Design and Cost Optimization of Digitally Assisted Assembly Components

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Abstract. Aiming at the challenges of the design and production of prefabricated components in the assembly construction industry, such as low design efficiency, diversification of component specifications, high mold manufacturing cost and so on, this study puts forward the use of digital technology, especially the solution of modularization and parametric design concept to optimize the design and production process. Through an in-depth analysis of a 24-story precast concrete prefabricated high-rise building, this study shows how to use design software such as Revit to achieve accurate design and efficient production, in order to reduce production costs and improve market competitiveness. The research results show that the application of digital technology, especially modular and parametric design, can effectively improve design efficiency, promote design standardization and modularization, and then reduce production costs and enhance market competitiveness. This study not only provides a new idea and direction for the future development of the prefabricated construction industry, but also provides a useful reference for the follow-up research.

Keywords: prefabricated architecture; digital technology; modular design; parametric design; production cost

1 Introduction

In today's construction industry, prefabricated buildings have gradually become a new trend because of their advantages such as high efficiency, environmental protection and sustainability. However, the deepening production design and production cost of its prefabricated components are still faced with challenges, such as low design efficiency, various component specifications, high mold manufacturing cost and so on, which limit the popularization of prefabricated buildings. In order to overcome these problems and promote the popularity of prefabricated buildings, this study focuses on the use of digital technology, especially the concept of modular and parametric design, to improve the design and production process. Combined with the latest research, we are committed to exploring solutions to reduce costs, improve efficiency and enhance market competitiveness. With the progress of digital technology, the application of CAD and BIM technology in architectural design is becoming more and more popular, which brings

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changes to prefabricated buildings. This study takes a 24-story precast concrete prefabricated building as an example, using Revit[1] and other design software to implement modular and parametric design, in order to achieve accurate design and efficient production, meet the needs of the construction industry for efficient, environmental protection and sustainable development, and provide new ideas for the future development of prefabricated buildings.

2 Application of Digital Technology in Precision Design.

The application of digital technology in the field of design has led to profound changes, especially in the field of accurate design[2]. With the help of cutting-edge CAD software and BIM technology, designers can build three-dimensional models with precision. These models not only show the geometric shape and precise size of components in detail, but also include important information such as material properties.

The key data such as the type, quantity and production cost of the required materials are extracted directly from the parametric model. This information provides a scientific decision-making basis for enterprises to make procurement plans and production strategies, which makes the allocation of resources more reasonable and the production process further optimized. In this way, enterprises can greatly reduce the phenomenon of material surplus or shortage, effectively reduce inventory costs, and significantly improve production efficiency, so as to gain a solid foothold in the highly competitive market. The application of digital technology in precise design has undoubtedly become an indispensable tool for efficient and accurate management of modern enterprises.

3 Application and Value of Parametric Design[3]

3.1 Parametric Design Significantly Improves Design Efficiency.

In Revit and other design software, parametric design enables designers to quickly generate and update design schemes by adjusting family parameters, such as size, shape, material and other key attributes. The real-time nature of this design method provides designers with real-time visual feedback, enabling them to explore and optimize a variety of design ideas in a very short time. More importantly, with the help of automatic optimization algorithm, parametric design can intelligently find the best design solution, thus greatly improving the overall efficiency of the design.

3.2 Parametric Design[4] Promotes Design Standardization and Modularization

Using parametric design, enterprises can establish a set of unified and standardized design parameters and rules to ensure that the fabricated components and moulds have a high degree of consistency and versatility. This standardized and modular design strategy not only simplifies the production process and enables production personnel to carry out efficient processing and assembly according to preset parameters, but also improves the controllability of product quality and the convenience of inspection. In addition, the modular design also gives the production more flexibility and scalability, so that enterprises can quickly respond to market changes and meet the diversified needs of customers.

3.3 Parametric Design can Effectively Reduce Production Costs and enhance Market Competitiveness.

By improving design efficiency and promoting design standardization and modularization, parametric design brings significant cost advantages for enterprises. The improvement of design efficiency means that designers can complete high-quality design work in a shorter time, thus reducing the cost of manpower and time. At the same time, the standardized and modular production mode optimizes the production process, reduces the waste and rework rate, and further reduces the production cost. In particular, the standardization of components and the versatility of moulds greatly reduce the manufacturing cost of moulds. These cost advantages make enterprises more flexible in pricing and stand out in the fierce market competition. More importantly, parametric design enables enterprises to respond quickly to market changes and launch new products that meet the needs of consumers in time, so as to continuously enhance market competitiveness.

4 Case Application of Digital Technology in Cost Reduction

4.1 Project Overview

The case of this study is a 24-story precast concrete prefabricated high-rise building, which adopts shear wall structure, with a total construction area of 15240.96 square meters. Among them, the prefabrication rate of prefabricated wallboards, beams, floors and other components is as high as 61.27%, and the prefabrication rate is high. There are many kinds of precast concrete components, including precast floor, precast beam, PC shear wall interior and exterior wall, precast staircase and so on. The purpose of this study is to deeply explore how to make, assemble, count and calculate the prefabricated components and their internal steel bars and embedded parts comprehensively and accurately through the concept of modularization and parametric design and with the help of Revit software[5]. In order to reduce the production and assembly cost of assembly components, and significantly improve the production efficiency.

4.2 Modular Design Application

In the field of digital technology, modular design is becoming more and more important. Its core idea is to decompose the complex assembly components into multiple modules with independent functions and similar structures. This decomposition strategy not only effectively promotes the standardization of assembly component production process, but also significantly improves the production efficiency, and greatly simplifies the complexity of design and manufacturing. Standardized design plays a decisive role in reducing the production cost of prefabricated components. By unifying the specifications and sizes of components, the usage of moulds of different specifications is significantly reduced, and the construction process is simplified. Further improve the production efficiency and save the cost. Accordingly, based on the concept of modular design, this study constructs four basic module families, including basic module, splicing module, aisle module and core cylinder module. These modules are set as the basic building units, and through their flexible combination, the basic floor layout of the building can be constructed efficiently, as shown in figure 1.

At the same time, in order to achieve accurate statistics of the building area and provide optimization guidance for household design, the corresponding family parameters are set for the above four modules in the Revit modeling to represent the respective building area. Through the systematic statistics of the information of these family parameters, we can quickly and accurately calculate the single-story building area under different module combinations, as detailed in Table 1. These building area data provide a direct reference basis for household design, which significantly improves the design efficiency on the basis of ensuring the accuracy of the design.

Fig. 1. Modular design and parameter schedule

Table 1. Building area statistics

Module type	Area/m^2	Quantity/piece	Total/m^2
Basic Module	47.61	6	285.66
Splice Module	20.25	5	101.25
Core Module	51.75	1	51.75
Corridor Module	27.36	1	27.36
Total			466.02

4.3 Application of Parametric Design

In this case, the prefabricated concrete components and production mold family are successfully constructed by using Revit modeling technology. These families contain many key parameters such as dimensions, specifications, material properties and so on, which lays a foundation for subsequent parametric design. Through the function of sharing parameters and nesting families, the sharing and accurate matching of parameters such as steel bar layout, pre-embedded parts and matching moulds in components are realized. This parameterized design method ensures the coordination and consistency among the parts. The key dimension parameters are associated, and the length, width and height of the beam are associated with the length, width and height of the die side die and end die, which ensures the accurate matching between the beam member and the die. At the same time, the beam length is also correlated with the length of extended longitudinal bars, the distance between stirrups and the number of stirrups, which further improves the accuracy and efficiency of the design. The section size of the beam is related to the shape and size parameters of the stirrups, as well as the position of the embedded parts, the opening position of the die and the size of the beam members. These associations ensure the integrity and coordination of the design and avoid possible design errors. As shown in figure 2.

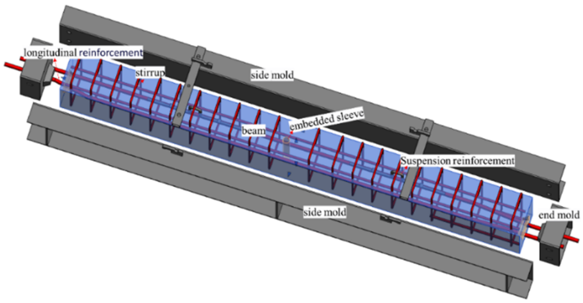

Fig. 2. Schematic diagram of the relationship between the component and the mold family

The production efficiency has been greatly improved. At the same time, parametric design can also easily count the amount of various materials and complete the statistics of material engineering quantity list. This function is of great significance for cost control and resource management, and contributes to the realization of lean production and management. In this case, the family parameter settings cover prefabricated beams, slabs, stairs, PC wallboards, moulds, and so on.

4.4 Optimized Cost Control for Prefabricated Components

The standardized production of prefabricated components is realized by designing four modules and ensuring that prefabricated components of the same or similar specifications are used in each module. This not only simplifies the production process, but also enables the production line to operate more efficiently, thus reducing production costs. Among them, the mold cost is significantly reduced, and the standardized component gauge means that multiple components can be produced using the same mold, which greatly improves the turnover and versatility of the mold. The replacement frequency and maintenance cost of the mold are reduced, and the production cost of a single component is further reduced.

According to the statistics of Revit components, there are 775 precast beams in this case, the total volume 161.41m3 is divided into 10 types of specifications, including ladder beams, their cross-section dimensions are uniform, only the length is different; precast plates are 1909, total volume 1036.78m3, divided into 9 types, the main difference is in the side mold; precast PC interior wall 690 pieces, the total volume is 1036.78m3, there are 5 types of specifications. Mold customization is based on component specifications, the fewer the specifications, the stronger the versatility. The precast beam end die and precast plate side die have strong versatility and can be used in different specifications of beam and plate members. In this case, the specifications of prefabricated components have been relatively standardized, which helps reduce the number of mold specifications, improve the versatility of molds, and further reduce costs.

5 Conclusion

This study deeply discusses the application of digital technology in the design and production of prefabricated architecture, especially the practical effect of modular and parametric design. The results show that these technologies can effectively reduce the production cost and improve the production efficiency. Through Revit and other design software, we have realized the accurate design and statistics of assembled components, optimized the production process, reduced material waste, and significantly improved the market competitiveness. This study not only provides support for the theoretical development of the prefabricated construction industry, but also provides technical guidance for practical operation. We firmly believe that the promotion and application of modular and parametric design will promote prefabricated buildings to occupy a more important position in the future market and contribute to the green, efficient and sustainable development of the construction industry. At the same time, this study provides a reference for the follow-up related research, and lays a foundation for the innovation and development of prefabricated building technology.

Although this study deeply discusses the application of digital technology in prefabricated buildings, it still needs to improve the whole life cycle management, data integration and so on. In the future, it is expected to expand the application of technology, achieve higher automation, promote the development of green buildings, and provide more personalized solutions.

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