Research Article

Civil Engineering Simulation and Safety Detection of High-Rise Buildings Based on BIM

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In the process of vigorously promoting the development of China’s smart city construction site engineering, the wide application of BIM technology and its advantages have been widely reflected in various places such as remote video site monitoring, visual chemical field technical data disclosure, and statistical engineering volume. BIM technology can effectively help enterprises manage the whole construction site, and can significantly and effectively improve the safety management level and work efficiency of the whole construction site. In this paper, a numerical simulation processing system for civil engineering is designed. This system can not only effectively predict and evaluate the design results of civil engineering but also help guide enterprises to obtain various earthquake-resistant and beautiful building structure designs, and various this kind of economical and reasonable engineering project construction decision-making. This paper uses simulation models to study the civil engineering of high-rise buildings, and conducts an in-depth study on the efficiency of simulation processing results and the analysis of visualization methods, which mainly include the efficient visualization of simulation time-varying vector fields and the efficient visualization after OpenSEES simulation processing.

1. Introduction

BIM 3D technology is mainly based on various building-related design materials and related data models of architectural engineering design projects. It uses a large number of digital information technologies to perform automatic simulation to simulate the real situation of 3D buildings [1]. Design-related management software automatically builds a model of a three-dimensional building to realize various functions such as the overall design, construction, and management of the three-dimensional building [2, 3]. With the continuous progress of China’s characteristic well-off socialist industrial market economy and national scientific production technology, the structural complexity of high-rise buildings continues to increase, and the steel structure design of high-rise buildings also puts forward higher requirements [4]. The requirements of structural scale and function are also constantly changing, which greatly increases the complexity of high-rise building design [5]. At the same time, the level of civil simulation of high-rise buildings should also be continuously improved to adapt to the changes in the architectural scale and functional requirements of high-rise buildings. The traditional two-dimensional drawing CAD architectural design and construction methods are prone to construction drawing design differences, collaborative work design problems are difficult to complete, collision design problems are difficult to discover in time, information communication between all parties is difficult to coordinate, and engineering quantity data statistics are difficult. Problems have brought a lot of inconvenience to the management of a large number of construction projects. BIM design technology can solve these complex problems efficiently [6–8].

2. High-Rise Building Design Based on BIM Technology

2.1. High-Rise Building Design Based on BIM Technology

2.1.1. BIM Architectural Model. The architectural model of the project is the modeling software Revit Architecture, with BIM technology as the core, which can be designed
according to the thinking and ideas of expert designers in various architectural disciplines, and designed and produced by these software applications. The products are of good quality and high precision.

2.1.2. BIM Structural Model. The project’s structural model adopts the BIM core modeling software Revit Architecture, which provides professional designers related to building structure with a set of specialized design methods and tools, which can effectively help architectural designers design high-efficiency building structures more accurately [9]. Revit Architecture is an intelligent building model built on the basis of advanced building model information technology. Through simulation and data analysis of architectural design documents, it accurately realizes the prediction and analysis functions, and uses the information contained in these intelligent building models [10, 11]. Geographic location coordinates and all other information greatly improves the quality and accuracy of architectural design documents.

In the construction project of a building A1# in a science and technology park, the structural model design was designed by a professional architectural structure design engineer. They used the Revit Architecture method to design and arrange the layout of the overall building structure.

2.1.3. BIM Electromechanical Model. The project electromechanical equipment model design adopts the construction modeling design software Revit MEP, with BIM as the design core. It designs various types of electromechanical equipment for professional buildings, such as heating, electrical, and land drainage [12, 13]. Design managers and architectural designers provide specialized building design management tools. Through advanced intelligent building professional information system model design technology, they can quickly design and develop extremely complex professional building information systems, and help derive professional building information systems with higher performance and efficiency [14, 15].

In the A1# project of a high-tech park area, the electromechanical system model was designed and used by professional electromechanical model engineers. Revit MEP completed the overall design of electromechanical water supply and drainage, HVAC, electrical, and other models, and established various plumbing. The design view and model template of the electrical system, respectively, clearly give basic parameter information such as the raw material and equipment component model of each electromechanical subsystem, and provide a complete statistical table of electrical wiring and electrical equipment model information.

2.2. BIM Collaborative Design. Project collaborative design uses BIM collaborative software Vault, which itself is a source control tool. Vault is not only powerful but helps all the data of the library stored in a SQL database.

In the development project of A1# office building in a Hangzhou high-tech park, this paper makes full use of the data resource management system platform in Vault and develops it into a data platform for BIM collaborative development and design. The specific process of BIM collaborative design can be roughly divided into the following five basic aspects:

1. The BIM collaboration method has been innovated, and the BIM collaboration model has been established using Vault’s database and information management platform.
2. Combined with the national standardized quality supervision and management system, it avoids the damage of management efficiency and fully improves the implementation of management functions. Management documents and archives must be filed through the Internet in time.
3. Vault + cloud technology realizes the design of Internet+, and realizes the submission of the overall architectural model of BIM.
4. Use parallel review of relevant data stored on Revit. At the same time, the staff can quickly carry out a workflow of level-by-level assessment through the classification of the assessment documents-real-time change management of the status.
5. Parallel file review on Vault. The software workflow of Vault review not only requires us to make full use of the technical advantages of various review software but also a set of continuous software review processes must be reasonably organized and designed in multiple software such as Revit and Navisworks, in order to truly achieve this parallelism.

2.3. BIM Pipeline Synthesis. Using BIM, the original two-dimensional graphic design drawings can be intuitively converted into a visual three-dimensional model for display on the Internet, which can directly optimize the comprehensive design and optimization of the structure of the electromechanical pipeline. In addition, the BIM technology used in this article also is able to realize the comprehensive design of the pipeline. This change directly provides the specific location and size of the space and holes reserved in the design of the electromechanical pipeline.

As shown in Figure 1, BIM technology can be used to analyze the clear height of the comprehensive arrangement of pipelines, and accurately calculate the vertical clear height of the building, so as to fully meet the functional requirements of the building.

Through BIM technology, we have carried out in-depth design for various types of building structural steel bars. By identifying and defining the characteristics and attributes of various types of steel bars, including data information such as types, diameters, and spacing of steel bars, various types of steel bars are identified in the building structure model. Carrying out three-dimensional positioning and shape display, so as to realize the three-dimensional visualization of the layout of the steel bars in the building structure, the collision detection between the steel bars of complex nodes,
and the accurate calculation of the blanking length of various types of steel bars were performed.

The in-depth analysis and design plan of the main reinforcement base of the project is to use a set of BIM design technology as the core reinforcement modeling design software Revit Structure, and use a BIM base reinforcement main structure design model drawing as the reinforcement design data carrier, and according to all, the steel bar design plan drawings provided by the author are designed for the deep analysis and design of the steel bar according to the longitudinal arrangement and distribution of the basic steel bar.

2.4. BIM Construction Drawing Output. By directly drawing the architectural drawings of various related disciplines through BIM technology, the information of the building can also be directly reflected in this model. BIM technology uses three-dimensional simulation modeling technology and parametric information technology to build a large database, and converts traditional drawings into data storage and extraction. In the whole process from the scheme design to the construction drawing design, the information of the building model will be continuously optimized and perfected. Through the output of these models to the construction drawing, it can save a lot of people’s time to draw the drawing.

In a high-tech park A1# building project, the three-dimensional model of the first floor building is shown in Figure 2.

3. High-Rise Building Structure Based on BIM Technology

3.1. Establish a Finite Element Model

3.1.1. Definition of Material and Section Properties. In this design project, there are detailed definitions for the material and section properties of the main body and its components of the steel structure, see Table 1 for details.

3.1.2. Import Revit Steel Structure Model into Midas Gen. First, the main model of steel structure needs to be built by using Revit in BIM, the structural modeling and design software as the design core. Two Revit and Midas Gen interface plug-ins need to be installed in the computer, respectively. After all the plug-ins are installed, open a Revit steel matrix structure model that has been automatically created, click the title menu in the structural modeling design software Revit, find send model to Midas Gen and click. Then, you can make some simple plug-in settings in the pop-up settings dialog box. Finally, Revit models of these steel structures can be smoothly imported into Midas gen, so this paper can carry out some finite element analysis on the models of these steel structures.

3.2. Load Type

3.2.1. Load Conditions. The stress load to be borne by the steel structure at the same time can be divided into four categories in detail, mainly including dead load, rain load, and wind load. The classification and structure size are introduced in detail as follows:

- Basic snow pressure s: 0.60 kn/ m2;
- Basic wind pressure L: 0.35 kn/m2.

3.2.2. Combination Condition of Static Load. The combination condition of static load is shown in Table 2.

3.3. Boundary Conditions. According to the structural requirements of the steel frame column foot in the design process of the steel structure, one part of the steel structure is regarded as rigid connection, and the other part adopts the articulated node algorithm, and each welded part is released and restrained one by one, thereby simulating the scene as the actual situation.

3.4. Response Spectrum Analysis. The algorithm of mode decomposition response spectrum is actually through the seismic acceleration design of the single-degree-of-freedom
4. Numerical Simulation of Civil Engineering

4.1. Topological Distribution of Particles in Stable Vector Field. In this paper, a topological layout method mainly used for streamlines has made some minor modifications to particle characteristics, and uses OpenCL to perform a parallelized layout acceleration. Compared with the implementation of a single-degree-of-freedom effect system, the seismic response spectrum and the principle of each order mode decomposition, according to the appropriate analysis combination calculation method to match the different modes of the different orders with each other, and carry out with the combination of seismic action effect analysis, the maximum seismic response value can be accurately predicted, and finally more seismic actions of the single-degree-of-freedom effect system can be calculated.

Usually, only the first several different modes have their main functions. Generally speaking, only the function combinations of 3 different modes need to be considered. The seismic class of the building construction site is Class II, and the seismic damping ratio of the structure is 0.02.

4.2. Topological Importance Analysis of Particle Multiframe Data. The topological structure of the particle is analyzed above, and the seed point of the particle is correctly set by referring to the topological structure model. For all time-varying topological data, each frame must have an experimental result of time-varying topology analysis to analyze the importance of the time-varying topology of different frames, whether it is a topological analysis of the entire time-varying field, or it is of vital strategic significance to guide the topological placement strategy of the entire time-varying field.

This paper extends the critical importance analysis technology of the article to the critical measurement of data topology information under the time-varying vector field. If a topological particle system is also counted according to this statistical model, however the joint probability of obtaining mutual information cannot be counted.

4.3. Feature Points of Topological Distribution of Particles in an Unstable Vector Field. For the three-dimensional unstable vector field, only similar calculation processing methods are used, and the calculation process is too complex. However, if you directly consider using particles with high convection occlusion and high quality tolerance, this complex problem can be quickly get an effective solution, as shown in Figure 4.

4.4. Interactive Placement. In addition to using automated calculations to ensure optimal placement and to ensure that the main features of the vector field are not missed as much as possible, this article also allows users to interactively add dots to their most interesting areas. The following is a detailed introduction to the interactive layout of several networks.

4.4.1. Body Layout Point. Body layout point refers to a point layout space that is like a cube. When realizing, pick the two-dimensional position P2D of a mouse, and then use the mouse wheel to adjust the depth desired by each user, and combine P2D with the depth reversely mapped to the three-dimensional coordinate P3D, and the keyboard is used to control the influence on the dotted cube. Finally, according to the coordinate area of this cube, a random point is generated according to the number of particles required.

4.4.2. Surface Layout Points. Sometimes users may need more detailed layout points, and surface layout points provide good distribution options. The specific operation is realized: the decision of the projection three-dimensional plane is a way of user interaction, using the control mouse and keyboard operations to determine the projection plane.

4.5. Analysis of Experimental Results of Interactive Placement. The following article shows a simple experimental result on the design of interactive dots. The experimental results will be introduced from two aspects: volumetric interactive dots and multipoint surface interactive dots.

Figure 5 shows the drawing effect comparison between the interactive method of body dot placement and the random dot placement method that does not use the method in this paper.

Source data: wind field data, specification: 66 × 66 × 66. The main parameters of the algorithm: number of particles: 8000, depth: 0.6, integration method: fourth-order Runge Kuta, integration step: 0.05. Result analysis: for a global random arrangement method as shown in Figure 5, the overall trend of the field can be grasped very well and accurately, but because of the occlusion problem, the details of the internal spiral structure cannot be seen well; using the volumetric interaction model in this article, it is possible for the user to arbitrarily select an area that one cares most about. Other places do not need to be placed, which clearly shows the spiral structure inside the field.
Figure 3: The layout template corresponding to different critical point types, improved by the streamline layout method.
5. Conclusion

The main research goal of this paper is to conduct a finite element analysis on the safety of high-rise buildings based on BIM. First, the basic definition of the raw materials and cross-section attribute models of the steel structure of high-rise buildings is carried out, and the attribute interface of the software design model is used to introduce this type of Revit steel structure model into the finite element analysis and calculation software Midas Gen to illustrate the main load measurement varieties and related load calculation and analysis methods and measurement standards. Then, through the finite element numerical calculation, the civil engineering simulation analysis of the internal member characteristics of the steel structure of the high-rise building was performed, and respectively, output the stress and deformation of the internal member of the steel structure of the high-rise building were analyzed. Then, the response spectrum analysis method is used to obtain the internal stress and displacement of the high-rise building steel structure under the action of strong seismic force. Finally, the results obtained by the above calculation methods are numerically analyzed according to the relevant international technical codes.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

