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Developing the Structural Information Model in Forward Design of BIM

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Abstract

The rise and application of Building Information Modeling (BIM) has effectively solved the problem of collaborative communication of professional information between architecture and structure disciplines. This paper has presented the general process and method of developing the structure model by using the forward design software based on IFC standard, then it has been applied to a high-rise shear wall project. The results show that the construction method of structural information model based on IFC standard can be applied to BIM forward design, which has provided a reliable method to promote the application of BIM forward design in engineering practice in China.

Keywords

BIM; Structure Information Model; Forward Design; IFC.

1. Introduction

BIM (Building Information Modeling) technology has been vigorously promoted in the construction industry since its inception, and China has clearly proposed in the "13th Five-Year Plan" [1] to accelerate the development of informationization in the construction industry, accelerate the integration of BIM technology in the whole process and apply the new BIM technology for construction production services. BIM technology has led a wave of ideological changes in the industry, such as architectural design, structural design, construction management, post-maintenance and other aspects of information can be effectively shared, integrated and exchanged through BIM technology.

BIM forward design is a radical change to the traditional construction project design process, which makes the building and structure can be presented in an intuitive 3D model, and the information of different dimensions and attributes can be integrated and managed in the same platform, which effectively improves the design efficiency and coordination, and then improves the design quality. Compared with the current BIM reverse design, which commonly uses "first CAD drawing, then modeling" [2], this BIM forward design method of "first modeling, then drawing" strengthens the symmetry, unity and guidance of information of the whole life cycle of planning, design, construction and operation and maintenance of buildings. It also avoids the problems of duplication of work, low design efficiency and waste of human and material resources caused by BIM reverse design [3].

The Structure Information Model (SIM) in traditional design is different from the Building Information Model (BIM), where the architectural design and structural design are usually carried out separately, but the design process is closely related, and the architectural design has to provide the necessary geometric topology information for the structural design. BIM is a collaborative model

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of building and structural information based on the IFC standard [4]. As the mainstream product data exchange and sharing standard in the international construction industry, IFC can be divided into resource layer, core layer, shared layer, and professional domain layer according to the structure level. The standard building model should contain geometric information, material information, load information, etc. are stored in the IFC resource layer, and the information exchange and sharing of the resource layer can be realized in the shared layer by using software supporting IFC standard. The core layer organizes and links the information of the whole information resource layer. By defining a generic finite element model based on XML format, the necessary structural component information can be extracted from the resource layer of IFC to form a standard XML file for structural design and analysis, and the extraction of structural unit connection nodes can be completed using the corner node coordinates of components in the IFC model [5].

There have been many achievements in BIM forward design software development in China, Jing Wang [6] et al. designed an independent platform CabrIFC, which can realize the sharing of building information between PKPM design software and IFC standard data, which can solve the problem of inconsistency in the description of some structural analysis information between the two. Xueyuan Deng [7] et al. established a basic method to automatically generate structural models for various structural analysis and design software conforming to the IFC standard. The research idea is to first construct a building model based on the IFC standard. The standard XML file for structural analysis and calculation is obtained from the model file through automatic extraction technique, and the structural model is modified and edited through the finite element model interface, as shown in Figure 1. Wenyong Wu [8] et al. proposed a more complete preparation point of BIM technology to establish GSRevit, a building structure design system, with data separation in the form of database plus file server.

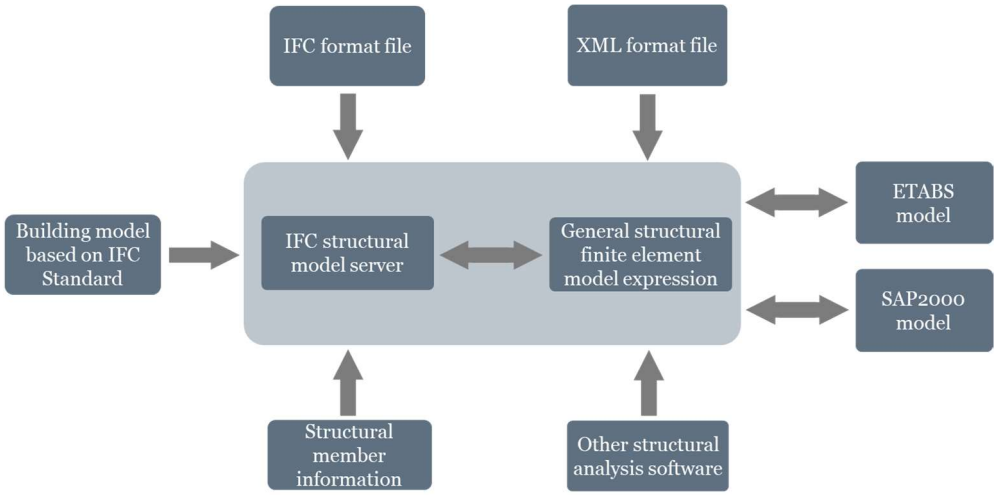

Figure 1. Automatic generation of basic frames for building structural models based on IFC standards

2. Structural Model Construction Method

Only when the structural information model is constructed in strict accordance with the IFC standard can we ensure the consistency and sharing of data between the building model and structural model to achieve BIM forward design and efficient transfer of structural information [9]. At present, there are many software for BIM design, such as Bentley's Architectural Desktop software, Autodesk's Revit series software, GRAPHISOFT's ArchiCAD series software and Dassault System's CATIA series software. Among them, thanks to the good 3D display function, Revit series software is widely used in the field of civil architecture, and its engineering model data supports IFC standard and has rich external data interface [10]. Thus, it is feasible to use the attribute set extension method in IFC standard as a technical means to build a specific structural information model by combining the

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attribute sets of existing components in IFC standard [11]. There are a variety of modeling software available, but the basic modeling idea of many software is the same. Using BIM modeling software for solid modeling through various 3D modeling commands, the data model will be visualized and the various parameters input will be organized, read, analyzed and calculated according to the requirements of the data model. The following section will describe how to build the structural information model from the whole process of BIM structural model building.

2.1 Non-geometric Information

To build the structural model, the first step is to input the overall information of the project to be built. The overall information of the structural model should include the structural form and number of floors, the relationship between building and structural floor numbers, material information, brick and mortar information, seismic and time analysis information, wind calculation information, basement information, code adjustment information, etc. These information and parameters belong to the non-geometric information of the structure, and they will be added in the form of shared parameters throughout the whole process of structural calculation and analysis as the overall information of structural analysis and calculation. The non-geometric information of each of these components will be described, stored and utilized separately, and the same category of information can be selected and modified at the same time, which greatly improves the efficiency of modeling.

2.2 Geometric Information

By and large, the structural geometric model construction is the same as the general building 3D model construction method, the only difference is that all the components of the structural model are force members and structural calculations are to be performed. The arrangement of the structural axis network is carried out first. Axis network is a planar mapping of geometric topology information, which is the basis for later model establishment, member placement, point positioning, and extraction of calculated dimensional data, and plays a pivotal role in structural model calculation. The orthogonal axis network, circular axis network, and single axis network are all input methods of axis network, among which batch axis network input is a more efficient method to create axis network.

After the completion of the axial network, it is necessary to arrange the elements according to the structural form. The most basic elements in the structural calculation are beams, slabs, columns and walls, and all the calculation data are obtained based on the dimensions of the basic elements. In this process, it is necessary to divide the basic elements into units, and then calculate and analyze them by superimposing different loads and working conditions. The creation of beams, slabs and columns and the modification of their cross-sectional information are based on the properties of the extended IFC entities, and by entering the required parametric information, such as geometry of the structural elements, material strength, etc., a data class is created that contains all the properties of these IFC entities.

After the layout of the members is completed, the constant and live loads of the members should be input according to the specifications to facilitate the subsequent structural analysis and verification. The load types include linear load, concentrated load, local linear load, distributed torque, concentrated torque, temperature variation, etc. The application of loads can be achieved by defining member property information. Different modeling software implement this differently, but the structural loads are stored in IFC-compliant model files as shared parameters and extended data.

After the load arrangement is completed, the structural model is basically completed. Next, structural analysis and calculation are required, and the design is adjusted reasonably according to the calculation results. This paper does not analyze it here. The structural model building method introduced above is applicable to various structural forms such as frame, frame shear, shear wall and cylinder.

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3. Application of Structural Model Building Method in a High-rise Shear Wall Project

Through comparison and selection, the authors concluded that GSRevit is a modeling software that better fits the authors' model building ideas. The authors selected a project of assembled concrete shear wall structure [12], and used GSRevit software for BIM structural information model construction in order to verify the correctness of the structural information model construction idea and expect to find possible problems and solutions in the modeling process.

First of all, the input of non-geometric information is carried out, and the input of structural information, material information, seismic information and various calculation information can be easily carried out in the corresponding module, and it can be coordinated with the later arrangement of the components to maintain consistency. After completing the information input, the axis network can be established, which is a more mature input method. Next, the elevation modification is carried out, because the number of structural layers and floor elevations have been determined during the input of non-geometric information, and the structural elevations have been generated in advance, so only some elevation modifications are needed in this step. The important step is to build the layout. In Revit, it is easy to establish various families, and the familiar walls, beams, slabs, and columns can be used in the form of families, and each individual family can define different properties. After the actual project verification, it is completely feasible to call various families for member layout in the structural model construction. The final step before the structural calculation is the load layout, and once the load layout is completed, the model can be initially verified for errors. The authors have basically completed the whole process of constructing the structural model with this project, which proves that the proposed idea of constructing the BIM structural model is correct, but there are still some detailed problems in the specific operation and practice.

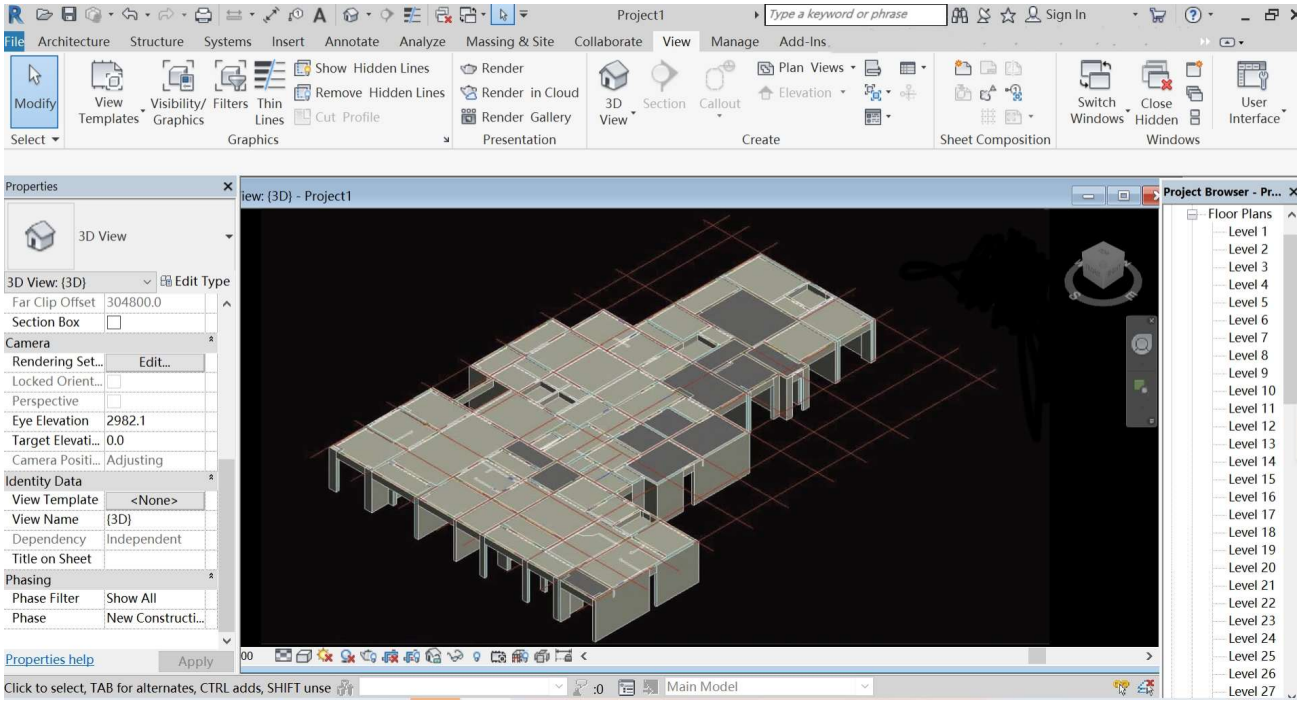

Figure 2. Examples of structural model building projects

First of all, the material strength and other parameters of the members need to be recorded in the general information of the model, but the self-contained properties of each member also contain the non-geometric parameters of the corresponding member. The problem is that both of them can be modified, but the modification logic of both is not clearly defined, so the structural member layout

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often has the problem of automatic layout errors. In this regard, corner point layout can be used as an alternative method. However, the plate on the corner point layout can only come out of the calculated reinforcement value, and the construction drawings cannot be automatically generated by the software at a later stage. It is known from the analysis that the reason for the error of automatic plate laying may be the incorrect connection of walls, beams and columns. The authors believe that there are two ways to solve the above problems, one is to strengthen the detail control when modeling, and the other way is to optimize the node determination and let the software correct the modeling deviation by itself.

4. Conclusion

(1) Structural information model construction uses BIM technology as a reliable method to realize BIM forward design and provide a basis for seamless integration of 3D visualization model and analysis and calculation model of the building.

(2) Realizing the construction of structural model can be carried out through the steps of non-geometric information input, axis network arrangement, structural member arrangement, and load input, which is to meet the requirements of structural analysis and calculation.

(3) The structural information model established based on IFC standard can get compatible support from modeling software and structural analysis software conforming to IFC standard, which lays the technical foundation for the construction of common structural model, the realization of integrated building design and later operation management.

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