Research on the Application of BIM in Engineering Construction Management

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Abstract

This study introduces BIM technology to achieve integrated management of project lifecycle data through the construction of 3D building models, site layout simulation, schedule optimization, and bill of quantities compilation. Specifically, this technology can establish a collaborative platform for all project participants, strengthen construction risk pre-control capabilities, implement dynamic progress tracking, and accurately track fund flows for each construction section. With the help of the information platform, managers can simulate fund allocation paths in advance, covering the entire process management from project decision-making to completion and delivery, forming an integrated management and control system encompassing the "three controls and three managements" (quality, safety, progress control, and contract, information, cost management). Ultimately, it achieves the goals of refined, flexible, and visual project management while improving construction efficiency and management effectiveness. It provides practical references for refined project management, information collaboration and sharing, and visualization of the entire construction process.

Keywords

BIM technology; Construction project management; Integrated application

1. Introduction

This paper introduces a BIM platform. Before the implementation of the construction project, this platform was used to simulate the construction of the project. The three types of drawings—floor plans, elevations, and sections—are integrated and modeled within the BIM environment for display, facilitating communication among relevant management personnel and allowing for early adjustment and optimization of the scheme. Simultaneously, it enables the pre-simulation of construction site layout and construction organization arrangements, eliminating doubts about the existing plan and significantly reducing capital and resource investment in the early stages of the project. Through the BIM platform, relevant documents involved in the construction management department for the Haibao Lun case, such as models, measures, site layouts, prepared schedule documents, and bill of quantities documents, can be organized. The Haibao Lun case is divided into work sections, completing the association between the model, project schedule, and cost before project implementation, clarifying resource and capital flows before project execution, and outputting the construction schedule. Virtual implementation can be carried out in aspects such as schedule execution, cost flow, data sharing, technology application, quality and safety management, construction organization design review and briefing, and construction scheme optimization. This achieves data sharing across various areas, simulates and displays virtual scenarios, and addresses potential problems and obstacles that may arise during the simulated project implementation process, from the earthworks stage to the final acceptance stage.

2. Domestic and International Research Trends

2.1. BIM Research Trends Abroad

The origin of BIM technology is the United States, where Chuck Eastman first proposed the BIM system, after which numerous scholars began researching related concepts. Over time, the advantages of BIM technology gradually became apparent, its development trend became increasingly clear, and many people realized that this technology would profoundly change the industry landscape. Consequently, BIM technology became widely popularized [1]. However, during the popularization process, it was discovered that BIM technology has certain limitations in its application, and the problems it can solve are relatively singular. In view of this, abroad began to reflect, recognizing that during project construction, BIM technology should not only focus on solving single problems. Thus, foreign scholars attempted to use BIM technology to comprehensively solve various problems in building construction projects [2]. Some beneficiaries of BIM technology even envisioned whether the technology could be extended to various departments, allowing project implementers to establish close connections with implementation areas, breaking the traditional situation of each acting independently in construction projects [3]. Currently, how to use BIM technology to achieve effective correlation between project managers and various construction areas has become the research direction for most people [4]. This shows that research in the BIM field abroad has gradually extended from initial singular exploration to the level of information-based communication and exchange. Specifically, foreign BIM technology further comprehensively utilizes resources such as manpower, finances, and machinery based on solving problems in the dimensions of time, space, and engineering quantity, building a unified BIM system integration system and model [5].

2.2. BIM Research Trends in China

China was relatively late in coming into contact with BIM technology, and its research and development started later. Since first encountering BIM technology in 2003, the management model of the domestic construction industry has gradually shifted from traditional extensive management to refined management to adapt to the information-based patterns and more refined management methods brought by BIM technology[6]. In this process, China gradually realized that BIM technology has broad development prospects in the future construction industry. Therefore, China began to vigorously promote and support the research and development of BIM technology. Some universities, construction units, and design units in the construction field that value the potential of BIM technology have established research institutions. However, there are currently not many research teams that truly master the core technology of BIM[7]. To achieve breakthroughs in key technologies, domestic research teams have shifted BIM technology from theoretical research to practical application, closely integrating it with project implementation, and identifying technical shortcomings through practice[8]. As research deepens, this technology has gradually matured and begun to spread to other fields such as bridges and civil engineering[9]. For example, case studies of projects like Hanyu Financial Business Center, Guangdong East Tower, and Shanghai Longhua Project show that BIM technology has brought huge benefits, but there are also some problems that are difficult to solve quickly[10]. Nevertheless, the changes brought about by BIM technology are significant, which have further strengthened the domestic team's determination to research BIM technology [11]. Discussions about the value of BIM technology have never ceased, and people can't help but wonder what level could be achieved and how great its potential is if the technology is further enhanced. Currently, China is further exploring and improving the concept of BIM [12].

3. BIM Project Construction Management Application Case

3.1. Project Overview

The building to be drawn in this project is a business premises for a certain religious group, located in Linfen City, Shanxi Province. The building structure form is a frame structure. In terms of usage nature, the building is a comprehensive building for charitable relief premises, exhibition halls, archives, etc. The total construction area is 9159.68m^2, with one underground floor and 9 above-ground floors, and a building height of 42.65m. The first above-ground floor of the building contains a lobby, reception room, charitable relief rooms, etc. The second above-ground floor is a patriotic education exhibition hall. The third to eighth floors are rooms for religious culture display rooms, religious affairs guidance department, library, editorial department, etc. The ninth floor is the archives room. (Figure 1)

Figure 1. Application Display in the Operation and Maintenance Phase

3.2. Reading and Understanding Drawings

From the drawings, it can be determined that the building height of this business complex is 35.90m, and the height difference between indoors and outdoors is 0.450m. During structural construction, it should be coordinated with other professional drawings such as architecture, plumbing, HVAC, and electrical power.

3.2.1. Establishment of Elevations and Grid Lines

After roughly understanding the drawing content, we began creating the Building Information Model.

The first step in starting the architecture is to determine the Project North. Project North is based on the main axis of the building's geometric shape, set by the designer for convenience according to the building's orientation. True North is the real-world north direction based on the site conditions. If the building project needs modification, the properties need to be changed from Project North to True North. Then, find the 'Location' option in the 'Manage Project' to rotate the building, and change the property from True North back to Project North. In the drawings for this project, it is not specified whether there is a deviation between Project North and True North, so we default to True North as Project North.

According to the drawing information, this project has one underground floor and nine above-ground floors. The underground floor height is 4.800m, the first-floor height is 4.300m, and the second to ninth floors are all 3.900m. Moreover, the roof of the ninth floor is the equipment room plan level. The roof level height of the equipment room is 6.350m. Therefore, the actual total height of the project is 41.800m. We use Revit software to create a blank structural project and adjust the view to the south elevation. The south elevation of the blank project has two system-set elevations. Using the Level function, we establish levels based on the data provided in the drawings.

After completing the level drawing, select the floor plan F1 and establish the corresponding grid lines. To make the grid lines as accurate as possible, we will import CAD drawings. First, set the filter for this plane. Select the site project in the architectural filter, set the project base point to visible, and create coordinate axes on the plane. To make the project drawing more accurate, we need to import the split drawings, set the drawing to be visible only in the current view, set the import units to millimeters by default, and use the 'Origin to Origin' positioning method to import the drawing.

After completion, the grid lines are shown in Figure 2. The creation of grid lines for other floors can refer to the above.

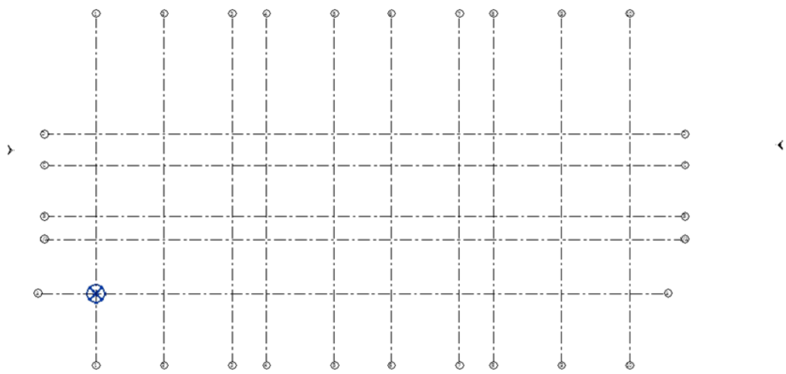

Figure 2. F1 Floor Grid Lines

3.2.2. Establishment of Columns, Beams, and Slabs

After completing the grid lines, the creation of the structural model's columns, beams, and slabs will proceed. This project uses a frame structure. The advantages of using a frame structure include: after the concrete frame is cast in situ, the overall structure has strong rigidity; with reasonable design, it can ensure good seismic capacity, and it can complete the casting of various special-shaped beams or columns; under the frame structure, components such as beams and columns are easy to standardize, facilitating erection and effectively shortening the construction period; frame buildings can flexibly partition space, have relatively light self-weight, and are widely used in building structures requiring large spaces.

Most of the structural columns are rectangular concrete columns. Their size is largest at the bottom floor and decreases on higher floors. When drawing, simply follow the elevations and dimensions given in the drawings. According to the drawings, there are four types of columns: 500500, 800800, 700700, and 600700. Draw the structural columns based on the pre-imported CAD drawings.

In the structural project, select Structural Column. For example, to create a 500500 structural column, select Column - Structural Column, copy the structural column family provided in the project, rename it to Structural Column - 500500, modify the size according to the given drawings, set the material to Religious Building - Reinforced Concrete, and save the project. For special-shaped columns with different cross-sections, they can be drawn using the Family Editor. Similarly, complete rectangular structural columns of other sizes. The columns on the first floor are shown in Figure 3.

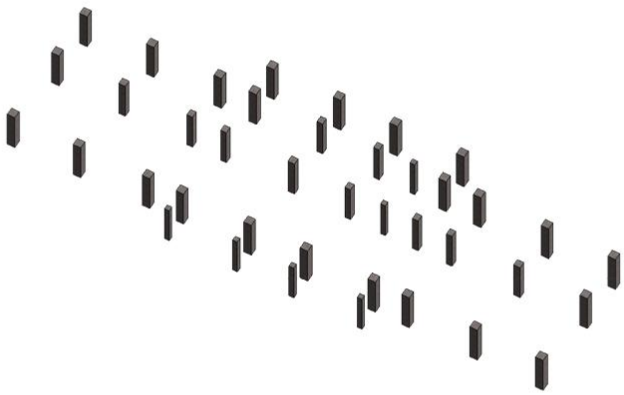

Figure 3. Distribution of Structural Columns on the First Floor Plan

After completing the structural columns, begin placing beams according to the drawings. In this project, the structural framing only includes rectangular concrete beams. Find the family for concrete rectangular beams in the family library, import it into the structural model, change the dimensions, and draw according to the drawings. As shown in Figure 4.

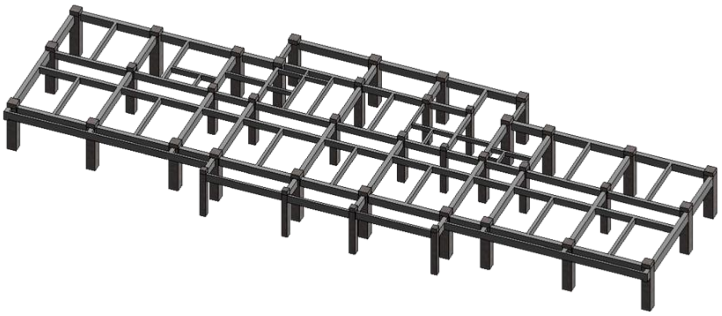

Figure 4. 3D View of First Floor Beams and Columns

After building the basic beam and column framework, draw the slabs in the structural framing. According to the structural drawings, the default slab elevation is -0.050m. Additionally, there are two types of slabs with different elevations in this project: the bathroom slab top elevation is -0.090m, and the fire control room slab elevation is -0.055m. Furthermore, when drawing the slabs, reserved openings need to be created according to the drawings, such as stairwells for stairs on each floor, pipe shafts for plumbing, and other vertical pipes. Post-chopping is strictly prohibited. As shown in Figure 5. Reserved openings for stairwells and reserved openings for pipe shafts.

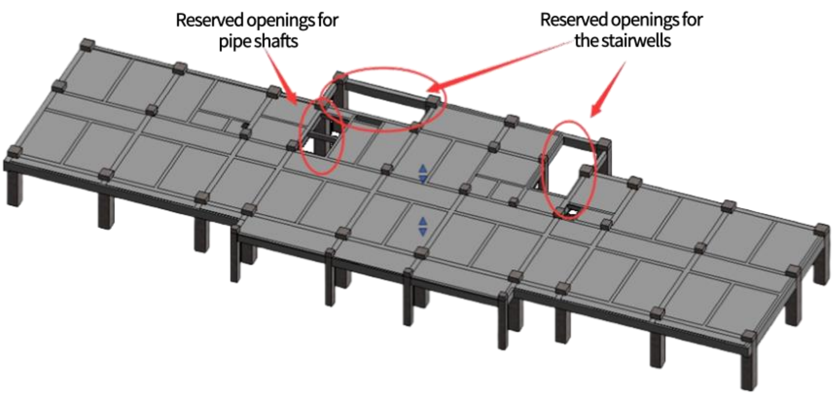

Figure 5. Stair Reserved Opening

After completing the drawing of columns, beams, and slabs, the establishment of the project's structural model is complete. As shown in Figure 6.

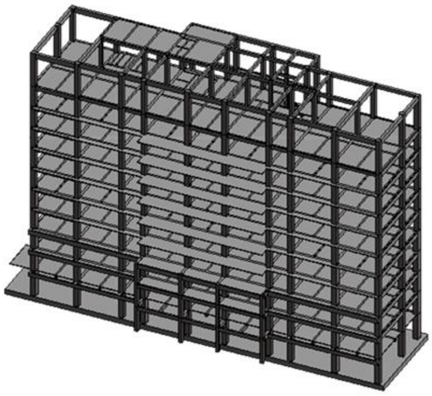

Figure 6. Structural Model

3.3. Establishment of the Architectural Model

The architectural model allows the designer to get a general idea of what the completed project will look like and is the foundation and main body of the Building Information Model. This chapter will describe the general process of creating the architectural model, allowing us to further understand the structural details of this model.

3.3.1. Establishment of Walls and Floors

Architectural walls are generally divided into exterior walls and interior walls. Here, we take the basic wall of metric 200 as an example. Go to Architecture - Wall, select Basic Wall - 200, copy this wall family, rename it to Religious Building - 200, modify the structure, and add materials to set the core layer according to the design drawings. Due to limitations of the family library, new material items need to be created as required. When drawing walls, you can use the pre-imported CAD drawing as an underlay for tracing. Compared to drawing directly on the grid lines, this method is more efficient. Combine the above steps to draw walls of other thicknesses.

Draw floors by editing parameters according to the values given in the drawings. The operation method is similar to editing walls. When selecting the drawing range, because the core layer has two boundaries, it defaults to picking the core boundary closer to the outdoor side. If you need to switch to the core layer boundary closer to the indoor side of the wall, you can press the spacebar after selecting the contour boundary line to switch positions. The contour boundary must be a closed loop. There must be no intersections or overlaps; otherwise, the floor cannot be created. Use tools like Trim/Extend to Corner to modify. Details are shown in Figure 7.

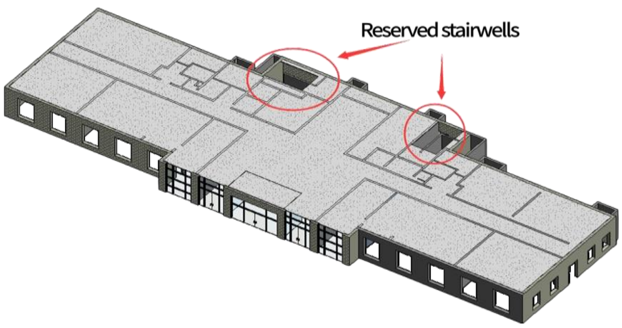

Figure 7. Architectural Walls and Floors

3.3.2. After completing the wall drawing, doors and windows can be added to the already drawn walls.

In Revit software, we need to create many door and window families of different sizes and materials. We can utilize Revit's extensibility by using software like " Component Dock " or " Family Library Master " in conjunction with Revit's built-in family library to create custom families.

The door and window families that need to be created for this project include: Wooden Fire Door, Solid Wood Composite Door, Glass Swinging Door, Glass Sliding Door Curtain Window, Glass Out-Swinging Window, Single Frame Glass Swinging Window, Single Frame Glass Sliding Window, Aluminum Alloy Full Louvre Window, etc. Examples of size diagrams and instances for some families are shown in Figure 8.

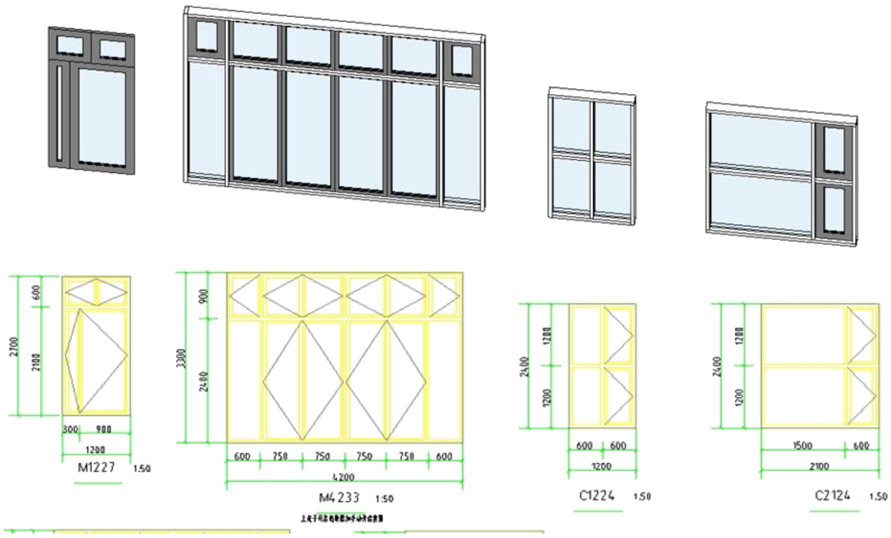

Figure 8. Comparison of Some Door Legends and Instances

3.3.3. Glass Curtain Wall

Glass curtain walls use frame support. Under a double-layer structure, injecting inert gas in the middle provides good thermal insulation. They are widely used in various buildings.

This project has four types of curtain walls. The creation of glass curtain walls is slightly different from walls. Select Curtain Wall under Architecture - Wall, draw the curtain wall according to the dimensions, switch views, and modify the curtain wall size. At this point, the curtain wall drawing is not yet finished. Door and window families from the Architecture tab cannot be directly added to the curtain wall, so curtain grids need to be added to the drawn curtain wall. Curtain grids essentially divide the drawn entire curtain wall into small parts, facilitating later module replacement. After dividing the curtain grid, we need to add mullions, remove excess mullions and replace appropriate panels using Tab.

In this project, according to the drawings, each curtain wall needs to have its grid drawn. Based on the given dimensions, draw the curtain grid. Curtain grids can only be drawn completely in vertical and horizontal directions and cannot be terminated midway. Therefore, after drawing is complete, use the "Delete Line" function to remove unneeded parts. Add aluminum mullions, select the drawn mullions, and modify the connections at the ends. Place the mouse on the boundary of the module to be selected, use the "TAB" key to select the panel, and replace it with the required panel. As shown in Figure 9.

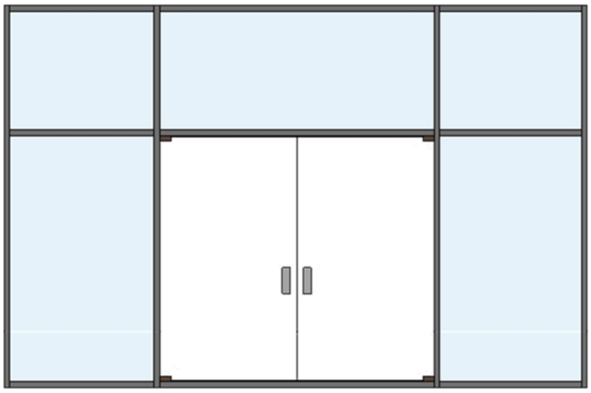

Figure 9. Glass Curtain Wall

3.3.4. Creating Stairs

There are two sets of stairs and two elevators in this project. Here, we mainly explain the drawing of stairs.

According to the drawings, both stairs in this project are two-run stairs from -1 to 9 floors. Because the floor heights of -1F and 1F are different from those of 2F to 9F, the number of steps will differ. When creating the floors, the openings for the two stair sections in the project have already been reserved. Use the Stair function under the Architecture tab, create reference planes according to the given dimensions, define the stair rise direction, and ensure the continuity of the handrail. After completion, it is shown in Figure 10.

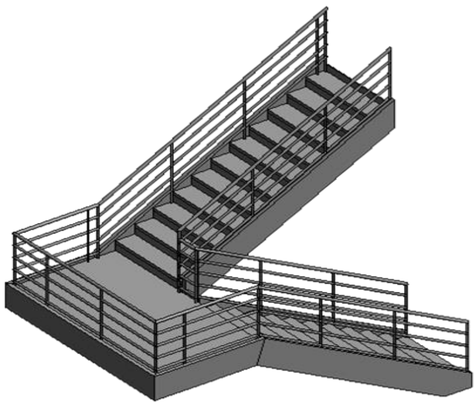

Figure 10. Partial 3D View of Stairs

3.3.5. Creating Ramps

After establishing the levels, there is a 0.45m height difference between F1 and the outdoor elevation. According to the drawings, create curved vehicle ramps at both ends of the outdoor platform and an accessible pedestrian ramp.

Open the 3D view, activate the Ramp command, use the draw arc tool, and draw the ramp according to the given dimensions. When drawing the ramp, set the ramp width, use the arc tool to determine the start and end positions of the ramp segment, define the slope direction, and complete the drawing. After drawing one segment, use the mirror command to complete it.

Set an accessible ramp on the right side of the entrance. We can draw this accessible ramp using the method described above, or we can select a similar component from external family libraries like " Component Dock " for placement. This method is relatively simpler. After completion, it is shown in Figure 11.

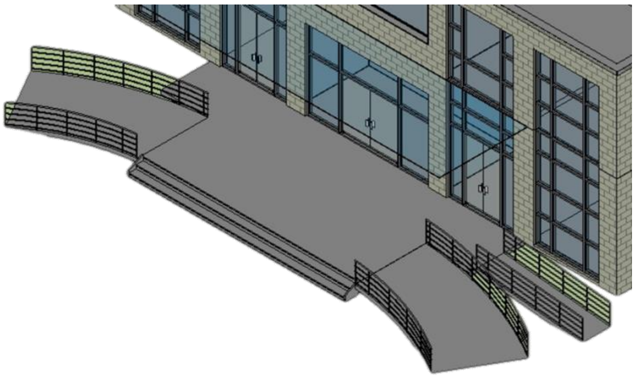

Figure 11. 3D View of Outdoor Ramp and Accessible Ramp

After completing each part, the architectural model is shown in Figure 12.

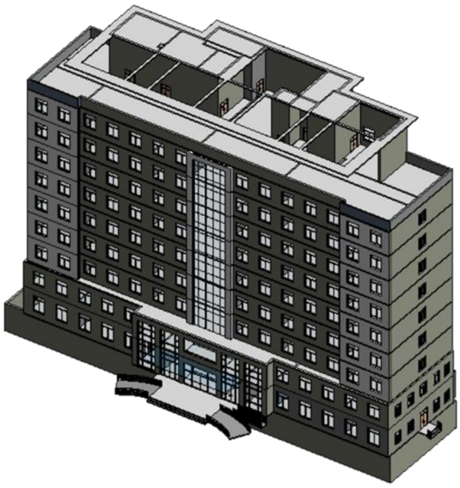

Figure 12. Architectural Model Display

4. BIM Construction Technology

4.1. Impact Analysis of BIM Construction Technology

4.1.1. Design Phase Optimization

BIM technology allows designers to collaborate in real-time on the same platform, avoiding compatibility issues between different software in traditional design. Through BIM's parametric modeling and structured design, designers can more accurately integrate and correct building structures, reduce design errors, and improve design efficiency.

BIM technology can help designers present their design ideas more intuitively. Through the building model, designers can experience the feeling of the architectural space, predict potential problems, and make timely adjustments.

Optimize functional zoning and space planning: In the Haibao Lun design, BIM technology can optimize functional zoning and rationally plan spatial layout. Through simulation and analysis, designers can ensure the functional requirements of each area are met while improving space utilization.

4.1.2. Refined Management in the Construction Phase

BIM technology can provide precise construction drawings and construction simulations, helping construction personnel better understand and execute the design. Through the BIM model, construction personnel can clearly see various parts and details of the building, reducing misunderstandings and errors during the construction process.

BIM technology can help construction personnel better plan the construction process and optimize resource allocation. Through simulation and analysis, construction personnel can identify potential problems and risks in advance and take corresponding measures for prevention. Meanwhile, BIM technology can also provide real-time construction progress and cost control information, helping managers better monitor and manage the construction process.

During the construction process of Haibao Lun, BIM technology can use functions like clash detection to identify and resolve conflicts in design or construction in advance. This can reduce pipeline collisions and rework on site, improving the overall efficiency of construction.

4.1.3. Intelligent Management in the Operation and Maintenance Phase

BIM technology can serve as a comprehensive management platform, integrating operational data from various systems of Haibao Lun. By monitoring and analyzing in real-time the status and performance of building equipment, managers can promptly identify problems and take corresponding measures for maintenance and optimization.

Improve operational efficiency and safety: BIM technology can help managers better understand the operational status of Haibao Lun, improving operational efficiency. Meanwhile, through simulation and analysis, managers can predict potential safety risks and take corresponding preventive measures, thereby enhancing the safety of Haibao Lun.

4.2. Case Application and Effect Analysis

4.2.1. Preliminary Planning and Design of the Model

After the cut-off wall is completed, and to benefit construction, dewatering wells should be set up before excavation. The dewatering wells should preferably be located at the four corners of the perimeter. The depth of the dewatering wells should exceed the building base slab and not be less than 1 meter. Relevant design parameters can be seen in Table 1 below:

Table 1. Parameter Table.

Parameter / Stratum	Shear strength index (consolidation fast shear)		Between soil and anchor bodyStandard value of ultimate frictional resistance qsik(KPa)	permeability coefficientK (cm/sec)
	Internal friction angle φ (degrees)	cohesion C(KPa)		
The first layer of miscellaneous fill soil	10.0	8.0	15	6.0×10-4
Layer 2 clay	21.7	64.9	60	3.0×10-5
Layer ③: Fine sand	26.0	/	40	3.0×10-3
Layer ④ round gravel	35.0	/	130	5.0×10-2
Layer ⑤ strongly weathered argillaceous sandstone	40 (similar to internal friction angle)	/	150	2.0×10-5

4.2.2. Establishment of the Deep Excavation 3D Model

The modeling process was completed using AutoDesk Revit software. The specific process is as follows:

(1) Create a new architectural project. First, draw the project's levels and grid lines. Levels are a very important part of the project composition. The first step is to set the building's floor heights. If levels need to be modified, the associated components will stretch or compress

vertically accordingly. Grid lines and levels together form a 3D space. Once levels and grid lines are determined, try not to change them. The drawing is shown in Figure 13:

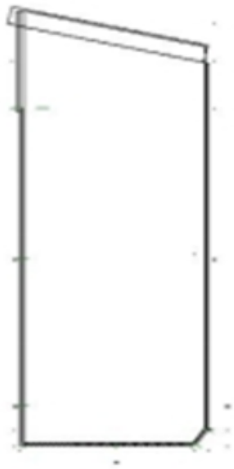

Figure 13. Deep Excavation Levels and Grid Lines

Set the project's actual geographical location. Build an architectural template, switch to the "Manage" tab, find the "Project Location" panel, click the "Location" button. After the edit box opens, select "Default City List" for 'Define location by', then enter the corresponding latitude and longitude (Latitude: 39.12, Longitude: 117.20), and finally click OK. This determines the project's geographical location by entering latitude and longitude.

(2) Use placed points to form the topography. First, open the architectural file, switch to the "Massing & Site" tab in the Revit project functional ribbon, find the "Site Modeling" options, then click the "Toposurface" button. Now, select "Place Point" on the toolbar, place points at various locations, modify the corresponding elevations, and click Finish. Now the entire topography is complete, and you can switch to the 3D view to see the effect.

(3) Creation of slope protection. Slope protection is generally created in elevation or section views, and the parameter settings are relatively simple. Pay attention to the top level and top offset settings, otherwise the slope might be too long. Generally, choose In-Place Model to create slope protection. Click "Model In-Place" under the "Component" tab. As shown in Figure 14.

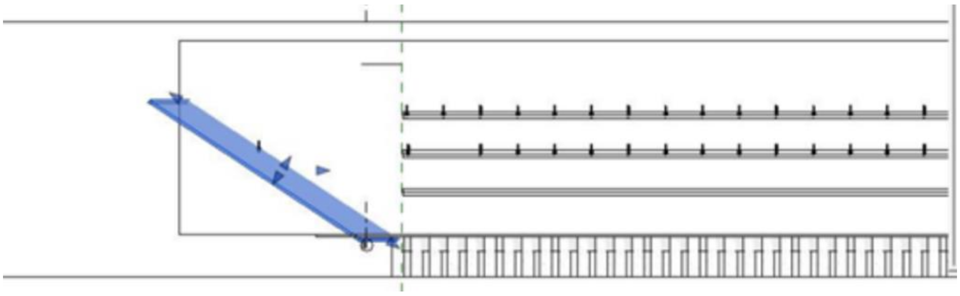

Figure 14. Establishment of Deep Excavation Slope Protection

Finally, the established Revit model for the Haibao Lun Center Station deep excavation is shown in Figure 15.

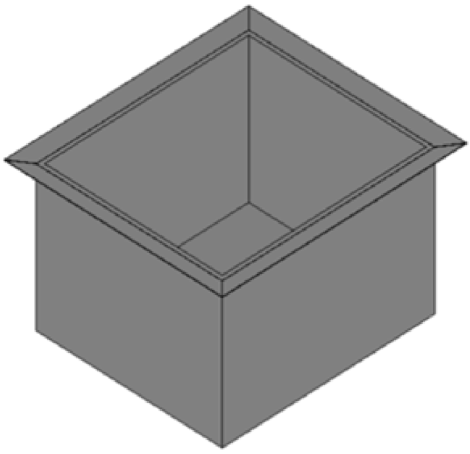

Figure 15. Deep Excavation 3D Model

4.2.3. Conducting Clash Detection Using Navisworks Software in BIM Technology

Import the Revit model into Navisworks and use the Clash Detective function to directly obtain the check results, as shown in Figure 16. Click on each corresponding clash point in the model, and the results will be displayed in the edit box on the right. The clash detection will finally identify components with problems or defects in their corresponding positions.

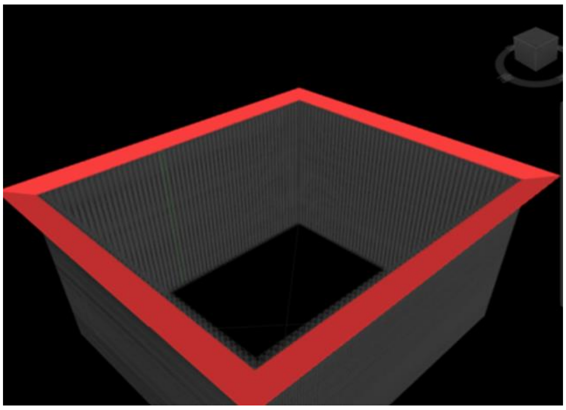

Figure 16. Clash Detection Diagram

By performing clash detection on the early-stage structural 3D model of this project, the results show a total of 447 clash points, among which 446 are new points and 1 is an active point. This proves that there were defects in the components of the early-stage structure. Analysis suggests it might be due to the high water content of the engineering soil, causing lateral displacement of some structural components. The slope cannot effectively slow down the damage to the components. Once the construction time prolongs, this structure could become a major hidden danger for the project, potentially leading to structural collapse, accidents, and significant personnel or property losses.

5. Conclusion

Taking the Haibao Lun case as an example, using BIM modeling technology to pre-construct the project allows for the early discovery of problems in the drawing information and the pre-formulation of optimization plans. Regarding construction site layout, rehearsing the site layout plan in advance based on the actual engineering situation, while explaining safety points of construction operations to employees, solved the hindrance of site layout issues to the smooth progress of the project. Through BIM technology, the project to be implemented can be associated with site-related documents, virtual construction animations can be created in advance to achieve project visualization, ensuring effective coordination and communication among project participants. Project components can be inspected in advance, strengthening the connection between all parties and reducing contradictions and conflicts.

In the application of BIM technology, each floor area of the Haibao Lun case was divided into work sections with the same workload and associated with costs. This enables the project team to understand the consumption of manpower, materials, and machinery in each area more clearly, gain early understanding of cost management and schedule planning, and facilitates the management of fund flows for each work section area. Faced with modifications to the planned scheme, the construction party can synchronize information immediately, automatically adjust fund changes within the area, quickly formulate optimal plans, improve flexibility and responsiveness during the construction process, reduce time, and enhance construction efficiency.

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