Minireview Article

Architectural design of building structures using BIM techniques —the design of a sales office as a case study

Abstract

Under the background of the rapid development of China's construction industry, construction-related technologies are constantly updated and upgraded, and BIM information technology is widely used in the construction industry. It can provide a visual and dynamic design model for building designers, builders, owners and other participants, and examine the defects of building design through module analysis, so as to minimize the probability of problems in building design and provide technical support for the orderly construction of building projects. Building is a complex which integrates civil structure, electrical system, water supply and drainage system and other multiple structures.Actively using new information technology in building structure design can not only effectively improve the coordination of building professional design and structural design, but also provide greater convenience for the optimization of structural design. BIM technology platform can analyze the characteristics of structural design through dynamic display in the early decision-making, design and later construction, so it is recognized by architectural colleagues. This text employs BIM technology to visually represent a plethora of information related to architectural structural design. It successfully accomplished the creation of a three-dimensional model for a two-story building in Sales Office Building 1, utilizing the Revit platform. This process included smooth loading of family files and component additions, thereby achieving personalized customization of the building. The utilization of BIM technology aligns with the current trends in architectural structural design.

Keywords: BIM technology; Architectural engineering; Structural design; Technology Application

Introduction

The application of Building Information Modeling (BIM) technology in the design of a sales office brings opportunities to observe and experience architecture from multiple perspectives, facilitating effective communication among different professionals, stakeholders, and construction entities. The development trend of BIM application involves multiple data sources, outputting a unified model, creating multi-level model databases, utilizing various platforms, and achieving diverse outcomes. BIM technology is not limited to a single building project but can be extended to communities, cities, and towns, enabling sustainable planning, construction, and smart interactions through the use of big data, Internet of Things (IoT), and cloud computing. Consequently, the concept of a "smart city" begins to emerge. BIM has already shown promising applications in project engineering and urban planning. For example, the China Institute of Building Standard Design has applied BIM technology to underground space design, promoting the development of coordinated use of above-ground and underground spaces.

1. Introduction to BIM Technology

1.1 Essence of BIM Technology

BIM, an abbreviation for Building Information Model, is an architectural engineering data model built on the foundation of three-dimensional digital technology. By leveraging the advantages of computer and digital technology, BIM establishes a comprehensive and practical information repository for architectural engineering data models. This includes not only geometric information, professional attributes, and status information related to building components but also non-component object-related status information such as space and behavioral characteristics. Through this three-dimensional data model that encompasses extensive architectural engineering information, BIM effectively integrates architectural engineering information. It holds significant application value in the field of architectural design and plays important roles in structural design, quantity estimation, equipment management, cost accounting, and property management. BIM injects vitality and vigor into the development of the construction industry by enabling comprehensive information management throughout the entire life cycle of a building.

1.2 Definition of BIM Technology

BIM technology is a software system based on computer and information technology. It is primarily used in architectural engineering design and also referred to as Building Information Modeling. This system utilizes its inherent 3D modeling and visualization capabilities to collect and apply various data and information related to the building structure in the process of creating the 3D model. By correlating the data with the parameters in the model, it enables more efficient optimization and refinement of design drawings during architectural engineering design. The real-time adjustments of the 3D model data through the visualization system not only enhance the accuracy of construction design drawings, but also contribute to reducing the overall cost of the construction project.

1.3 Characteristics of BIM Technology in Structural Engineering Application

During the entire design process, BIM technology can be effectively utilized in structural engineering by integrating different disciplinary design contents through collaborative design. It ensures a more comprehensive and scientifically-driven forward design flow in conjunction with various professional requirements. The application of BIM in the structural discipline entails the following key characteristics: Firstly, it enables the establishment of computational analysis models, thereby enhancing the practical value of the Building Information Model and enriching the model information, in turn increasing the workload and improving model consistency. Secondly, it facilitates the use of plan-based annotation to express construction drawings. Plan-based annotation presents a series of information related to component elevations in a two-dimensional manner. BIM design can project corresponding design information onto the 3D model, enabling localized application through software processing. Thirdly, structural engineering involves reinforcing information, which makes it challenging for BIM technology to fully address steel reinforcement modeling. Lastly, after establishing a sound computational model, BIM technology can produce construction drawings for structural engineering. However, making extensive calculations and modifications are necessary when revisions are needed, resulting in significant cost waste and lack of flexibility in modification.

2 Creating the 3D Model

This project involves a two-story building structure located at the sales office. During the design process, a 3D model was created using the Revit platform to facilitate forward design.

2.1 Establishing Worksets

Given the large scale of this construction project and its involvement of various professional knowledge, it requires coordination and collaboration among architectural, structural, HVAC, electrical, plumbing, and other disciplines to complete the project. In the context of BIM forward design, each discipline should establish worksets, and within the same discipline, multiple work subsets can be created based on different design content. For example, in the forward design of this sales office, the architectural discipline can divide the work into subsets such as wall worksets, floor slab worksets, and door/window worksets, while the plumbing discipline can further divide their worksets into water supply, drainage, hot water, fire water, and recycled water worksets. Additionally, a significant advantage of BIM forward design is its ability to significantly improve the efficiency of collaborative design among different disciplines. Each discipline can set permissions to view and manage the design content of other disciplines through relevant worksets within their respective discipline.

2.2 Creating Levels and Grids

Levels and grids together form the three-dimensional space of architectural design and serve as the fundamental elements for creating a solid model. In BIM forward design, levels and grids, as the foundational data, are prerequisites for facilitating collaborative design among various disciplines. The BIM design software, Revit Architecture, utilizes the three-dimensional spatial framework composed of levels and grids to position elements such as beams, columns, floor slabs, walls, doors, and windows. BIM forward design represents the three-dimensional expression of a construction project, an upgrade from traditional 2D design drawings. Therefore, the establishment of levels and grids relies on the data provided by 2D design drawings. In the modeling process of this sales office, using commands such as "Levels" and "Grids," a three-dimensional spatial system with mutually perpendicular dimensions of length, width, and height was created. Specific numerical values were designated to define the spatial positions of different architectural components. Additionally, in order to enhance clarity and comprehensibility of the complex interface presented by the integrated display of multiple disciplines in the Revit platform, annotations for dimensions and numbering are also necessary.

2.3 Loading Family Files

Family files can be considered as the fundamental building blocks of Revit models. The combination of different family files forms various elements, which, when further combined, create a complete architectural model. The BIM family library can be categorized into standard component families, specific component families, as well as standalone families and host-based families based on their usage. Standard component families, also known as system component families, are predefined basic elements in Revit Architecture. They can be directly applied to model construction by adjusting parameters such as length, width, height, etc. In this project, common component families like walls, floors, ceilings, and stairs were utilized. However, architectural designs are unique, and standard component families may not fully meet the needs for personalized expression in architectural schemes. In such cases, specific component families are employed. Specific component families can be loaded as design resources or created by modeling personnel based on design parameters. Standalone families refer to individual components that can be used independently, such as walls and columns, while host-based families rely on specific hosts to exist, such as doors and windows. Furthermore, family files possess adjustability and replicability. By copying and moving family files with the same parameters or modifying family file parameters, the required elements for modeling can be quickly constructed, significantly enhancing modeling efficiency.

2.4 Creating Primary Walls and Structural Columns

Walls, as the most fundamental components of a building, not only serve structural and enclosure purposes but also bear the responsibility of separating different functional zones. Therefore, creating primary walls is crucial for constructing a BIM model. In Revit modeling, walls can be created by adding the "Wall" family file from the system component families and adjusting parameters such as plan location and height. The BIM model can also visually express information about wall thickness, construction methods, and materials used. In the construction of this sales office project model, the floor plans of each level were sequentially imported and aligned with the coordinate system formed by the gridlines and levels. Walls were then drawn in the corresponding positions by adding family files. After wall creation, the placement of structural components can proceed. Structural components can be categorized into vertical and horizontal structural elements due to their different positions. Vertical structural elements refer to structural columns, which are still positioned according to the floor plans and building heights. Horizontal structural elements include structural beams and floor slabs, which need to be drawn by adding family files based on the design details after walls and structural columns are created. Revit Architecture provides a range of structural tools to meet the structural modeling needs in the modeling process, providing crucial design references for integrated pipe systems and clash detection in various disciplines.

2.5 Adding Other Components

Once the primary components such as walls, columns, and floors are created, other components that constitute the building model, such as doors, windows, roofs, and stairs, can be drawn in sequence. Doors and windows come in various types and are usually loaded as specific component families. They cannot be used independently and need to be attached to walls, columns, and other primary components, which are created through independent creation. The roof in this project is a sloped roof. When drawing the roof, the "Roof" tool from the system component families was loaded. The roof slope was adjusted based on the roof plan design file to obtain a 3D model that matches the actual project (refer to the image below). Drawing stairs is relatively more complex. Unlike other integral components, stairs consist of treads and handrails. The treads are drawn first, and then the handrails are automatically generated along the direction of the treads. In the type properties, construction type, representation, tread depth and height, materials, and decorations, among other parameters, can be set for the stairs.

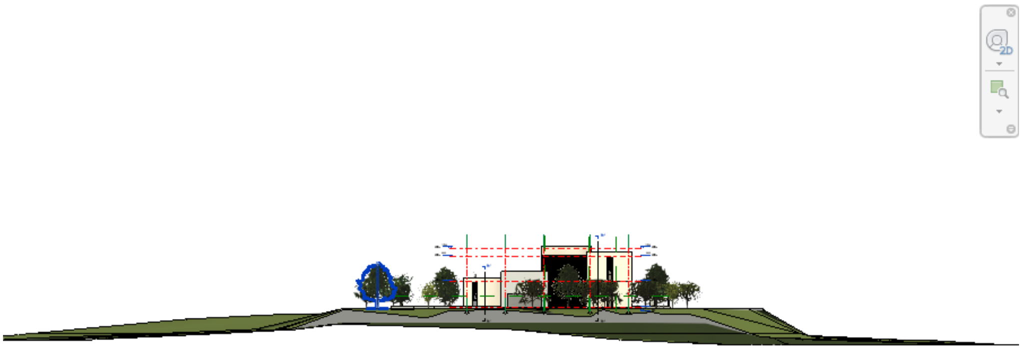

Fig 1. Drawing stairs

2.6 Conducting Scene Rendering

The predominant advantage of architectural scheme design led by BIM forward design lies in its ability to simulate real-life scenarios with exceptional accuracy, achieving a "what you see is what you get" visual design. The current project of the sales office leverages this advantage by not only incorporating the necessary basic elements of the architectural structure, but also enhancing the interior walls based on their respective functions. Additionally, various perspectives were selected to render different scenes within the building using the Revit platform, resulting in an authentic sensory experience. This user-centric design not only adds a touch of humanistic care to the rigid electronic data of the BIM model but also upholds the original intention of architectural design.

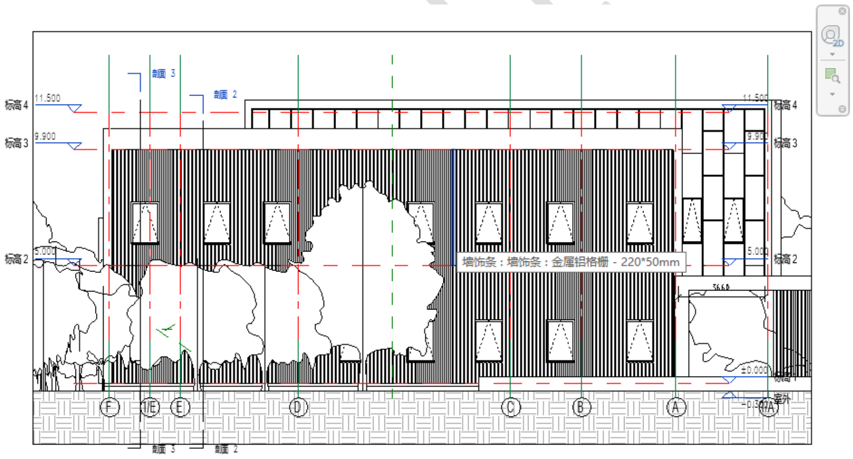

Fig 2. Conducting Scene Rendering

3 Conclusion

In summary, in the structural design work of construction projects in our country, the practical strategies of BIM forward design have been explored from the perspectives of model management, design process, and design methods. The procedures such as establishing worksets, creating elevations and axes, loading family files, creating main walls and structural columns, adding other components, and rendering scenes have been sorted out to illustrate the application of BIM forward design in a sales office. It is hoped to explore the value and application methods of BIM forward design through summarizing and organizing practical experience. As there are some personalized requirements for the structure design, the difficulty of design is also very high, and the installation coordination requirements of related functional systems require designers to constantly improve their abilities and optimize the information integration efficiency. BIM technology can visually reflect many information related to structural design and is consistent with the current development direction of architectural structure design.

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