraint analysis, and the logistics unit needs to conduct a transportation constraint analysis.

By observing the trend of the three curves in the figure, we can judge the progress deviation and cost deviation of the construction project by using the difference between the curves. Then, according to the current deviation value, the subsequent cost is predicted to determine the cost deviation after the end of the final project. The curve method can visually observe the cost deviation, but it is mainly used to show the accumulated cost deviation. As shown in Table 1.

Table 1 Summary of cost control methods for construction projects

Project cost control method	Specific method
Project cost analysis table method	Monthly cost analysis table, weekly cost report, monthly cost calculation table, final forecast report, etc.
Engineering cost analysis method	Target cost difference analysis method; Labor cost analysis, material cost analysis, machinery use fee analysis, etc.
Cost accumulation curve	Banana curve, cost-time cumulative graph
Cost deviation analysis method	Table method, bar chart method, curve method

According to traditional cost control methods, even if there is no deviation in the calculated results, it can only indicate that there is no deviation in the overall cost during this time period, and cannot guarantee that there will be no local cost deviation during this time period. Even if the cost deviation is detected, it is difficult to determine which part of the construction occurred during this period due to the lack of detailed data from accounting personnel.

3.2. Analysis of influencing factors of prefabricated building schedule management

At present, the construction industry in China mainly relies on design institutes for structural design, material suppliers for construction material supply, and construction units for on-site construction. The various links are not tightly connected, resulting in low work efficiency, low construction quality, slow construction progress, and high building energy consumption. Traditional construction generally adopts cast-in-place integral construction, which has developed quite mature in China. Construction personnel guide on-site construction with their rich technical experience, and the design stage has little impact on the construction stage. For safety reasons, prefabricated shear wall structures are usually used in structural design. This design method is reliable, but the beam and slab systems are not fully separated, resulting in more connections between prefabricated and cast-in-place overlapping parts, resulting in complex node construction and increasing the difficulty of template installation. Workers have many complaints about this, and their work enthusiasm is not high. Compared to the cast-in-place system, the construction period is significantly behind. The collaborative design of the entire building is to improve the functionality of the standard floor. A building generally contains standard floors and components connecting the standard floors. On the basis of standard floors, building blocks are combined into a whole building, and generally, the incomplete function of equipment is mainly considered. The functions of each building floor and structure floor are relatively independent and can exist independently, while the equipment floor is different, mainly in the following aspects: the integrity of the pipeline system in the equipment requires the pipeline to be connected from top to bottom or from bottom to top. In the three-dimensional model, the construction site environment is clear at a glance, which is convenient for

project managers to fully grasp the environmental information of the construction site. Reasonable planning of the construction site can avoid safety accidents such as the collision between machines in the construction process, the collision injury caused by machines to workers, the unreasonable parking position of mechanical materials, and the collapse of foundation pit slope due to excessive load. Combined with the construction simulation and the actual project construction progress, the construction site environment can be dynamically planned at any time, and the travel routes of vehicles and machinery in different periods and the activities of operators can be reasonably planned, which can effectively reduce the safety hazards such as lifting injuries, object strikes and landslides during the construction process.

In the preparation stage of production, the manufacturer prepares the required materials and molds through component model information, formulates production plans earlier, and vacates finished product storage locations; In the production stage, the design unit will input the detailed design information into the model, and the component information will be automatically converted into a format that can be recognized by the production equipment, immediately starting the production of prefabricated components. Using accurate and comprehensive component information to guide component production, improving component production quality and accuracy, reducing rework and project delays caused by component non conformance and unavailability, and thus addressing the significant impact of poor component quality on progress. In the quality inspection process, if cracks or other quality issues are found in the components, the operator can also transmit this information to the cloud BIM management platform for administrators to view and propose countermeasures. The same operation will be performed in the subsequent component inbound and outbound processes, and all production information of the components will be included on the cloud BIM platform. Utilize construction simulation processes to guide component production, improve component production accuracy, and reduce rework or even downtime caused by unqualified components; On the other hand, using the construction simulation process to guide on-site component lifting, a clear understanding of whether the working surface on the construction site is sufficient and whether the overlapping of processes is reasonable can be achieved throughout the entire construction simulation process, thereby accelerating the construction progress. Therefore, for the construction of prefabricated building, the use of BIM technology to manage the progress will significantly accelerate the progress and ensure the realization of progress goals.

4. Conclusions

Compared with the traditional construction mode of cast-in-place concrete buildings, prefabricated concrete buildings have obvious advantages, such as component size standardization, resource saving and higher construction efficiency. Therefore, the development trend of our country's future construction industry is bound to vigorously promote prefabricated buildings, and BIM technology has given great technical support to the information development of modern construction industry, accelerating the establishment of PC component serialization and standardization system of prefabricated concrete buildings. Aiming at the problem that the design and construction of prefabricated buildings are separated from each other at present, the collaborative scheme and BIM implementation method are carried out in the design stage, and the BIM design and deepening design model are adopted, which provides collaborative information carriers and means for all participants in the design stage, solves the problems of unreasonable component separation and insufficient precision in deepening design in the design process, and greatly reduces the changes in the construction process. This paper discusses the application of BIM based modular design method in prefabricated building, and it can be concluded that the BIM based modular design method has been optimized in the architectural design process. It can simultaneously consider the diversity of architectural design, the efficiency of manufacturing and the constructability of installation, and can realize the standardization and marketization of components, thus reducing the construction cost and promoting the development of architectural industrialization.

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