The Application of BIM Technology in Building Structure Design

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Abstract. Under the background of digital and intelligent transformation of the construction industry, BIM technology has become the core technology and an important starting point to accelerate the innovation and development of the construction industry. It is one of the important tools covering the whole life cycle of construction projects. In particular, in the upstream design stage, the application of BIM technology is more direct and comprehensive. However, the practical level of BIM technology in structural design is low, which obviously lags behind the majors of machinery, electricity, and pipeline. In this regard, this paper will take the building structure design process as the breakthrough point. Then, it will combine many advantages of BIM technology "forward design" to propose a set of building structure design modes based on BIM. It can solve the problems of weak application ability of data information, complicated design steps, and difficult collaborative design among disciplines in the traditional building structure design process. This can promote the quality and efficiency of building structure design greatly. In addition, this paper will also explain the building structure design mode under BIM technology based on examples. It will show the realization methods of each key node in the design process by combining Revit, PKPM, and other software. In this way, the practical significance of BIM technology in the professional design of building structures can be verified.

Keywords: BIM technology, Building structure design, Forward design, Revit.

1 Introduction

At present, under the new wave driven by digital technology, China's construction industry has ushered in a critical period of strategic turning. Digitalization, intelligence, and greening transformation are the general trends; the integrated application of new technologies, new models, and new formats has become an inevitable choice for the construction industry to seize the commanding heights of development [1]. Among them, BIM technology, as a set of building digital information management systems, can give full play to the practical advantages of the three-dimensional building information model. It can provide information integration, sharing, and visualization services for the design, use, operation and maintenance of construction projects . It can

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also help the construction industry to quickly complete digital transformation and upgrading and promote the sustainable development of the construction industry [2]. The design stage of architectural engineering is the upstream of the life cycle of architectural engineering. It is the key to the construction and implementation of engineering projects and the starting point for applying BIM technology. With its "forward design" mode, the three-dimensional architectural information model combines the traditional two-dimensional graphic design process to form a comprehensive, visible, and cooperative architectural design method [3]. However, due to its complexity and particularity, the design process of building structure specialty still focuses on traditional methods, and the practical level of BIM technology is low. This obviously lags behind the majors of machinery, electricity, and pipeline and has become a shortboard in the forward design mode of BIM. In view of this, based on many demands in the process of building structure design, this paper puts forward a set of building structure design modes with BIM technology as the core. It shows the realization methods of each node and steps in the design process with practical cases. The BIM technology's ability to solve problems is highlighted, such as weak information application ability, complicated design steps, and difficulty in collaborative design among disciplines. The designers' grasp of the integrity of building structure can be enhanced, improving design accuracy and optimizing design effect.

2 Application of BIM technology in building structure design

The application of BIM technology in the structural design of architectural engineering revolves around the structural model design. Compared with the traditional graphic design mode, the construction of a structural model starts at the scheme design stage. It is constantly improved in the subsequent stages of preliminary design, deepening, and drawing design. A complete BIM structural model can describe the geometric dimensions, load arrangement, constraints, steel bar arrangement, structural requirements, and the relationship between components in a parametric form [4]. Fig. 1 shows the design process of building structure in BIM forward design mode.

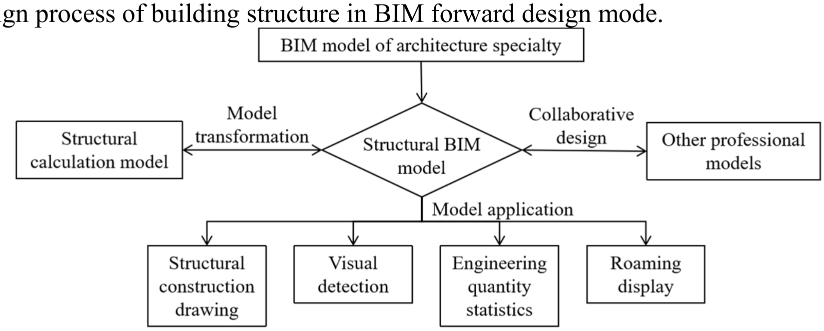

Fig. 1. BIM building structure design process

Among them, the structural calculation model is obtained by special structural calculation software through conversion interface technology. Its interior mainly includes the geometric shape, material physical characteristics and load action of the building structure [5]. Through accurate calculation, the model can predict the behavior and performance of building structures and provide optimization strategies for subsequent design and construction.

2.1 Project overview

The proposed project in a certain place is a factory workshop with a building area of 4517.03 m^2 and 10 floors. The structural form is a reinforced concrete frame structure. The design service life of the building is 50 years, the seismic intensity is 8 degrees, and the basic earthquake acceleration is 0.10 g. The building structure floor constant load is 5 kN/m^2. The floor constant load is 4 kN/m^2. The beam constant load is 8 kN/m^2. The roof live load is 2 kN/m^2. The snow load is 0.5 kN/m^2. The basic wind pressure is 0.6 kN/m^2.

2.2 Revit structural design model

The process of building engineering structural model creation is based on the actual geometric model creation process and the order of actual building engineering project construction from low to high [6]. In the actual design process, the designer can facilitate the establishment of the project model according to the structural template file preset by the system, as shown in Fig. 2. With reference to the mode, the designer completes the addition and arrangement of structural columns, beams and floors in turn. The adjustment and setting of the properties of various components are also completed, such as the material of columns, the position of upper and lower ends, and the connection constraints of various beams.

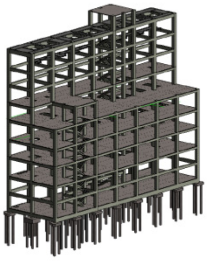

Fig. 2. Physical model of structure specialty

After the design of the physical model of the building structure is completed, loads will be added to each component model. The load is divided into three types: point load, linear load, and surface load. The load properties of different components are determined according to the working conditions. The design value of the load combination effect is calculated according to the Load Code for Building Structures and the proposed load data table. Formula (1) shows the calculation formula of the standard combined effect design value. Formula (2) shows the calculation formula of the combined effect design value. Among them, S_{GK} is the constant load effect value, S_{QK} is the variable load effect value, ψ is the combination coefficient of variable loads, m is the number of variable loads participating in the combination, n is the number of constant loads participating in the combination, and γ_G is the partial coefficient of constant loads. In order to ensure the safety of the structure and combine various load design values that may appear at the same time, Revit provides various editable load combinations [7]. As shown in Table 1, it is the basic information of the main components of the project.

$$S = \sum_{1}^{m} S_{GK} + S_{QK} + \sum_{2}^{n} \psi S_{QK} \tag{1}$$

$$S = \sum_{1}^{m} \gamma_G S_{GK} + \gamma_Q \gamma_L S_{QK} + \sum_{2}^{n} \gamma_Q \gamma_L \psi S_{QK}\text{, } S = \sum_{1}^{m} \gamma_G S_{GK} + \sum_{1}^{n} \gamma_Q \gamma_L \psi S_{QK} \tag{2}$$

Table 1. Load data table of some components of the project

No.	Category	Component name	Size (mm)	Load
1	General floor panel	LM1	400*100*4200	5.0 kN/m^2
2	Toilet floor panel	LM2	500*120*4200	5.5 kN/m^2
3	Accessible roof	LM3	400*100*4200	6.5 kN/m^2
5	Exterior wall	Q1	240×2500	7.7 kN/m
6	Interior wall	Q2	120×2500	3.8 kN/m
7	Parapet wall	Q3	240×1200	6.14 kN/m

2.3 PKPM structural calculation model

After the construction engineering structural model is created, the structural calculation model will be reconstructed in PKPM, as shown in Fig. 3. Common calculation and analysis items include story drift angle, torsion period, translation period, and shear-weight ratio [8]. Taking the shear-weight ratio as an example, as an important parameter in the seismic design of buildings, it is mainly to limit the minimum horizontal seismic shear force of each floor to ensure the long-term safety of building structures [9]. The calculation formula is shown in Formula (3), where V_i represents the floor shear force of the i-th floor corresponding to the horizontal earthquake, and G_j represents the gravity load of the j-th floor. The calculation results are shown in Table 2. The results show that the shear-weight ratio of each floor is greater than 1.60%, which meets the seismic code of buildings.

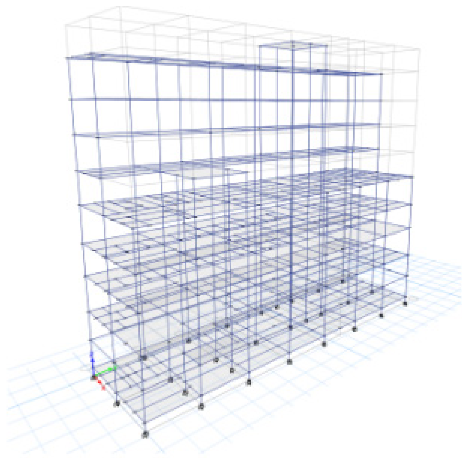

Fig. 3. Calculation model of the building structure

$$\lambda = \frac{V_i}{\sum_{j=1}^{n} G_j} \tag{3}$$

Table 2. Shear-weight ratio of each floor

Direction	X	Y
1F	2.80%	2.76%
2F	3.25%	3.17%
3F	3.41%	3.33%
4F	3.72%	3.66%
5F	4.06%	4.03%
6F	4.54%	4.52%
7F	5.41%	5.37%
8F	6.23%	5.97%
9F	6.88%	6.76%
10F	7.43%	7.26%

2.4 Application of building structure model

After the structural calculation model is processed, the calculation information will be fed back to the BIM structural model. After this stage of design and calculation, the building structure model has been further deepened, which is ready for the subsequent model application. In the drawing stage of structural construction drawing, BIM still uses the flat method to divide the view and add corresponding marks to form the final construction drawing. Fig. 4 shows the schematic diagram of stair reinforcement and the construction drawing of some column members [10].

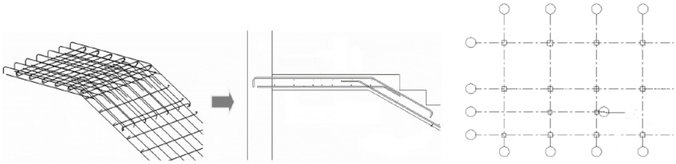

Fig. 4. The schematic diagram of stair reinforcement and the construction drawing of some column members

3 Conclusions

Based on the understanding of the concept of BIM technology, this paper selects Revit as the support software platform. It confirms the practical application and popularization significance of BIM technology in architectural structure design by combining design practice and actual engineering projects. The design process of building structures under the "forward design" mode of BIM technology fully embodies the practical advantages of BIM technology. It can effectively solve many problems faced in the traditional design mode and improve the BIM application level of structural specialty. In the follow-up research, the conversion efficiency between the structural calculation model and structural design model will be further improved. The calculation and analysis projects will be enriched, contributing to the digital development of the modern construction industry.

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