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The application of prefabricated BIM technology in the production and demolition stages of the whole building life cycle

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Abstract. With the development of engineering construction, the concept of building lifecycle management (BLM) is put forward. The building life cycle is a full cycle process starting from material and construction production, including multiple stages of planning and design, construction and transportation, operation and maintenance, as well as demolition and disposal. With the popularity of the concept of sustainable development, "recycling" instead of "completely abandoning" has become a trend. This coincides with the concept of the whole life cycle of a building. Prefabricated BIM (Building Information Modeling) is an important branch of BIM. It plays an important role in the construction of the whole life cycle of buildings due to its characteristics such as visualization, information sharing, and appropriate technology composite, especially in the production and demolition stages. Through qualitative analysis of the advantages of BIM technology and case analysis, this paper focuses on the important role played by BIM technology in the production and demolition stages. The application of BIM technology in construction animation simulation, site layout, and site planning is studied to effectively improve work efficiency and ensure construction quality. Besides, corresponding models and optimization of demolition methods are proposed based on different demolition needs. It can be concluded that in the production stage, BIM technology can be used for structural design, visual three-dimensional (3D) design, collaborative design, and optimization design, while in the demolition stage, BIM technology can be used for space management.

Keywords: Full Life Cycle, BIM Technology, Prefabricated Construction, Production Stage, Demolition Stage.

1. Introduction

A large number of on-site operations in traditional construction methods are replaced by prefabricated components of prefabricated buildings. Building components and accessories are processed and manufactured in factories, transported to the construction site, and assembled and installed on-site through reliable connection methods, thus realizing the design-simulation-construction-demolition assembly line building construction mode [1]. The construction efficiency is greatly improved, and the control of the building life cycle is also beneficial. Prefabricated buildings are assembled by prefabricated components. The BIM family is essentially a parametrable universal component, and modifying the parameterized properties of the component can quickly change the three-dimensional (3D) geometry of the component. During the creation, splitting and construction processes of assembled

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components and corresponding BIM components can be created in the BIM model, and the components can be split, simulated, operated, and maintained for management [2].

With continuous deepening of research on prefabricated buildings, some research results have been achieved in the separate stages of building construction. Ma Chenguang et al. studied the adaptation point of BIM technology and prefabricated buildings, emphasizing the important role played by prefabricated components in the design stage [3]. The application of BIM technology in the design of prefabricated structures can make the design process more efficient. The design quality has also been improved effectively; Han Bing studied the application of BIM technology in the production and on-site assembly stages [4]; Zhao Weishu et al. focused on the application advantages of assembled BIM technology in the demolition stage, aiming to make BIM technology fully participate in the entire life cycle of the building and give full play to the value of the technology [5].

In this paper, the design stage and construction stage are integrated into the production stage, and the demolition stage in the operation stage is taken as the research focus. By mainly studying these two stages of production and demolition in the whole life cycle of the building, the author illustrates the application of BIM technology in the production and demolition stages and analyzes the relationship between them to better serve the extension of the whole life cycle of the building.

2. Application of prefabricated BIM technology in the production stage

2.1. Application in the design phase

The application of prefabricated BIM technology in the design stage is mainly reflected in the structural design, the process of which is summarized in Figure 1.

Figure 1. A flow chart of the process of the structural design.

2.1.1. Calculating and analyzing the structure. The advantages and characteristics of BIM technology include its visualization, simulation, flexible use of 2D and 3D viewing, and self-inspection and optimization of structures realized by using the inspection function of Revit. After determining the basic structural units of beams, columns, walls, and floors in a structure, mechanical simulation and collision detection can be carried out to generate corresponding inspection reports, the location of unreasonable red marking can be modified and optimized, the type of component placement or material can be changed, and the corresponding solutions can be obtained. After the structure is arranged, it is necessary to set the overall information of the structure and arrange the load on the corresponding components [6]. According to the general instructions of structure design, the general information, earthquake information, wind calculation information, etc. are set. According to the warning, the practical problems such as the over-reinforcement of the components and the over-limit of the displacement angle between the layers are solved. After the model calculation of the layout load is completed, the horizontal reinforcement is carried out. If the warning is encountered during the process, the reinforcement can be modified. For example, when encountering cracks or deflection that exceeds the limit, one can return to modify the plate reinforcement and recalculate before making sure it is correct, thus automatically generating construction drawings according to the selection of reinforcement settings and construction drawing habits.

2.1.2. Obtaining construction drawings. Drawing ability is another advantage of BIM technology. Figure 2 is the floor structure construction drawing. After ensuring that the structure is the optimal structure, the structure construction drawing can be generated. It is a general guide for the subsequent

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construction process. The core of prefabricated buildings is the prefabrication of components, which are assembled on-site after all the components are prefabricated in the factory. This requires a clear placement position and the determination of the location of each component. Ensuring the stability of the building structure is the basis of ensuring the extension of the life cycle of the building. In other words, only the reasonable stability of the structure itself can increase the service life of the building. The determination of the construction drawing is one of the standards for the completion of the production stage. Detailed labeling and unified standards can also be realized by using the advantages and characteristics of information sharing of BIM technology so that the subsequent construction can be smooth and efficient.

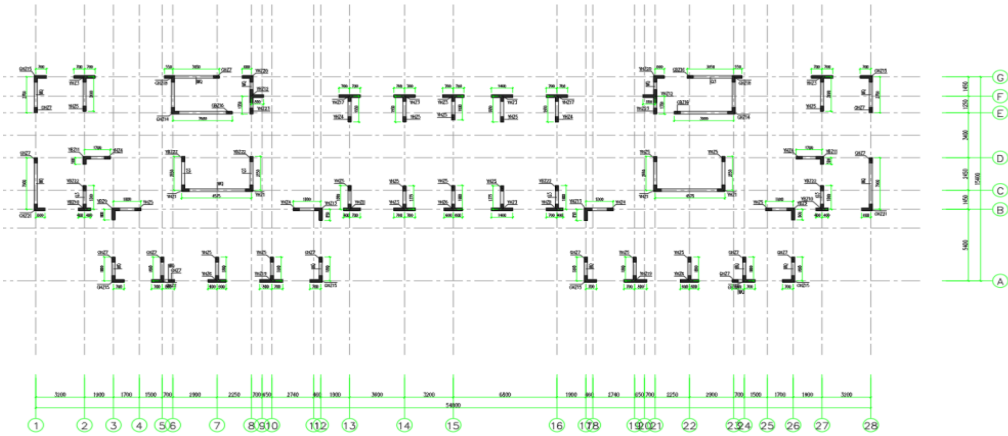


Figure 2. Floor structure construction drawing.

2.1.3. Building overall separation and component separation. According to Figure 3, the input of prefabricated components of different categories can obtain horizontal and vertical split diagrams to achieve the overall splitting of the building into parts. The subsequent building is no longer a monolithic behemoth, but more like the result of assembling some components [7]. The effect of splitting is often reflected in the installation sequence of prefabricated buildings rather than the traditional fixed mode. It is not a fixed order from top to bottom and from left to right. Approaches such as building in groups and splitting up and down at the same time can be possible for the fastest and best installation sequence for the target building. The whole building is divided into parts, the parts can still be divided into specific components, and the further design after the splitting is the design for the split components.

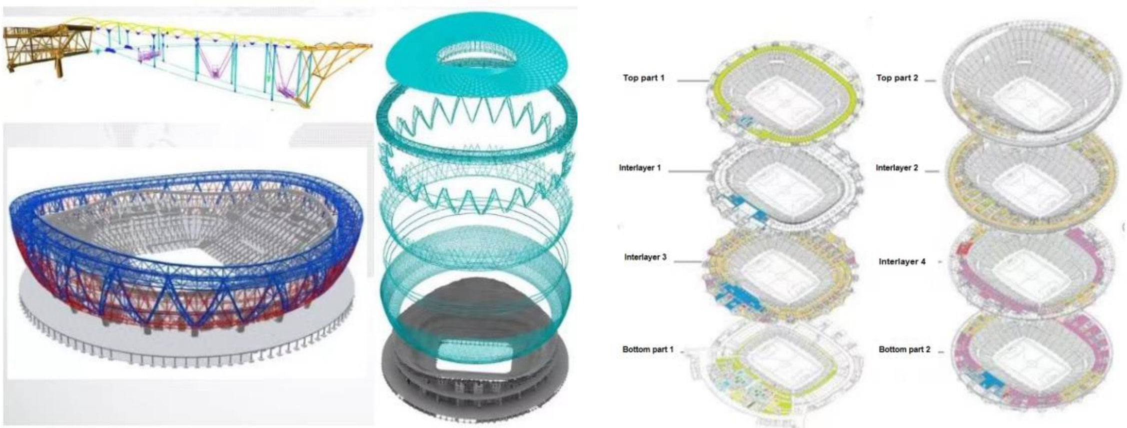


Figure 3. Overall split diagram.

2.1.4. Further design of prefabricated components. The prefabricated components can be regarded as a separate Revit file and an independent BIM model. As seen in Figure 4, the final in-depth design of the prefabricated components can be generated by parameterizing the rebar layout, automatically drawing the corresponding machining drawings, and then making corresponding modifications [8].

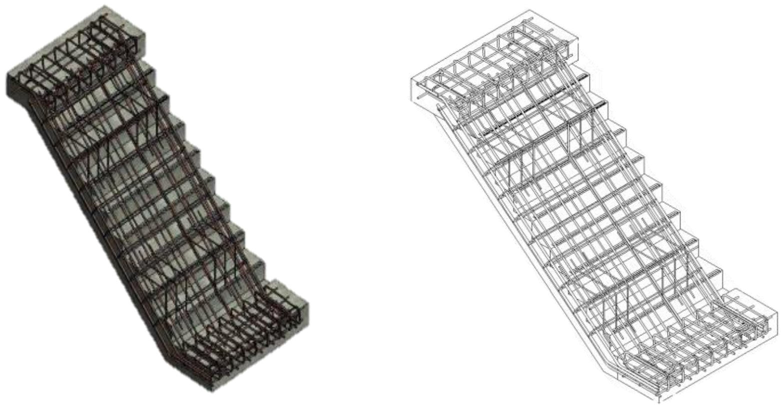


Figure 4. Further design drawing of the prefabricated component.

The process is summarized in Figure 5.

Figure 5. A flow chart of the process in the design phase.

2.1.5. Creating a prefabricated component family library. Building a component family library can improve modeling efficiency. After the model of each profession is built, the model of each module of the prefabricated building is optimized through collision detection, and the construction is guided by the model. A specific family library platform is used for standardized management of assembled BIM components [9]. The components uploaded by designers can only be displayed after a special review, and then the components will appear in the component library application interface and be applied by project personnel. The assembled components will be collected and sorted, the component library platform will be uploaded, the assembled components will be managed, and the standardization of assembled the BIM design will be ensured.

2.1.6. Three-dimensional visualization collaborative design. There are two ways of BIM collaboration: the first is to use Revit software working sets for collaboration and the second is to use Revit software link modes for collaboration. The newly developed BIM closed-mold plug-in combines the benefits of Revit links and working sets. By using closed-mold plug-ins, one can build a model or close the mold remotely and online in a project. The use of the closed-mold plug-in can help quickly discover various collision problems, optimize the design according to the closing results, and reduce the design rework [10].

2.2. Application in the construction phase

An advantage of the BIM technology is that it is suitable to be combined with other technologies. In the construction stage, the combination of BIM technology and BIM-FILM can be used to simulate the construction process and timely analyze whether construction indicators such as construction sequence and construction center of gravity need to be adjusted. GIS (Geographic Information System) technology can comprehensively analyze the site layout of the construction site and classify different functional areas to achieve orderly and efficient construction. In addition, as shown in Figure 6 and Figure 7, it can also produce animations to preview the effect of the site layout, so as to have a prior understanding and preparation of the construction environment and sites [11].

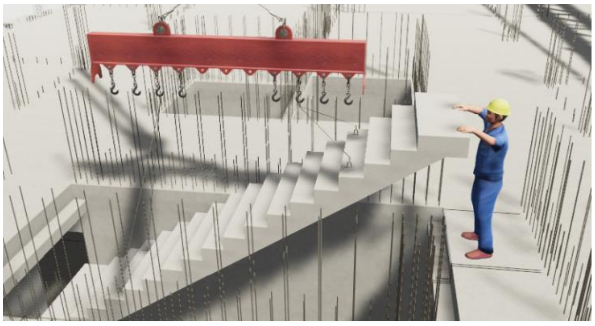
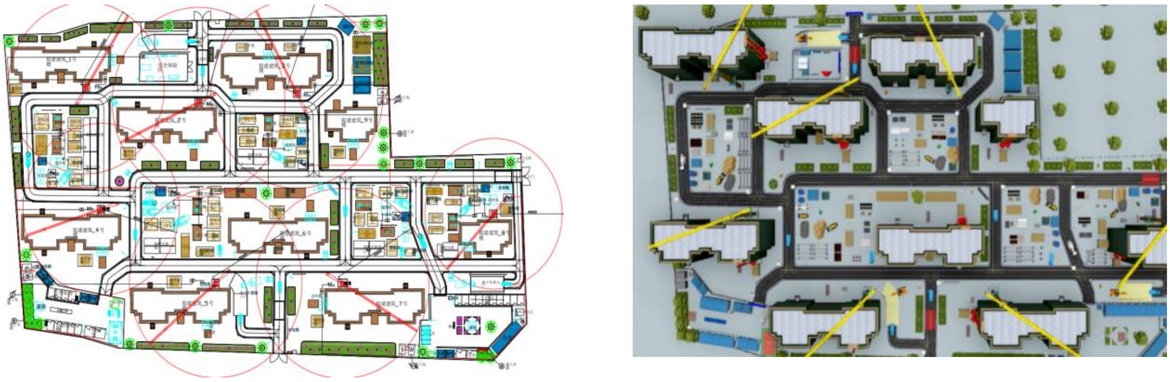


Figure 6. Construction animation simulation.



(a) Example 1 of the effect of the layout plan. (b) Example 2 of the effect of the layout plan.

Figure 7. Examples of the site layout plans.

3. Application of prefabricated BIM technology in the demolition stage

3.1. Application advantages of prefabricated BIM technology in demolition

3.1.1. Comprehensive information. Maximizing the use of BIM resources and giving full play to the advantages brought by the built BIM model will bring a lot of convenience to the demolition work, simulate and optimize the demolition plan, facilitate management, and improve the demolition efficiency. Based on the systematic, professional, and flexible design and construction of prefabricated buildings, the possibility of reusing their component materials will be increased during the demolition process [12]. During demolition, component materials with recycling value can be selected through the BIM model for redevelopment and secondary utilization, so as to realize the optimal allocation of building resources, reduce the impact on the environment, and promote green development. Compared with traditional cast-in-place buildings in the past, BIM technology plays a significant role in prefabricated buildings, and the application advantages are more obvious.

3.1.2. Visual database. The visualization function in BIM technology is divided into two aspects, one is the visual three-dimensional physical map, and the other is the visualization process [13]. Different from the traditional two-dimensional drawings that require users to imagine themselves, three-dimensional physical drawings can realistically present the appearance of the building project and the internal structure decoration, installation equipment, etc. in front of the user, even including

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the construction equipment that is usually hidden and cannot be directly seen on the spot. For instance, the water supply equipment can be three-dimensional displayed [14]. The visualization process of BIM, which can be simulated, is made of building components that are designed with parameters. Through the interaction and feedback visibility between the same components, the whole construction process is simulated, the complex internal relations during the construction process and the construction technology and process of key parts are accurately displayed, and various possible situations are predicted, so as to identify and resolve problems in a timely manner [15].

3.2. Preliminary preparation phase

3.2.1. Durability evaluation of precast components. According to the requirements of safety and applicability of precast components, the durability grade of precast components is evaluated, and the service life is predicted. Since prefabricated building components are generally reinforced concrete structures, the object of durability evaluation of building structural components is the reinforced concrete structure. However, the deterioration mechanism of reinforced concrete is complex and there are many factors affecting durability. By referring to the influencing factors in the relevant evaluation standards, the influencing factors are summarized and a correlation analysis is carried out. Moreover, quantifiable information on each factor is extracted and relevant data is obtained by fitting with a similar matching algorithm.

3.2.2. Optimization of the demolition scheme. At present, the demolition project in China is still in its infancy, the technical level is low, and the management consciousness is confused. Due to the interaction of various factors, it is difficult to form a complete decision-making scheme for building demolition, so the selection of the scheme depends on the subjective experience of the demolition personnel to a greater extent. There is a lack of comprehensive consideration of all aspects of factors and conditions, which can lead to one-sided opinions. Since the BIM model covers all information about buildings from the stage of decision-making and planning to that of use and maintenance, the introduction of BIM technology can bring objective and comprehensive information reference and provide strong technical support and basis for decision makers, thereby making decisions more scientific and reasonable. Before making a decision on the application of BIM, the most important thing is to make technical preparations and fully understand the details of the demolition project. Through the BIM model, the demolition personnel can consult the project characteristics, flat facade size, hidden engineering data, construction process record information, structural design service life, equipment specifications, model suppliers, installation, and other relevant data. With the help of the BIM model, the whole process of construction and construction technology at that time can be simulated, especially the full-size three-dimensional display of the more complex and technically difficult structural forms, so that decision-makers can intuitively and graphically understand the overall structure of the building, and find the key parts of the structural system and the difficulties in construction operation. Additionally, various problems that may be encountered during the demolition process and what needs attention can be recorded. According to the previous assessment results of prefabricated components, the appropriate demolition sequence can be arranged, and the demolition plan and schedule for each part of the pre-demolition building can be formulated [16]. Besides, a site survey can be carried out when necessary, and a feasible construction organization design plan can be formulated. On the basis of the BIM model, the advantages of GIS spatial data integration, geographic simulation, and geographic analysis are given full play. The demolition of urban buildings is mainly by blasting demolition or mechanical demolition, with manual demolition as the auxiliary method. BIM technology is used to simulate the blasting scene and determine the explosive point setting of the blasting scheme, so as to accurately select the blasting point and determine the blasting intensity, constantly improve the blasting scheme, reduce the emission of construction waste and the impact on the environment, and improve the recycling rate of building materials. The complex structure of modern buildings causes heavy tasks in demolition projects. If another commonly used demolition method is adopted, that is, the demolition form with machinery is regarded as the main and the manual form as the auxiliary, then how to arrange the construction sequence and cooperation of personnel and machinery will put forward high requirements for the decision-making and deployment of decision-makers and the on-site management ability of managers. The practical application of BIM technology can solve the problems of site layout and site management. The demolition site is simulated, the demolition process is optimized and designed, and the resource allocation is improved with BIM technology to enhance the efficiency of demolition [17].

4. Connections between the production stage and the demolition stage in the building life cycle

The purpose of this paper is to emphasize that the application of prefabricated BIM technology in the production stage and that in the demolition stage are correspondingly linked as a whole instead of two independent parts (see Figure 8). Demolition can be regarded as a reverse process of production, in which the location of prefabricated components is defined and the preliminary estimation of the use situation is provided. What needs to be done in the demolition stage is to replace the same prefabricated component to realize the cycle process. Instead of demolishing the whole building, the replacement and upgrading of the internal prefabricated component can be realized as few as possible. All the bases are based on the information resource-sharing platform provided by BIM, and dynamic real-time detection is realized through technology composite, so that the building can achieve "maximum utilization value". (The maximum utilization value is the synchronous replacement of prefabricated components, and the ideal state is that all components lose their original functions at the same time, rather than replacing or dismantling the whole in order to replace a certain part, which can better use resources and improve the utilization rate of resources).

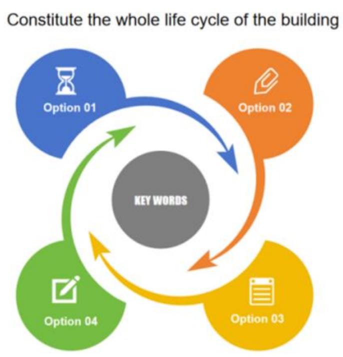

Figure 8. An inextricably link between production and demolition.

5. Conclusion

At present, the application of BIM technology in the production and demolition stages of the whole life cycle of a building is still in an initial exploration process. However, after discussion and demonstration from different angles and in different ways, prefabricated BIM technology can also be closely combined with the production and demolition stages through component prefabrication and construction, which has a large application space and huge potential to be explored. By analyzing one part of the application possibilities, the author hopes that assembled BIM technology can fully participate in the whole life cycle of the building, thereby making the best use of everything, maximizing the value of BIM, and bringing considerable benefits to society.

To conclude, in the production stage, BIM technology can be used for structural design to obtain the three-dimensional appearance of the building, and it can also cooperate with other technologies to realize a technical composite to integrate scattered answers into the optimal solution; meanwhile, BIM technology can be used for construction animation simulation, site layout, site planning, and other applications to effectively improve work efficiency and ensure construction quality. Before construction, the process and possible situations are simulated to the maximum extent. In the demolition stage, the paper studied the use of BIM for space management and proposed corresponding models and optimization of demolition methods based on different demolition needs. Demolition and production are the two stages of the whole life cycle of the building discussed in this paper. With the concept of sustainable development deeply rooted in today's society, it is necessary to pay attention to these two stages, so as to avoid too much waste and achieve greater production efficiency and service value [18].

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