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Application and Research of BIM Technology in the Construction of Ningbo International Conference Center

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Abstract: The Ningbo International Conference Center Project incorporates elements of Chinese traditional culture into its architectural style, resulting in the world’s first cantilever bridge international conference center. During the construction process, it faced challenges such as complex engineering geological environments and diverse architectural styles. By harnessing building information modeling (BIM) technology, many challenges encompassing intricate environmental conditions, architectural structures, and construction complexities are effectively visualized in three dimensions, thereby offering viable solutions for engineering implementation. In the scheme design stage, BIM technology plays a pivotal role in bridging the gap between design and construction, optimizing engineering pile and wall material designs. During the deepening design stage, BIM aids in refining designs through intricate node optimization for the ultralong comb type inclined water panel curtain wall and glued wood column decoration, thereby enhancing construction efficiency. Additionally, BIM technology has also played an important role in the simulation and scheme analysis of the entire construction process of complex steel structures. Through the implementation of BIM technology, numerous challenges encountered during the construction phase of the Ningbo International Conference Center project have been effectively resolved, which serves as a valuable reference for employing BIM technology in large-scale international conference center projects.

Keywords: Ningbo International Conference Center; complex engineering geological environment; BIM technology; intricate node optimization; scheme analysis

1. Introduction

In the engineering procurement construction (EPC) general contracting mode, the construction unit, as the owner, will contract the construction project to the general contractor, and the general contractor will undertake the design, procurement, and construction of the entire construction project, and be fully responsible for the quality, safety, duration, and cost of the contracted construction project. Finally, a construction project contracting mode that complies with the contract agreement, satisfies the intended function, meets the usage conditions, and passes the completion acceptance is submitted to the construction unit. Integrating BIM technology into EPC project management and utilizing the advantages of BIM in 3D visualization and collaborative management in the design and construction stages is a problem that many construction enterprises have been exploring for a long time. Various construction enterprises have been trying to integrate BIM technology into project construction management and have accumulated much experience [1,2].

BIM technology has multiple application scenarios in the design phase. Xu et al. [3] presented the implementation of BIM management and BIM technology in the renovation project of Changyuan Village, located in Nanshan District, utilizing the BIM5D platform.
Wu et al. [4] conducted comprehensive research and exploration in the engineering design calculation, model assembly, result integration, data sharing technology and other aspects, summarized the application process and technical experience, and opened a technical channel for the joint application of BIM in the survey and design of water transport engineering. Li et al. [5] introduced the collaborative design and management of BIM technology in the whole life cycle of a China Resources super high-rise project. Nguyen et al. [6] introduced a novel approach involving the integration of the design for manufacturing and assembly (DfMA) principles and parametric building information modeling (BIM) to develop a preassembly analysis system (PAS), which enables enhanced information exchange and reduces onsite assembly errors during prefabricated bridge construction.

The above research studies focus on the design phase, while BIM technology also plays an important role in the construction phase, including deepening design. Xu et al. [7] used BIM technology to carry out forward deepening design on the plain concrete formwork, innovatively designed a height-adjustable bottom support device for the large plain concrete formwork and a decorative plain wall external scaffolding tie device, and achieved good construction results. Zhang et al. [8] proposed a method and process for combining high-precision 3D scanning with BIM technology to monitor the unloading process at large sports stadiums and verified its scientific validity and reliability in practical applications. From the perspective of the reuse of steel structure components, Yang et al. [9] proposed a BIM-based dismantling scheme and evaluation method for steel structure components and applied BIM information query technology to obtain and search for component information in the dismantling scheme, realizing the integration of dismantling information and the automatic export of reuse component list. Tong et al. [10] proposed an innovative method for the design and construction of a large-span profiled hyperbolic steel string-grid structure and integrated BIM technology into the construction process. Wu et al. [11] applied BIM technology to model the structure and formwork system of large-span irregular hyperbolic thin shell plain concrete structures, deepened the design, and optimized the layout of the formwork and keel, achieving good results. Zhang et al. [12] summarized the application process and corresponding data collection and processing methods of combining 3D scanning with BIM technology. By establishing a BIM model and scanning, processing the data obtained from 3D scanning, and analyzing the deviation between the BIM model and 3D scanning, the application ideas of 3D scanning technology in construction were obtained. The combination of the two technologies can better control the quality of construction projects. Zhang et al. [13] introduced digital technology, with project safety, quality, environment, and progress as the core drivers, to build a smart command center platform that integrates project management, safety and quality monitoring, video monitoring, personnel attendance monitoring, material and equipment monitoring, environmental monitoring, and BIM lightweight models, to carry out digital construction site planning, promote orderly construction site management, and improve construction efficiency.

The aforementioned studies have introduced the application of BIM technology in various aspects, such as design, construction management, and quality control [14–16]. However, the utilization of these BIM technologies is limited to a single link in the construction process, with few cases where it has been implemented throughout the entire project’s construction process. Particularly for large complex projects that involve scheme design, deepening design, and construction phases [17]; not only does this require repeated communication and coordination among all parties involved, but it also involves a changeable building environment with diverse structural forms and complex node designs [18,19]. The EPC mode provides the possibility of a linkage between the design and construction. By utilizing BIM technology effectively, there can be a significant increase in construction efficiency for such projects.

The Ningbo International Conference Center project is a construction endeavor of immense magnitude, the total construction area is 406,200 square meters. The building incorporates nine elements of traditional Chinese architecture, including pavilions,
platforms, towers, verandahs, boats, corridors, and bridges, and stands as the world’s first corridor bridge international conference center with a complex construction environment and challenging construction process. This paper takes the Ningbo International Conference Center project as an example to introduce the application of BIM technology in the entire process of large-scale conference and exhibition construction, and studies and discusses the application scenarios and advantages of BIM in large-scale EPC projects. On the basis of EPC mode, BIM technology can be applied more deeply and run through the design and construction stages. By establishing a three-dimensional model, extracting model data, and identifying drawing problems as early as possible, designing and construction can be discussed together to optimize design drawings, achieve cost savings, shorten construction periods, and improve the quality and efficiency of engineering construction. In the scheme design stage, BIM technology is utilized to establish the pile foundation model in the construction drawing design phase. The BIM model serves as a carrier for conducting symposiums among various stakeholders including linkage design, procurement, and construction parties to clarify the optimal pile foundation scheme. During the construction stage, integration of weathered rock and engineering pile models through BIM technology assists in determining the appropriate depth of engineering piles to ensure high-quality construction of foundations. Furthermore, BIM simulation technology is employed to simulate the entire process of complex steel structure engineering construction, analyze potential challenges during construction, and optimize deployment strategies. In the decoration deepening stage, BIM is used to enhance efficiency by optimizing complex nodes within ultra-long comb-type inclined water panel curtain walls and glued wood column decorations. These research findings can be widely applied throughout all stages of construction using BIM technology with significant implications for improving project quality.

2. General Situation

The Ningbo International Convention Center is aimed to be a modern international convention center with “international first-class standard and rich charm of Jiangnan of China.” The project consists of four units, namely a multi-function hall, main venue, summit hall, and hotel, with a land area of 22.7204 ha and a contract value of 4.2 billion yuan. The project adopts the general contracting mode of integrated EPC engineering for housing construction, electromechanical engineering, municipal engineering, and landscape engineering. It relies on BIM technology for on-site digital control to achieve the purpose of efficient construction and perfect performance.

The total construction area of the project is 406,200 m², of which the total capacity area is 311,700 m² (excluding the landscape tower), the landscape green area is about 476,300 m², including a roof garden area of about 30,200 m², the building and square pavement area of about 63,300 m², and the ground does not count the construction area of 84,870 m². It includes an L1-level urban transportation channel, a public construction ground floor elevated level, underground 29,960 m² from south to north consisting of the hotel, summit area, main venue, and multi-function hall in four areas. The multi-function hall and the summit area have two basements, the main venue has a single basement, and the hotel is structured as an overhead structure. Each monomer is connected in the form of a double-deck corridor bridge on the west side, with a total length of about 1300 m from north to south and a width of about 140 m from east to west, as shown in Figure 1.
The main venue contains several large exhibition halls, of which the largest exhibition hall covers an area of 5500 m², 77 m long, 68 m wide and 11 m high. The first floor of the multi-function hall is mainly composed of an exhibition hall, a hall, and other functional rooms. The net area of the first-floor exhibition hall is 6605 m², the height is 6 m, and there are 280 booths. The second-floor exhibition hall is 163.8 m long and 67.65 m wide, with a net area of 10,850 m², a net height of 14 m, and 476 booths. The summit district covers a total area of 17,100 m² and consists of four major venues. The press conference hall on the first floor covers an area of 2510 m², the summit banquet hall on the first floor covers an area of 2170 m², the summit meeting hall on the second floor covers an area of 2675 m², and the summit photo hall on the second floor covers an area of 1271 square meters. The hotel has a total indoor area of 42,300 m², a hardcover area of about 37,900 m², of which the public area is 13,700 m², a room area of 19,800 m², and a room walkway of 40,400 m². The hotel has a total of six floors, each unit is shown in Figure 2.

The steel structure consists of a steel truss roof, steel eaves, and a steel gallery bridge. The steel truss adopts plane and three-dimensional trusses, of which the maximum span of the summit area truss is 45 m, the maximum span of the main venue and multi-function hall truss is 72 m, the maximum weight of a single truss is about 320 t, and the maximum span of the corridor bridge is 36 m. The components are mainly box-type and H-type components, and the material is Q420.
The project adopts pile cap foundation and frame structure. The pile foundation is a bored pile, the pile diameter is 800 mm, the deepest pile foundation is 80 m, and all the piles are inserted into the weathered rock layer of 1 m. The spacing of the frame column network is $9 \times 9 \text{ m}^2$ and $18 \times 18 \text{ m}^2$, as shown in Figure 3.

Figure 3. Pile foundation of Ningbo International Convention Center.

3. Research Content and Methods

After years of development, the scope and depth of BIM technology have become relatively mature in both the design and construction stages. However, there are still obstacles that cannot be integrated. BIM in the design stage has not fully considered the needs of the construction stage, and construction has not been able to better undertake the design stage model. It is difficult to further deepen the application of BIM based on the design model. This is currently the pain point and difficulty in the application of BIM in the design and construction stages. To better solve this pain point and difficulty, we are based on the Ningbo International Conference Center project, integrating BIM technology throughout the design and construction stages by establishing a three-dimensional model, extracting model data, identifying drawing problems as early as possible, conducting design and construction linkage discussions, optimizing design drawings, and achieving the goal of cost savings, shortening construction periods, and improving project quality and efficiency.

In EPC projects, achieving integrated whole-process management of design and procurement necessitates the use of BIM technology. This technology should be employed to manage the entire process of project design, procurement, construction, and completion. When managing project design, it is crucial to focus on the rationality of the design content and identify any areas that can be optimized. This enhances the overall quality of the design content and ensures that the design leads the entire project towards its goals. In terms of procurement management, decisions should be based on the design foundation, selecting high-quality and reasonably priced materials. Over-investment in procurement should be avoided, as precise cost control is a key aspect of quality control. Taking comprehensive management during the construction process as an example, management should cover safety, site division, construction progress, EPC project progress, and construction quality. During actual management, BIM simulations of the construction site’s real conditions should be conducted, and various construction phases should be reasonably arranged. This enhances construction efficiency while ensuring the safety of the construction personnel, thereby preventing conflicts and safety issues that could affect construction quality.

The application of BIM technology should span the entire project, necessitating the formation of a high-quality BIM technical team to strengthen design and construction optimization, ensuring the smooth progress of EPC projects. BIM technology can utilize its expertise in construction design and quality control to resolve errors and omissions in 2D design drawings. The integration of 3D technology enhances the drawings’ guidance capability for the construction process. It addresses improper parameter selections in design, adjusting them to enhance construction quality and efficiency while avoiding overdesign, thus improving the economic benefits for the client. In practical application, BIM technology resolves errors and omissions in complex design content such as structure and
MEP (mechanical, electrical, and plumbing), aligning the design content with practical requirements and avoiding discrepancies between construction costs and design plans at the completion stage. This fosters quick and efficient coordination solutions.

Regarding construction quality control, BIM models should be reviewed to ensure their design meets construction requirements, preventing issues from arising. Important construction content should be checked to avoid clashes between civil engineering and MEP systems, thereby improving construction quality and reducing the likelihood of rework. Moreover, as models serve as critical carriers of building information data, dedicated personnel should manage them. First, manage model precision, from the LOD200 model during the preliminary design phase to the LOD400 model during the construction drawing development phase. As project construction progresses, model precision should be continuously refined and perfected to match the physical building perfectly, facilitating the operational phase later. Second, manage model applications, considering the building industry's characteristics of multiple specialized trades and significant technical barriers between them. The initial trades must fully consider the needs of subsequent operations to ensure seamless coordination between processes. Through 3D models, we can visually display the conditions required for preceding and subsequent processes, identify potential shortcomings, and appropriately modify plans to achieve effective inter-process connections. This requires model management personnel to possess multi-disciplinary skills, a clear understanding of BIM technology’s application points in the project construction process, and the ability to identify potential inter-process connection issues. This enables them to organize discussions and clarify modification plans. Implementing these measures throughout the project process can significantly enhance project efficiency and scientific rationality.

In summary, based on the existing research framework related to BIM technology [20], the overall process of BIM technology application can be summarized as shown in Figure 4.

**Figure 4.** The overall process of BIM technology application.

4. **Application of BIM Technology**

Based on the actual situation of the project, combined with the characteristics of the EPC mode, the project BIM team makes the BIM application objectives of the project clear: integrate the application of BIM technology into EPC project management, realize the efficient linkage of design, procurement, and construction, create added value, and improve the quality and efficiency of project management. The application process of BIM is mainly introduced in the following three stages.
4.1. Application of BIM in Construction Drawing Design Stage

4.1.1. Green Livable, Low Carbon Energy Saving: Sunshine Analysis

To effectively arrange the green vegetation surrounding the building, a three-dimensional model of the building and its surrounding landform was established, as shown in Figure 5. Ecotect 2011 software was utilized to analyze solar radiation and sunshine distribution in the project area, as shown in Figure 6. The analysis reveals that during winter, the sun altitude angle is relatively low, resulting in a larger projection area for the building. From 9:00 to 15:00, the north side of the project falls within this projection range with less than one hour of cumulative sunshine time. Conversely, good sunlight exposure can be observed on both the west and south sides during winter, particularly with more than five hours of sunshine time in the southeast corner. During summer, when there is a higher sun altitude angle and a smaller building projection area, buildings facing north and south are not obstructed by neighboring structures, leading to significant heat gain. Therefore, it is recommended to enhance the landscape greening layout around the project during summer by incorporating shading trees and turf while planting deciduous trees in winter for shade provision, thus achieving harmonious coexistence between nature and architecture. Additionally, materials with high solar reflection coefficients should be used for ground surfaces, while permeable bricks should be employed for constructing landscape roads.

![Image](image-url)

(a) Summer solstice all-day projection occlusion (b) Winter solstice all-day projection occlusion

Figure 5. 3D model of the building and surrounding landscapes foundation of Ningbo International Convention Center.

![Image](image-url)

(a) Accumulated Sunshine Time throughout the year (b) Annual surface radiation of the site

Figure 6. Ecotect sunshine analysis diagram.

4.1.2. Green Livable, Low Carbon Energy Saving: Daylighting Analysis

This project adheres to a two-star green building standard. The original building scheme of the hotel has three atriums, and the width of the atrium is slightly more than 20 m, which makes the rooms on both sides of the atrium receive insufficient daylight and cannot meet the green building standards. Through the BIM model to establish the hotel monomer and the refined three-dimensional model of the guest room, in order to increase the lighting of the hotel, the overall layout of the project is finally optimized to the chevron design, and two outdoor courtyards are set up, as shown in Figure 7. Using the green building Swell lighting analysis software (GB-DALI) as an analysis tool, the lighting of the
project is analyzed, as shown in Figure 8. There are 405 hotel rooms, 398 of which meet the requirements, with a satisfaction rate of 98.27%. The total area of the inner area is 10,690.8 m², with a standard area of 10,000.9 m² and an area ratio of RA94%, far greater than the required 60%, which is in line with the green building standards.

Figure 7. Optimization of Hotel Building Scheme with BIM Technology.

(a) Hotel building scheme before optimization  (b) Optimized hotel building scheme

Figure 8. Green Swell daylighting analysis software (GB-DALI 2014) daylighting analysis diagram.

(a) Daylighting analysis chart on L 2 floor of hotel  (b) Daylighting analysis chart on L 3 floor of hotel

4.1.3. Strict Control of Budget Estimate, Reducing Cost and Increasing Efficiency: Optimization of Engineering Piles

The pile foundation for this project lasted 108 days. During the early stage of construction drawing design, a pile foundation model, as shown in Figure 9a, was established to rapidly derive and model the total number of engineering piles, which amounted to 1649. The large number of engineering piles, significant fluctuations in the supporting rock layer, and difficulties in rock judgment resulted in a long construction period that did not meet project requirements. To reduce the cost and increase the efficiency and accelerate the construction progress, the optimization scheme for pile foundation is implemented based on the BIM model, as shown in Figure 9b. The proposed approach involves excavation of the silt layer, backfilling with concrete, and utilizing the clay layer beneath as a load-bearing stratum to collectively support the upper load along with the cast-in-place piles. In order to determine the cost of the backfill scheme, according to the establishment of the BIM model, the engineering quantity of the silt layer is calculated to be 2071 m³. The implementation of BIM technology optimization resulted in a reduction of 419 cast-in-place piles, shortening the construction time for pile foundation by 52 days and achieving cost savings of 23.57 million yuan.

Figure 9. Optimization diagram of Pile Foundation.

(a) Pile Foundation Model Before Optimization  (b) Optimized pile foundation model
In the case of pile optimization, the advantages of BIM technology application mainly include the following two points: First, the calculation of engineering quantities is accurate and fast. According to the preliminary design drawings and the rock elevation data in the geological survey report, the engineering pile model and rock layer model can be established quickly to calculate the elevation of the bottom and top of the pile so as to obtain the number of engineering piles. According to the number of piles, the time required for pile foundation construction can be calculated, and the progress of the construction of the engineering pile can be found early, avoiding the potential risk of the construction period. The advanced application of BIM technology provides sufficient time for the optimization of pile foundation drawings. The muddy clay layer is curved. The traditional method is to measure the earthwork amount using the triangle net method, which is low in accuracy and time-consuming. The muddy rock layer model generated by BIM technology can accurately calculate the earthwork amount with high efficiency. Second, the BIM model is convenient for program discussion. The three-dimensional pile foundation model and rock layer model generated by BIM software can visually view the type and length of the pile and the position relationship between the pile and the weathered rock layer, improving communication efficiency.

4.1.4. Strict Control of Budget Estimate, Reducing Cost and Increasing Efficiency: Optimization of Wall Materials

This project has a large amount of masonry engineering due to the many functional partitions of rooms and the complicated layout of various types of walls. In the design stage of construction drawing, BIM technology is used to rapidly model various building wall quantities. Combined with profit and loss analysis and construction period analysis, it is concluded that the slab wall has high construction efficiency, and the large-scale use can reduce the loss of masonry engineering and shorten the masonry time. Finally, the optimization direction is confirmed by replacing as many concrete block walls as possible with concrete slab walls. To facilitate the discussion of optimized design, different colors were used to distinguish wall materials in the BIM model, and the distribution of each wall was clearly and intuitively expressed in the three-dimensional model, as shown in Figure 10. Final design confirmation: except for the wall and wading room, the concrete block was replaced with a concrete slab, and the final design was optimized, achieving good economic benefits.

Figure 10. Three-dimensional wall distribution map.

4.2. Application of BIM in Construction Phase

4.2.1. BIM-Based Approach for Determining the Depth of Engineering Pile into Rock

The project spans a maximum distance of approximately 1300 m in the north-south direction, encompassing a total of 3656 engineering piles. Design specifications mandate that these piles penetrate the weathered rock layer by no less than 1 m. Geological survey findings reveal significant variations in the depth of this weathered rock layer. While it is relatively shallow, around 15 m deep, on the northern and southern sides near the
mountainous areas, it reaches depths exceeding 80 m in the central region adjacent to the river channel. Due to time constraints, relying solely on geological survey reports without employing columnar sampling and surveys poses considerable challenges in accurately determining each pile’s elevation within the rock formation.

There are two challenges associated with determining the depth of engineering piles embedded in rocks: Firstly, the available geological survey reports and engineering geological data only provide information on the depth and elevation of weathered rocks at exploration holes, which may not necessarily correspond to the precise location of the engineering pile. Given that there are significantly more engineering piles than exploration holes, relying solely on elevation data from weathered rocks at exploration holes is insufficient for accurately assessing rock conditions on-site. Secondly, it is crucial to establish a consistent horizontal position relationship and elevation alignment between the engineering pile model and the weathered rock layer. This necessitates sharing an axis network and elevation system between both models to ensure relative positional accuracy and elevation consistency.

To address this issue, BIM technology is employed to utilize point-like elevation data of the weathered rock layer. By connecting two points to form a line and three points to create a surface, a comprehensive model of the weathered rock layer is generated. Through integrating this model with the engineering pile design, it can determine the intersection point between each pile and the weathered rock layer. Considering the required depth for embedding piles in rocks (set at 1 m for this project), it can ascertain the necessary elevation for each engineering pile’s base. Consequently, the complex task of determining pile depth within rocks is transformed into a straightforward measurement problem concerning hole depth control during construction, thereby facilitating field pile foundation construction, and ensuring its quality, as shown in Figure 11.

Based on the CAD drawings depicting weathered rock contours in the geological survey report, this project imported the drawings into BIM software for processing and generated a three-dimensional model of the rock, as shown in Figure 12a. Simultaneously, a three-dimensional model of engineering piles was established using construction pile foundation drawings, as shown in Figure 12b. The integration of the rock model and three-dimensional pile foundation model information was achieved within the BIM software, as shown in Figure 12c. The elevation of the pile bottom was marked, and two-dimensional CAD drawings, along with a detailed table containing pile number, quantity, and bottom elevation, were exported to guide the on-site construction of engineering piles. The representative data were carefully selected to compare the actual pile bottom
elevation with the BIM-derived data. The findings demonstrated a high level of consistency between the two datasets, thereby validating the accuracy and reliability of the BIM-derived information, as shown in Table 1. The comparison between the two different methods in terms of time, cost, and quality control is presented in Table 2. As depicted in the table, the implementation of BIM technology for determining the depth of engineering pile into rock significantly enhances construction efficiency, reduces costs, and improves construction quality.

Figure 12. BIM assisted pile foundation construction three-dimensional wall distribution map. (a) 3D model of rock diagram; (b) 3D model drawing of engineering pile; (c) 3D integrated model of engineering piles.

Table 1. The comparison of elevation of pile bottom.

<table>
<thead>
<tr>
<th>Pile Number</th>
<th>The Actual Elevation of the Pile Bottom (m)</th>
<th>Pile Bottom Elevation Based on BIM(m)</th>
<th>Percentage of Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>359</td>
<td>−69.12</td>
<td>−69.08</td>
<td>−4%</td>
</tr>
<tr>
<td>385</td>
<td>−69.60</td>
<td>−69.55</td>
<td>−5%</td>
</tr>
<tr>
<td>438</td>
<td>−66.66</td>
<td>−66.69</td>
<td>3%</td>
</tr>
<tr>
<td>573</td>
<td>−64.34</td>
<td>−63.44</td>
<td>−10%</td>
</tr>
<tr>
<td>223</td>
<td>−68.57</td>
<td>−68.59</td>
<td>2%</td>
</tr>
<tr>
<td>592</td>
<td>−63.71</td>
<td>−63.67</td>
<td>−4%</td>
</tr>
<tr>
<td>358</td>
<td>−69.10</td>
<td>−69.05</td>
<td>−5%</td>
</tr>
<tr>
<td>692</td>
<td>−63.36</td>
<td>−63.39</td>
<td>3.00%</td>
</tr>
<tr>
<td>503</td>
<td>−69.99</td>
<td>−70.00</td>
<td>1.00%</td>
</tr>
<tr>
<td>458</td>
<td>−65.06</td>
<td>−65.10</td>
<td>4.00%</td>
</tr>
</tbody>
</table>

Table 2. The comparison between the two different methods in terms of time, cost, and quality control.

<table>
<thead>
<tr>
<th>Comparing Elements</th>
<th>Traditional Model</th>
<th>BIM Model</th>
<th>Advantages of BIM Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time Cost</td>
<td>30 days</td>
<td>2 days</td>
<td>Save 28 days of time</td>
</tr>
<tr>
<td>Expenses Cost</td>
<td>The price is higher</td>
<td>The cost is virtually negligible</td>
<td>Cost savings</td>
</tr>
<tr>
<td>Quality Control</td>
<td>Difficult to operate, low accuracy</td>
<td>Easy operation and high accuracy</td>
<td>Enhance the level of precision significantly</td>
</tr>
</tbody>
</table>

4.2.2. Tamping the Foundation, Pre-Control: Existing Bridge Collides with Structural Foundation

There is a collision between the existing bridge and the project infrastructure on Bai-shi South Road. To solve the on-site construction problem, BIM technology is used to establish a three-dimensional model of project pile and bridge No. 1 based on as-built drawings and on-site measurement data, and then collision detection is carried out, and it is found that there are four collisions, as shown in Figure 13. Based on this, the solutions to the on-site problems are put forward: (1) Remove the abutments that collide with the cap at places 1, 2, and 4, and keep the rest; (2) Bridge floor is used as the construction surface of cast-in-place pile; (3) Remove the pre-tensioned prestressed hollow slab beam on the upper part of the bridge floor, and then construct the underwater bearing table; (4) Lay
subgrade boxes between abutments and piers, with spans of 13 m, 16 m and 13 m respectively, and then construct the bridge deck superstructure.

Figure 13. Collision detection diagram of No. 1 bridge and structural foundation.

4.2.3. Construction Simulation and Scheme Preview: Scheme Simulation of Steel Platform on Water

This project gives full play to the practical application of BIM simulation construction technology on important and difficult issues. By establishing a high-precision BIM model and simulating working conditions combined with the ideas of the scheme maker, the whole process of construction is simulated by using BIM animation simulation. Taking the construction scheme of the water steel platform as an example, BIM simulation technology is used to simulate the whole construction process of the steel platform, analyze the difficulties encountered in the construction process, adjust the construction deployment, and put forward solutions to ensure the smooth construction process. As shown in Figure 14.

(a) Construction of steel pipe pile on bank  
(b) Construction of first span steel platform  
(c) Construction of steel pipe piles on steel platforms  
(d) Steel platform main passage pavement
4.2.4. Construction Simulation and Scheme Preview: Tower Arrangement

The layout of the tower crane is related to a series of problems, such as the turnover of materials in the construction process, and unreasonable layout will affect the normal development of the working process. The integration of the tower crane model with the main structure model and the field layout model will conduct collision detection, avoiding the collision risk between the tower body and the main beam of the structure, and rationalizing the location of the tower crane can avoid a series of subsequent demolition and reform problems to the greatest extent. This project makes full use of the BIM model to arrange tower cranes on site in advance, maximize the working efficiency of group tower operations, and propose the optimal solution for tower crane layout. As shown in Figure 15.

Figure 15. Layout of the towers.
4.2.5. Construction Simulation and Scheme Preview: Simulation of Integral Lifting Scheme of Steel Truss

The roof truss of the multi-function hall is divided into three blocks for separate lifting, as shown in Figure 16. It is assembled on a floor of 9.35 m and is the construction form of zoning lifting. A 25 t truck crane was used to carry out high-altitude bulk construction of the preassembly section truss, and then a 25 t truck crane was used to carry out assembly construction on the 9.35 m floor facing the lifting area. After the assembly was completed, zoning lifting was carried out.

![Figure 16. Multi-function Hall Steel Structure Construction Division.](image)

Taking the multi-function hall as an example, the maximum installation elevation of the truss here is 31.87 m, and directly below it is the floor level of 9.350 m. First, each lifting zone of the roof steel structure is assembled into an overall lifting unit on the mezzanine roof structure (+9.350 m) directly below it, and the lifting platform (lifting point) is set up on the top of the supporting column of the roof steel structure. Among them, 12 groups of lifting platforms are set up in lifting zone 1 and lifting zone 2, and 10 groups of lifting platforms are set up in lifting zone 3. One XY-TS-195 hydraulic hoist is arranged for each group of lifting platforms, and the lower lifting point temporary joists and reinforcement rods are installed at the lower chord of the lifting unit truss and the corresponding position of the lifting point. The upper and lower lifting points are connected by special bottom anchors and special steel strands, and the hydraulic synchronous lifting system is used to raise the whole to the designed installation elevation and dock with the preassembly section. After installation, the rod parts are installed to complete the installation of the roof steel structure. The construction process of the pre-assembly section and the on-site pre-assembly process of the lifting section are simulated by BIM.

The construction process of the pre-assembly section is as follows: 1. Four groups of support frames are set up, two groups are rooted on the 9.350 m floor slab in the inner field, and two groups are rooted on the three floors outside the field; 2. Install support rods; 3. Install the upper chord of the cantilever truss; 4. Connect part of the upper string between the belly rod; 5. Install lifting support rods, lower chord rods, and belly rods; 6. Install the adjacent preassembled suspension truss in the same way; 7. Install the connection between the truss member complement; 8. The outfield support frame is removed; 9. Off-site lifting measures rod installation; 10. Remove the support frame and install the elevator, as shown in Figure 17.
(a) Support frame set up

(b) Support rod installation

(c) Top chord mounting

(d) Upper chord between the belly bar connection

(e) The supporting rod, lower chord rod and belly rod are installed

(f) Installation of adjacent one pre-installed cantilever truss

(g) Installation of inter-truss links

(h) External support frame removed
The on-site pre-assembly process of the lifting section is as follows: (1) lay out the plane position of the floor truss; (2) install the lower string tire frame; (3) assemble the lower chord frame; (4) install the upper string tire frame; (5) assemble the upper string and upper abdominal rod; (6) assemble the middle belly rod, as shown in Figure 18.

**Figure 17.** Construction simulation of the preloading section.

**Figure 18.** Simulation of the on-site assembly process in the hoisting section.

It is necessary to set up reasonable lifting points for hoisting large-span steel structures with hydraulic synchronous lifting equipment. A hydraulic lifter is arranged on the lifting point, that is, the lifting platform. The hydraulic elevator relates to the corresponding lower lifting point on the lifting steel structure through lifting the special steel strand.
The lifting platform layout is shown in Figure 19, and the lifting platform design is shown in Figure 20.

Figure 19. Hoisting platform layout.

Figure 20. Platform 3D real scene map.

4.2.6. Data Orientation, Accurate Control: Depth Application of BIM Data

The project features a high space and long-span structure system, with large beam section sizes and numerous overweight beams. Manual identification of these overweight beams in the plane drawing would undoubtedly be time-consuming and prone to errors. However, the utilization of BIM technology enables quick identification of overweight beams with high efficiency and accuracy. By establishing a three-dimensional model of
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The determination formula of the overweight beam is determined: 
\[ S = b \left[ 1.3 \times (G_{1k} + G_{2k} \times h + G_{3k} \times h) + 1.5 \times \gamma_L \times (Q_{1k} + Q_{2k}) \right] \]. This formula is input into the model, automatically marking the overweight beams in red, as shown in Figure 21. Furthermore, a two-dimensional structural diagram is derived from this model to guide on-site construction.

Figure 21. Overweight beam position marking diagram.

The utilization of BIM technology enables the swift extraction of dimensions for overweight beams, significantly enhancing identification efficiency and accuracy. Additionally, the integration of BIM models facilitates their application in business calculations and technical disclosures, thereby achieving a comprehensive utilization of these models. A comparison between the traditional approach and the implementation of BIM is presented in Table 3.

Table 3. The comparison of the traditional approach and BIM approach for identifying overweight beams.

<table>
<thead>
<tr>
<th>Comparing Elements</th>
<th>Traditional Model</th>
<th>BIM Model</th>
<th>Advantages of BIM Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time Cost</td>
<td>8 days</td>
<td>1 days</td>
<td>Save 7 days of time</td>
</tr>
<tr>
<td>Business Calculation</td>
<td>5 days</td>
<td>0.5 days</td>
<td>Save 4.5 days of time</td>
</tr>
<tr>
<td>Technical Disclosure</td>
<td>Two-dimensional drawing display</td>
<td>3D Model Display</td>
<td>Enhance the level of technical disclosure</td>
</tr>
</tbody>
</table>

4.3. Application of BIM in Further Design Phase

4.3.1. Professional Collaboration, Quality Improvement: Mechanical and Electrical Deepening Design

Based on the preliminary design drawings, the project's mechanical and electrical BIM team establishes a mechanical and electrical BIM model, integrates it with the civil construction model, and carries out the preliminary layout of the integrated pipe. For areas with dense pipelines that cannot meet the requirements of net height, the project raises funds for the design in advance and reserves holes in structural beams, panels, walls, and other components to facilitate the penetration of mechanical and electrical pipelines in the later stage and ensures the realization of building functions. As shown in Figure 22a. The pipeline alignment is optimized in the three-dimensional model to ensure that the net height requirements are met and the construction rationality and feasibility analysis are carried out. Pipeline collision is found through collision inspection, reasonable overturning avoidance is found in the model, and the spatial position of the electromechanical pipeline is finally determined, as shown in Figure 22b. Position and height mark the pipeline in the plan to produce BIM in-depth drawings that can be used directly for site construction. Three-dimensional scanning technology was adopted on-site to obtain an accurate point cloud data model of the steel structure in the main venue in a short time, as shown in Figure 23. After integration with the Revit model, the position deviation of the
on-site steel structure is checked, and the Revit model is reversed. Based on an accurate
BIM model, it is convenient to discuss the construction plan of mechanical and electrical
decoration in the later stage.

![Figure 22](image)

(a) A structural hole drawing  
(b) Pipeline synthesis diagram

**Figure 22.** Mechanical and electrical deepening design.

![Figure 23](image)

**Figure 23.** 3D Point Cloud model of the main conference hall.

4.3.2. Professional Collaboration, Quality Improvement: Refined Decoration Deepening Design

The project hardcover BIM team is based on the refined BIM model, as shown in Figure 24. By exporting and deepening the drawing, and improving the accuracy of the drawing, the drawing errors and omissions can be avoided ahead. At the same time, the linkage of the model, one modification everywhere, updates, improving the efficiency of map modification.

![Figure 24](image)

**Figure 24.** Hardcover model drawing.
4.3.3. Digital Lifting, Auxiliary Deepening: Glulam Column Decoration Construction

BIM Deepening

The four monomers of the multi-function hall, the main venue, the hotel, and the summit hall are connected by the corridor bridge. The corridor frame and corridor are covered by the steel square column with glulam veneer to meet the decorative effect of their appearance.

This project proposes the decorative construction technology of a glulam column, and the overall structure is divided into a galvanized square keel, two L-shaped plates, and one straight plate. The adjacent position of the metal skeleton adopts a special-shaped connecting aluminum plate for edge sealing and closing. The connecting aluminum plate is divided into two kinds, namely, the special-shaped aluminum plate at the straight section and the special-shaped aluminum plate at the corner section. Through the combination of 3 plates to achieve the effect of the column. The BIM model is used to help deepen the design, and all parts are pre-processed in the factory and assembled flexibly on site, reducing the difficulty of construction and improving the construction efficiency. The corresponding glulam column structure is shown in Figure 25. The installation process of the pillar structure can be divided into: prefabricated plywood factory production and transportation; metal skeleton installation; special-shaped aluminum plate production and installation; panel installation.

![Figure 25](image)

**Figure 25.** Structure drawing of glulam column; (a) Galvanized Square Pipe Keel installation; (b) Special-shaped connection aluminum plate installation; (c) L-shaped plate; (d) Straight plate; (e) Overall structure drawing; (f) Field effect.

4.3.4. Digital Lifting, Auxiliary Deepening: Surface Structure Template BIM Deepening

There are special-shaped curved concrete panels in the building of this project. For special-shaped curved concrete structures, accurate formwork size and angle are of paramount importance. However, the relevant data of formwork cannot be obtained through conventional two-dimensional drawings, so BIM modeling is adopted, as shown in Figure 26. The radius, curvature, and arc length of the shaped surface can be directly obtained, and the template is customized by the manufacturer to achieve the effect of “tight stitching”.
4.3.5. Digital Lifting, Auxiliary Deepening: Ultra-Long Comb Slant Hanging Clean Water Panel Curtain Wall BIM Deepening

This project runs through the outer sides of four individual corridor Bridges, with ultra-long special-shaped plain plate curtain walls of more than 1000 m. As an important part of the overall architectural expression, an ultra-long comb inclined hanging plain plate curtain wall requires high accuracy in the overall installation. However, the ultra-long comb inclined hanging plain plate curtain wall structure with a length of more than 1000 m brings great difficulties in controlling the overall installation accuracy. Due to the comprehensive influence of factors such as the site limitation, the cross-construction of various specialties on the site, and the ultra-long span of the curtain wall, the ultra-long comb inclined hanging water panel curtain wall has problems such as greater difficulty in construction and difficult to control the installation accuracy.

To this end, the BIM team of the project uses BIM technology to carry out integrated design and construction of the main structure and curtain wall, deepen the overall modeling, optimize and adjust the curtain wall skeleton, etc. From the design source, the space interference between the two systems is solved to ensure that the curtain wall structure has a reliable connection with the main structure at different locations. The curtain wall structure was optimized through BIM modeling, and the overall structure was divided into independent units, as shown in Figure 27a. Make it have the conditions of batch digital processing, order in the factory in advance, as shown in Figure 27b, on-site flexible assembly, improve the construction efficiency, and reduce the difficulty of construction.

(a) Comb type inclined hanging clear water curtain wall unit
4.3.6. Digital Lifting, Auxiliary Deepening: STRUCTURAL Form Optimization BIM Deepening

The longest span of the dougong gallery bridge in this project is about 1300 m, and the maximum installation height of the aluminum square tunnel ceiling is 28.5 m. The aluminum square tunnel components are designed in a staggered arrangement with different angles, and the maximum inclination is about 75 degrees, which has the characteristics of a difficult layout design, complicated installation process, difficult construction, and high-quality control requirements. In the process of 3D digital modeling, the aluminum plate and aluminum square grid are finely modeled, as shown in Figure 28. Based on this, the construction drawings are drawn to clarify the arrangement sequence of aluminum plates, the arrangement rules of an aluminum square grid, and the spatial position of an aluminum square grid, etc., which are used to guide the on-site construction.

Figure 27. Ultra-long comb inclined hanging clear water board curtain wall deepening processing drawings.

(b) Batch machining drawing of factory unit

(e) Realistic view

Figure 28. Roof aluminum square ceiling 3D model.

(1) Structural optimization design: the arch structure has reasonable force, and the structure has unfavorable force after flipping. To solve the adverse force caused by the self-
weight of the wooden structure, light aluminum is used to replace the wooden structure to solve this problem. The anti-arch bracket is assembled by a combination of several linear light aluminum materials. Compared with the direct use of curved components, linear components are easier to process and manufacture, convenient transportation and on-site construction assembly errors are easy to control, and construction accuracy is controllable. By adjusting the length and angle of each component, the reverse arch roof support structure can realize the roof structure with different directions, different curvature, different column spacing and different eaves requirements. By setting up several groups of reverse arch roof support structures, the extension application of two or more spans of the roof can also be realized. The structure form is optimized, two rows of structural support are added to optimize the force, two connecting tie rods are added outside the plane to maintain the integrity of the plane, and the structure fulcrum is added in the place where the force is complicated. Through the above improvement and optimization, the force of the reverse arch structure system is more reasonable, as shown in Figure 29.

Figure 29. Optimization of inverted arch structure system.

(2) Node deepening design: Key detail nodes are deepened to ensure node reliability and ease of installation. Aiming at the connection nodes of the roof keel and the imitation wood grain aluminum square pass hanging below, the connection form of “galvanized steel pipe lower pendant + curved Angle steel with open holes + long round hole connecting plate” is proposed, as shown in Figure 30.

Figure 30. Grid connection device optimization.

In addition to the above application directions, the BIM model can be used in building comfort analysis, energy-saving simulation analysis, fluid performance analysis such as air and water flow, environmental temperature, visibility, and noise analysis, evaluation and experimentation, cost analysis and control of different life cycles, performance-based evaluation of building fire protection, and emergency evacuation in emergency situations by simulating the “real world” situation, Help design buildings that are more scientific, reasonable, and meet functional requirements. In addition, BIM technology has a wide range of application scenarios in the operation and maintenance phase.
5. Conclusions

The Ningbo International Convention Center, which is located in Dongqian Lake, Ningbo City, is divided by the river, and the site is scattered. In water construction, the working conditions are more complicated, resulting in the construction difficulty of the pile foundation and steel structure platform in the early stages. The main form of a single roof structure is a long-span steel truss system, the roof steel structure has a large span, and the roof truss is difficult to assemble. The maximum span of the truss is 72 m, and the maximum weight of a single piece is about 320 t. The unique engineering characteristics determine that the on-site structure installation needs to adopt unconventional installation methods, which greatly reduces the operability of construction. At the same time, the architectural design is integrated into the elements of Jiangnan of China: the architectural design of 1300 m of ultra-long dougong gallery bridge and the design of ultra-long comb slant hanging water panel curtain wall of over 1000 m have increased the difficulty of construction and put forward extremely high requirements for the construction technology. These characteristics bring great challenges to the application of BIM, and provide a platform for the integration of BIM and technology.

This paper provides a detailed study and demonstration of the application of BIM technology in the construction phase. Based on the actual situation of the project and combined with the characteristics of EPC mode, the project BIM team makes clear the BIM application objectives of the project: integrating the application of BIM technology into EPC project management and realizing the efficient linkage of design and procurement. By utilizing BIM technology effectively, there can be a significant increase in construction efficiency for such EPC mode projects. In this paper, the exploration and application of BIM in EPC projects are carried out in the following three stages: construction drawing design stage, construction phase, and further design phase. BIM technology can be used to simulate building renderings, visual simulation of sunlight and lighting, and virtual animation construction of “being in between,” facilitating communication and exchange between owners, designers, and construction parties. The BIM model can also be widely used in construction simulation, scheme preview, and construction accuracy control, etc. In addition, BIM technology has also shown great potential for application in further design phases, such as mechanical and electrical deepening design, glulam column decoration construction, and structural form optimization. The innovative application points of this project, such as engineering pile optimization, wall material optimization, auxiliary rock judgment, tower layout, and electromechanical deepening design, have strong promotion and application value, especially suitable for large-scale EPC conferences and exhibition projects. For areas with many engineering piles and complex geological conditions, the use of BIM technology to link the design and construction parties can achieve good optimization benefits.

As demonstrated in this paper, on the basis of EPC mode, BIM technology can be applied more deeply and run through the design and construction stages. Although we have created benefits and achieved certain results for the construction of the Ningbo International Conference Center project by linking the design and construction parties, it is still not deep enough. The interactive construction participants are only limited to the design and construction parties. In the future, we will use the project as a carrier to apply BIM technology throughout the scheme stage, construction drawing design stage, construction stage, and operation and maintenance stage so that all parties involved in the project can achieve positive interaction, solve problems in advance, and contribute the value of BIM to the full life cycle construction of the project.

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