

Information Construction Technology of Free-Form Surface Steel Grid

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Abstract: Taking the construction project of National Network Security Talents and Innovation Base Exhibition Center as an example, the application of building information model in the construction process of free-form surface steel structure is analyzed in this paper. The results show that the application of Building Information Modeling (BIM) technology to the construction of free-form surface structure improves the work efficiency of the construction team in multi-disciplinary collaboration, surface component manufacturing, and construction process design, and subsequently improves the construction speed and construction quality.

Keywords: BIM; Free surface; Steel structure; Construction technology; Informationization

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1. Introduction

The Ministry of Housing and Construction, the National Development and Reform Commission and other 13 departments jointly issued the guidance in promoting a coordinated development of intelligent construction and construction industrialization, calling the construction industry to complete the digital and intelligent upgrading, form a multi-disciplinary integrated intelligent construction industry system, improve project quality and efficiency and effectively stimulate domestic demand, and promote economic growth. Many scholars and engineers responded to the call to study the informatization and intelligence of buildings.

Yang et al.,^[1] used BP neural network to influence the temperature effect and wind load on the steel structure roof, and reopened the BIM software. Based on the real-time detection data, by combining these two, they constructed the visualization method of steel structure temperature-wind load response, and timely feedback the construction personnel to take measures to reduce the construction error. In addition, Chen Ming et al.,^[2] developed the commercial BIM software Revit secondary to solve the problem in the difficult modeling of space truss, which realized the refined modeling of steel structure nodes and parametric batch modeling of steel structure components, and further greatly improved the progress and modeling efficiency of space truss information model. Next Jie Yalong et al.,^[3] took the Qinghe station construction project of Beijing-Zhangjiakou high-speed railway station as an example to analyze the application of BIM in the site optimization layout, pipeline layout, and foundation pit support scheme in the process of large-span steel roof truss construction, and showed that the use of BIM technology greatly improves the efficiency of steel structure hoisting and assembly. Huang et al.,^[4] analyzed the application of BIM technology in the free-form surface structure engineering of table tennis hall in Hangzhou Asian

Games, and use of BIM technology can solve the problems of curtain wall layout, and construction process support design of special-shaped grid structure. Further Shi et al., [5] studied the application of BIM technology in the construction process of large-span truss string structure, where BIM modeling was conducted based on the spatial coordinates of the measurement points, and the construction process was simulated to determine the existing problems in the construction scheme. Additionally, adjustment measures were made before the construction to improve the accuracy of truss installation. Furthermore, Fu et al., [6] used BIM technology to perform the forward parametric design of Changtai Yangtze River Bridge. By comparing the forward and reverse modeling methods, they found out the best automatic transmission method of the parameters and refined modeling of the bridge structure, thereby shortened the design cycle of the long-span bridges, and subsequently improved the design quality. In addition, Luo et al., [7] used BIM technology and spatial structure design software STCAD to study the design of complex spatial structure based on BIM technology from three aspects; 1: IFC standard model; 2: Automatic meshing of spatial structure based on BIM; and 3: Spatial structure design based on BIM. The studies described above demonstrated that BIM technology has a very high application value and prospects. It is not only improving the efficiency and effect of complex spatial structure design, but also plays an important role in improving the construction quality and progress of the construction projects, and promoting the continuous advancement of urbanization. Wen et al., [8] proposed the method of transforming free-form surface into a combination of surface and oblique surface by using the principle of differential approximation, and solved the design and installation problem of free-form surface metal roof panel in the construction project of Nanchong Four Centers and One Center through BIM technology. Next Wu et al., [9] analyzed the application of BIM technology in the design and construction management of the commercial sightseeing area of the Shanghai Center Building. The technical application results show that BIM technology can promote the collaborative work of construction professionals, and improve the communication efficiency, where it integrates personnel, systems, and practices into a single process, and can be used in the design, manufacturing, and construction stages to increase the value of the project, including shortening the construction period, reducing the waste, and improve the quality. Taking a commercial plaza project in Fuzhou as the engineering background, Zhao et al., [10] adopted BIM technology for the whole process management, designed, and developed the corresponding data framework, which greatly improved the management and construction efficiency. The real-time feedback on the project progress and the display of three-dimensional model mobile terminal are realized, which is convenient to predict the construction period, ensure the connection of each construction section, and improve the construction efficiency.

At present, there are few studies on BIM technology usage in the construction process of free-form surface spatial steel structure. Taking the exhibition center project of National Network Security Talents and Innovation Base as an example, this paper studies the application of BIM technology in the construction of free-form surface structure in the aspects of multi-disciplinary collaboration, information construction site management, information security management, and information construction.

2. Engineering situations

The national network security talent and innovation base exhibition center project is located in the eastern side of the network security base sharing the center area. The planning and construction results showed that the center can be used as a commercial operation center, property management center, customer experience center, and as a social communication center. The main functions of the center include virtual sand table display, multi-functional hall, VIP reception hall, conference room, and others. It will provide an important communication platform for the investment negotiation, conference service, summit exhibition, and planning display of the network security base, and become an important window for the external reception and publicity of the network security base, and also as an important landmark building of the network

security industry city. The total land area is around 1500 mu, and the building has the first grade of fire resistance, the second grade of structural safety, and the height of the building is about 17 m. The architectural design adopts the design concept of “never exceeding the moment, free, and boundary”. The layout adopts the form of medium axial symmetry, while the square volume reflects the characteristics of modern network stability. The transparent facade shows the internal steel structure grid, reflecting the combination of science, technology, and humanities.

The steel structure system for this project is complex, where the roof is a single-layer reticulated shell with parallelogram cross-section. The cross sections on both sides of the parallelogram are perpendicular to the ground, and the upper- and lower-surfaces are curved with twisted surfaces. In addition, the types of steel structure components are diverse, including box arch, pipe swing column, H beam, and other structural forms. Increasing the difficulty of deepening design lofting, modeling, and drawing expression leads to low deepening efficiency. Therefore, on the basis of the correct understanding of the design intent, to ensure the accuracy of the deepening design model, to achieve accurate, and clear drawings in place, is the difficulty of engineering deepening design.

3. Cooperative technology of freeform surface structure informatization specialty

Adhering to the design concept of “freedom with boundaries,” the designer combines the surface symbolizing ‘freedom’ with the boundary symbolizing ‘safety’ to form a design style with network security characteristics. The outdoor rendering, and indoor effects of the exhibition center are shown in **Figure 1** and **Figure 2**. The surface reticulated shell adopts Rhino and Grasshopper parametric modeling design by adjusting the parameters to control the surface shape, and strive to meet the premise structural of stress by keeping the natural, and smooth surface shape.

Illumination simulation software is used to simulate the angle and illuminance of sunlight at different times, which provides the basis for the design of lighting wells and glass domes. In the analysis software, the multi-point sunlight irradiation of buildings is simulated to maximize the use of natural light.

The outdoor wind environment, temperature, and sunshine of the exhibition center are simulated by using Ecotect, Computational Fluid Dynamic (CFD), and other energy consumption analysis software. The influence of environmental factors on indoor temperature, humidity, illumination, and noise is simulated, which provides as a theoretical basis for building and mechanical and electrical design.

In the design stage, the platform family library is used to establish the professional models of the construction to realize data sharing in the whole life cycle of the buildings. The equipment is manufacturers into the platform, to complete the establishment of the equipment family library, information entry, and bidding procurement.

The construction model of different stages is uploaded into the platform. The construction and design personnel, and other participants of the project work together on the CITIC intelligent construction platform, and BIM technology is used to assist in construction organization, planning, schedule management, cost management, quality control, and construction process guidance.



Figure 1. Outdoor rendering of exhibition center

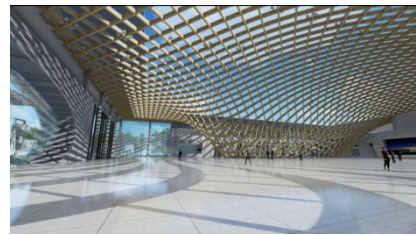


Figure 2. Indoor effect diagram of exhibition center

4. Information construction site management

The Pinming, and Guanglianda software was used for three-dimensional site layout modeling. The scientific layout of the site gates, walls, temporary roads in the field, materials processing and stacking sites, publicity slogans, and temporary facilities in the office area and living area was realized, which laid a solid foundation for safe and civilized construction. The 3D construction site layout is shown in **Figure 3**. Additionally, the relevant site parameters and material list are extracted in advance to provide detailed information for subsequent steel structure hoisting and comprehensive data for later cost management, and the visualization of EPC project management is shown in **Figure 4**.

BIM technology is used to visualize the plane elements in the construction site, comprehensively consider the site conversion of each stage, and optimize the site with the concept of green construction. Through the establishment of site model and enterprise standard family library, the construction general layout of foundation, structure, and decoration stage is conducted, and the site dynamic management mechanism is formed.

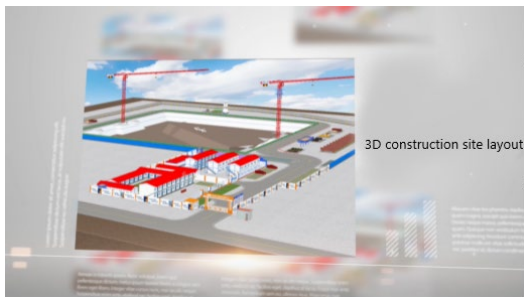


Figure 3. 3D construction site layout

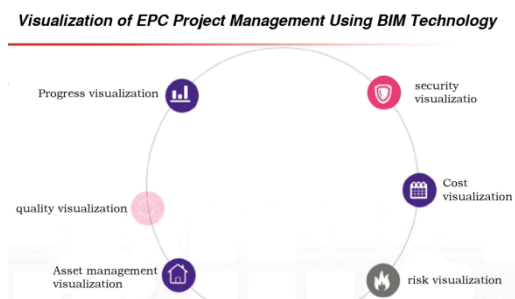


Figure 4. Visualization of EPC project management

5. Information security management platform

This project is based on management system standards, combined with information technology to build an intelligent security management platform. In technology development, the platform is based on NET Framework, and MVC is based on B/S as the main framework, further using SQL Server Entity Framework 6.0 as the data layer framework to develop the server-side functions. The front-end uses the Bootstrap development interface based on JQuery, and uses Ajax for server-side and client-side data interaction. In terms of user use, the software adopts multi-level permission control, mainly considering the actual situation of user roles such as management, general contractor and subcontractor, and further strengthens the safety production management of construction site through this platform. The mobile intelligent security software could not only assist the work of safety management personnel, but also enable the decision-makers to timely understand the construction progress, the safety of production the operation process, and also the safety of equipment and facilities on the site. It can carry out statistical analysis on the potential safety hazard and construction situation on the site, supervise and manage the safety management work of each construction site in time, and also improve the safety and efficiency of engineering construction.

The platform makes full use of mobile Internet, intelligent terminals, cloud services, and other technologies in the construction process. Based on safety production regulations and standards, safety operation rules, enterprise safety production management system, and standardized major hazard database through special safety inspection and normal inspection, and the on-site safety hazard investigation is connected with the standardized accident hazard database. By using mobile intelligent terminal equipment and transmission technology, all the personnel and the whole process are involved in the dynamic and closed-loop tracking and management of on-site safety hazard information collection, real-time transmission, investigation and rectification, and hazard elimination. Realization of enterprise safety

management information real-time collection, automatic push, intelligent analysis, prediction and early warning, safety status assessment, and performance management. The system automatically converts accident potential into safety risk value, and realizes quantitative risk assessment and analysis.

Through this system, the company's project safety supervision and management can achieve a dual transformation from passive supervision to active supervision, and from a post-supervision to prior supervision and in-process supervision. Through the implementation of hierarchical management, the system meets the monitoring of security risks at various management levels. Additionally, the risk warning is realized through the quantification of the risk value of the hidden dangers. The system provides scientific basis and decision-making reference for all kinds of safety management work such as hidden danger investigation, risk early warning, safety performance evaluation, and statistical analysis of enterprises through statistical analysis of accidents and risks in different latitudes. Professional, practical, and efficient enterprise safety production inspection and risk control system is an effective means to improve enterprise safety management, and improve the efficiency of safety production inspection and risk control to achieve the advance control of accidents and move forward.

6. Information construction of freeform curved steel structure

6.1. Design of information-based electromechanical engineering support and hanger

According to the BIM design model and the measured building structure size, the deepening design of mechanical and electrical pipeline layout is conducted. The BIM plug-in MagiCAD and other software are used to design the support and hanger of the construction BIM model based on the specification, the atlas, the calculation, and the analysis. Subsequently, the section diagram is drawn to guide the prefabricated installation and pipeline installation of the support and hanger on the construction site.

6.2. Piping segmentation, stacking, and installation

As shown in the following diagram, the BIM related software is used to segment and number the pipeline of the construction BIM model. The segmentation standard is optimized according to the model, the pipeline material and the arrival size. The number label is made, the prefabricated pipeline is prefabricated, the number is pasted, the classification storage is carried out, and the installation is carried out according to the three-dimensional BIM drawings and number sequence.

6.3. Informatization construction of steel structure engineering

According to the calculation model provided by the design unit, and based on the analysis of the working state of structural components under various working conditions, the BIM implementation team uses TEKLA, AUTOCAD, and self-developed plug-ins to deepen the design. It greatly improves the efficiency and accuracy of the design, and further provides great convenience for the project construction. The steel reticulated shell of this project is large in scale and complex in structure, where the whole structure is formed by the angle change and bending of 400* 150 parallelogram section. Additionally, the construction scheme of factory unit block processing and site point support high-altitude docking is adopted.

Based on the Tekla model data and generated drawings, accurate cutting, inventory management, the lofting and setting up of the profiling jig were guided. Then the bending and twisting components, unit block assembly, welding, and painting were conducted. Finally, based on BIM software output on the component two-dimensional code label, the complete shipment, fabrication of bending, and torsion members is shown in **Figure 5**.

This project simulates the structural stress state, force transmission path, stress and deformation in the construction process by BIM software, and based on the results of finite element analysis software, the construction work of component installation and support unloading was conducted.

The output results are calculated by Midas Gen software to guide the site construction, and the finite element calculation results are shown in **Figure 6**. This project through the use of BIM model for clamping inspection, in the way of computer simulation construction leading to collision detection, thereby greatly avoid the collision between professional problems, subsequently improve the construction efficiency of the project.

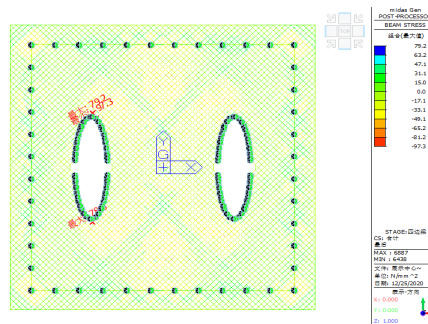
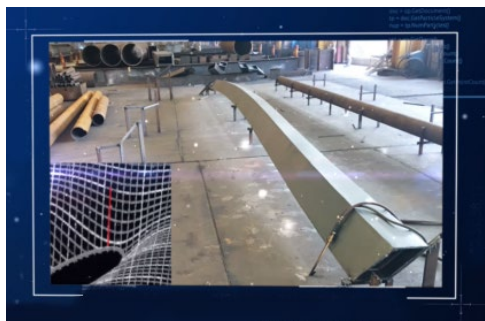


Figure 5. Fabrication of bending and torsion members **Figure 6.** Structure stress nephogram after unloading

7. Conclusions

Based on the construction project of National Network Security Talents and Innovation Base Exhibition Center, this paper analyzes the role of BIM technology in the construction of free-form surface structure. The use of BIM technology has some advantage such as improving the efficiency of professional cooperation in the construction process, avoiding the construction difficulties caused by structural design, speeds up the feedback speed of safety problems in the construction stage, improving the manufacturing and installation accuracy of free-form surface components, and significantly improves the construction quality and construction speed.

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Disclosure statement

The authors declare no conflict of interest.

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