Research on the Application of Intelligent Construction Technology in Hangzhouxi Railway Station

GUO Xiang[1], DONG Guangyan[2], XIE Yalong[3], LIU Wei[1], DU Liqiang[4], TONG Yuchao[4], LI Chunhong[1]

1. Beijing Jingwei Information Technology Co., Ltd.;
2. Shanghai-Kunming Passenger Dedicated Railway Zhejiang Co., Ltd.;
3. Institute of Computing Technology, China Academy of Railway Sciences Corporation Limited;
4. China Railway Construction Engineering Group

Abstract: Relying on the construction management of Hangzhouxi Railway Station, this paper analyses the comprehensive application of intelligent construction technology and the establishment of the common data environment (CDE) by using BIM technology. This paper gives the idea that such issues are deeply explored as large-span curved surface structure improvement, steel structure construction monitoring, special-shaped ticket check canopy construction, prefabricated machine room construction, grid construction management, etc. so as to form an intelligent construction management system based on BIM technology. The system has achieved good application results in economic benefits, social benefits and environmental benefits, which can promote the gradual transformation to a more digitalized, networked and intelligent Hangzhouxi Railway Station, and lay a solid foundation for achieving the construction goals of controllable construction period, excellent quality, green and low carbon, etc.

Keywords: intelligent construction; Hangzhouxi Railway Station; BIM; digitalized; networked; intelligent

---

(This paper is selected from *China Railway*)

1 Introduction

With the rapid development of high-speed rail construction, the construction of China's railway passenger transport hubs has entered a stage of rapid development, developing from a simple transportation distribution center to a comprehensive transportation hub in the city [1], gradually showing the characteristics of high system integration, high intelligence, highly association of states, and comprehensive integration [2]. Therefore, higher requirements are put forward for the traditional construction industry [3] with a low level of informatization and industrialization, extensive production mode, low labor productivity, and high resource consumption.

The transformation and upgrading of the construction industry is the general trend. In the *Guiding Opinions on the Coordinated Development of Intelligent Construction and Construction Industrialization* (J. SH. [2020] No. 60) jointly issued by the 13 ministries and commissions including the Ministry of Housing and Urban-Rural Development of the People's Republic of China, the National Development and Reform Commission of the People's Republic of China, and the Ministry of Science and Technology of the People's Republic of China, etc. in July 2020, it is stated that: “We should use digital and intelligent upgrades as the driver to innovate and break through relevant core technologies, and increase the application of intelligent construction in all aspects of engineering construction” [4].

In the existing literature research, DING Lieyun [5] believes that intelligent construction is a new generation of information technology characterized by digitalization, networkization, and intelligentization, as well as computational data, computational algorithm, and computing power, and it is also a new model of engineering construction combining the civil engineering construction based on the digitalization of architectural elements and a new generation of information technology; XIAO Xuwen [6] believes that intelligent construction is an advanced stage oriented to the entire life cycle of engineering products, which realizes the improvement of construction production level and the empowerment of on-site operation under ubiquitous perceptual conditions; QIAN Qihu [7] believes that intelligent construction collects, transmits, analyzes, processes, and simulates data through perception systems, communication systems and intelligent platforms, thereby assisting decision-making; MA Zhiliang [8] believes that intelligent construction applies intelligence and wisdom to engineering projects to achieve the goal of a labor-saving, economic, safe, and high-quality construction process.

Through the application of intelligent construction technology, the shortcomings of the traditional construction industry can be effectively solved, which is of great significance in promoting the upgrading of the construction industry[9-10]. Taking Hangzhouxi Railway Station as an example, the application of intelligent construction technology in the whole process of the passenger transport hub is studied to provide reference for the practice of intelligent construction technology.

2 Project Overview

The planned Hangzhouxi Railway Station is located in the west of Hangzhou City. It is a supporting project for the 19th Asian Games in Hangzhou in 2022, and also a pro-people project to facilitate the travel of the masses and improve the modern comprehensive transportation system. The Hangzhouxi Railway Station covers an area of 512 200 m^2, of which the station building project covers an area of 99 900 m^2, and the station yard project has a total scale of 11 platforms and 20 lines. It is a large-scale transportation hub complex project including a high-speed rail station, a subway station, and superstructure properties. The steel structure of the station building mainly consists of the lower main support columns, connecting corridor, steel structure roof, cloud valley arch, and drop-off canopy (see Figure 1), with a total steel consumption of 56 000 tons. The plane projection of the above-ground structure is 450 m in length and about 302 m in width. The station building has 2 floors underground, 6 floors above ground, and 8 floors in some areas, with a building height of 60.75 m.

The station building of Hangzhouxi Railway Station has a complex structure, and the main construction difficulties are as follows:

(1) The steel roof has a complex structure.

The roof adopts “rectangular square pyramid space trusses + orthogonal rectangular trusses” to form a long-span multi-curved space struc-

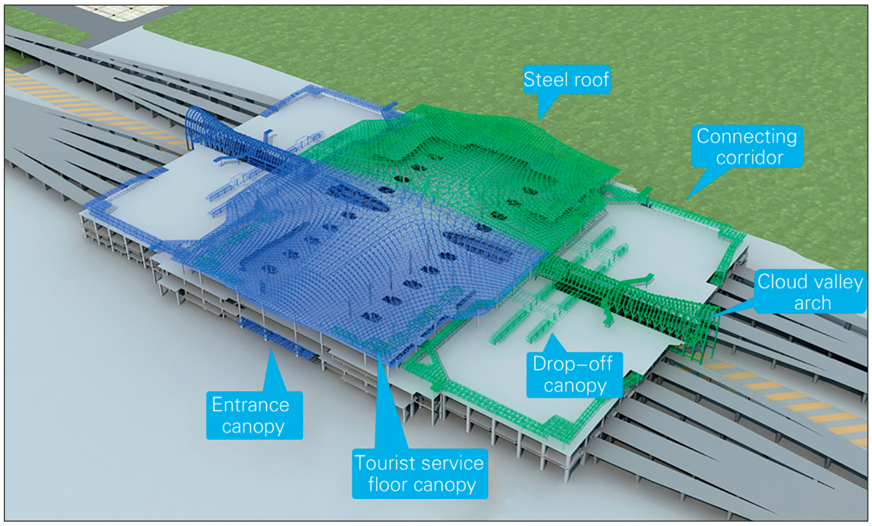


Figure 1 Rendering of steel structure of Hangzhouxi Railway Station

ture system, with a maximum span of 78 m, a projected area of approximately 79 000 m^2, and a total mass of 11 000 tons. The station building roof and the waiting hall ceiling are both hyperboloidal; the roof steel structure is large in volume and complex in structure (see Figure 2).

(2) The construction nodes are numerous and complex.

The joints between the prestressed box girder and the steel column on the rail bearing layer include: column main reinforcement, beam main reinforcement, prestressed reinforcement, column cap reinforcement, and beam bottom haunching reinforcement, which are intricate and difficult to arrange (see Figure 3). The section size of the maximum stiffness steel structure node is 4.0 m×4.0 m× 3.2 m, and the maximum mass of a single steel structure node is 31.5 t.

(3) The construction organization is complex and the turnover materials are backlogged.

The project has a tight construction period and many structural layers, all of which are prestressed. The prestress needs to be tensioned when the age of concrete reaches 28 days before the lower layer of scaffolding can be dismantled, which takes up a lot of turnover materials.

(4) The single-layer construction area is large, and it is difficult to arrange logistics for surrounding auxiliary projects.

The construction area of the station building is 500 m long and 310 m wide. There are as many as 7 auxiliary projects in the surrounding area being constructed simultaneously, which interact and restrict each other. Two subway lines that run through the central station building area in the north-south direction and one east-west subway line on both the south and north sides of the station building form an I-shaped enveloping pattern, and there are a large number of structural common columns between the station building and the subways. Meanwhile, auxiliary projects such as municipal traffic dispersion roads and driving ramps in the four quadrants

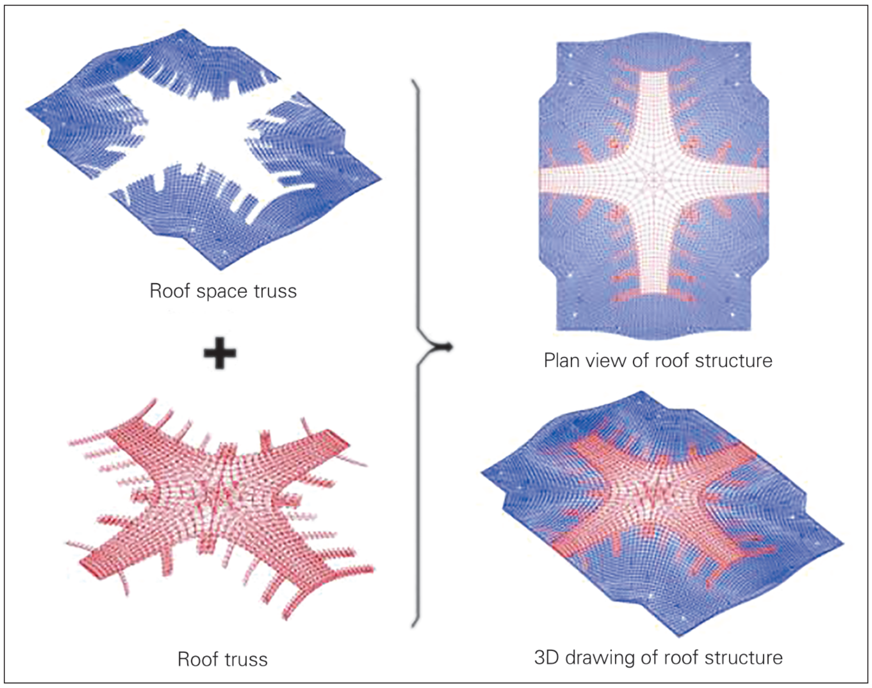


Figure 2 Roof structure form

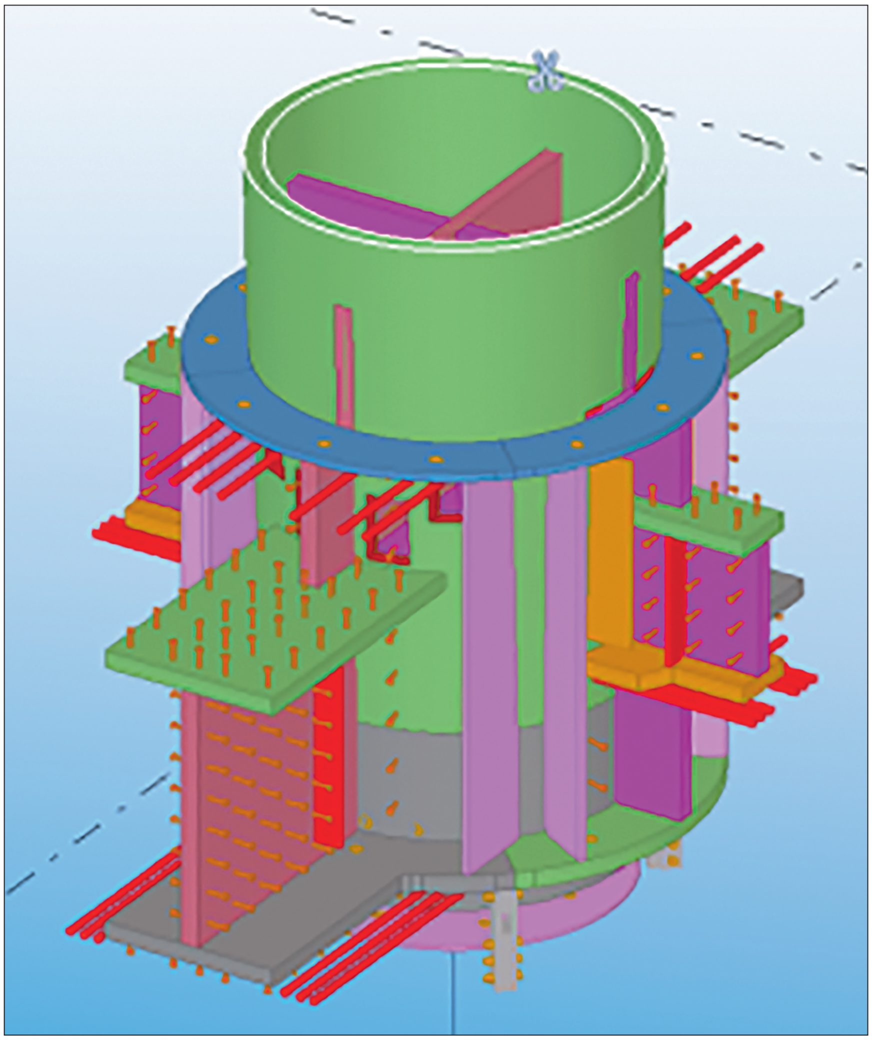


Figure 3 Beam-column nodes at the rail bearing layer

will be constructed simultaneously. The east and west sides are the Huhang yard and Hanglinji yard under construction in front of the station. The site does not meet the conditions to set up a circular construction road, and it is difficult to organize materials.

3 Technology Route of Intelligent Construction

According to the characteristics of the Hangzhouxi Railway Station Project, BIM technology is used to formulate a detailed technical route for its engineering application of intelligent construction, and a BIM collaborative management platform is integrated and designed to achieve the following collaborative management of intelligent construction:

(1) Standard collaboration. Under the organization of the overall leading group, the modeling standards and parametric standards suitable for Hangzhouxi Railway Station are developed, and based on the national standards and the group standards released by the Railway BIM Alliance, unified modeling standards, data standards and coding standards are developed to integrate complex design content into models in the form of data, with data and information delivery as the core. As the project progresses, in the process of design, construction, and completion delivery, the models are gradually refined and the information is gradually improved, and finally digital models consistent with the completed physical entity on site are obtained, so as to improve delivery quality, reduce the difficulty of professional collaboration, reduce information difference, and improve the project management level.

(2) Work collaboration. The developer, the construction unit, and the consulting unit are coordinated to establish a common organizational structure, set up a unified system working mechanism, and clarify the responsibilities of all parties and the review procedures (see Figure 4). The establishment of BIM models is basically synchronized with the design of construction drawings. BIM models can integrate the design content of multiple disciplines, and through model comparison and collision detection, it can continuously check the design and provide real-time feedback on problems, coordinate various disciplines to adjust the design content, and track the problems in a closed loop to ensure the consistency of the drawings and model. After all design problems are closed, designers of all disciplines countersign the BIM models and construction drawings after check, and then submit them together.

(3) Data platform collaboration. A unified collaboration platform is established for design, development, construction, and consulting units as a public data environment, which supports online lightweight browsing and management of models and family libraries, associative management of models and drawings, and delivery management of design results.

Since the ordinary BIM engine cannot satisfy the online browsing of large-scale models of Hangzhouxi Railway Station, a BIM engine (a graphics engine tool is independently developed by using digital-analog separation technology to transform models into a light-weight format) is independently developed by combining

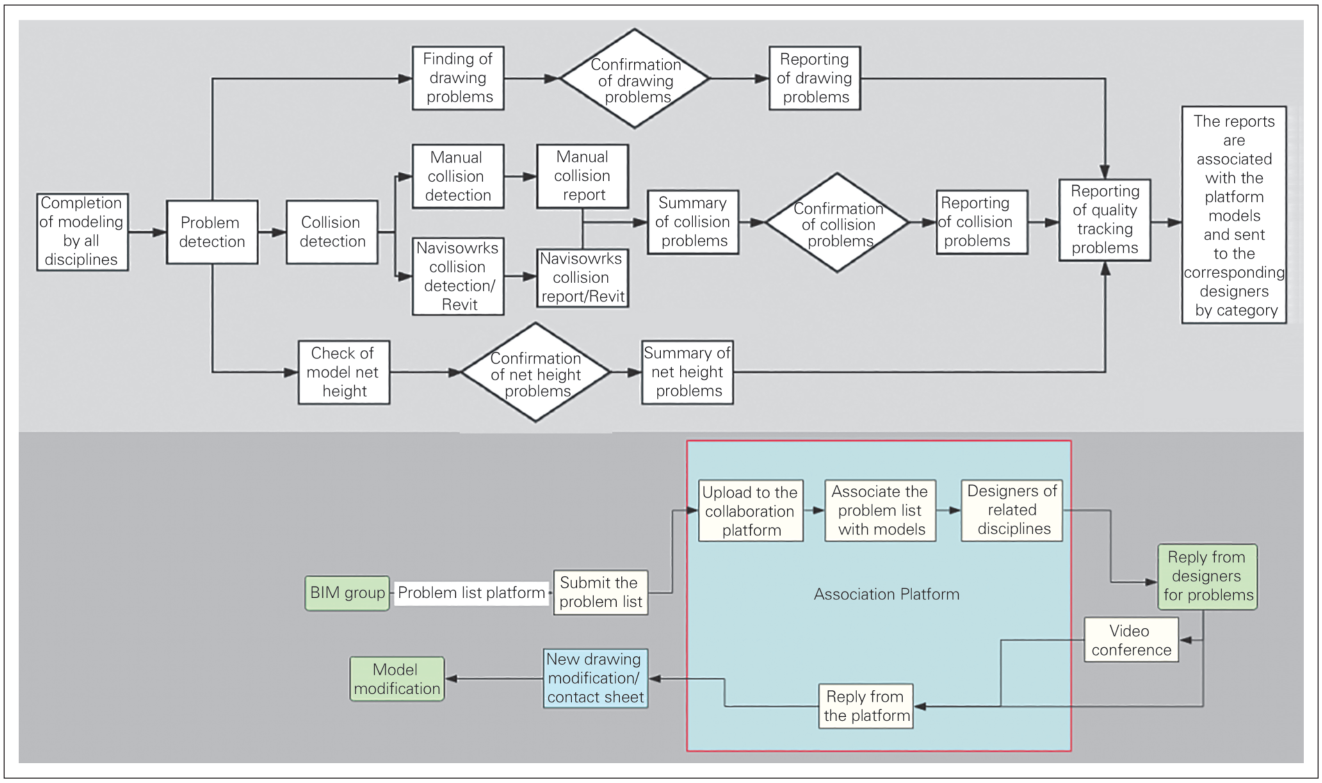


Figure 4 Work collaboration flow chart

the latest model engine technology and scenario-based algorithm optimization, which increases the model compression ratio to 1∶50 while meeting management requirements, and supports model roaming, sectioning, measurement, explosion and other functional operations.

In terms of model management, the platform supports the management of multiple versions of a single model, comparative analysis of multiple versions, and comparative analysis based on the number of components; it supports customized management of model list tags, and can filter and display content based on tags. Model files are classified and managed according to floor and component types. According to the scenario selected by the user, it supports partial loading and display of the model to improve the smoothness of the model; it supports the management of model components in the form of a structure tree, supports bidirectional association of model and document data, and supports linked retrieval function for drawing-based attribute query and attribute-based drawing query.

4 Key Points in the Application of Intelligent Construction Technology

By analyzing the characteristics of the station building project of Hangzhouxi Railway Station, the common collaboration data environment (CDE) is established by using BIM technology, and intelligent construction technology is applied mainly in such aspects as large-span curved surface structure improvement, steel structure construction monitoring, special-shaped ticket check canopy construction, prefabricated machine room construction, and grid construction management. The key points in the application are as follows:

(1) Simulation of the construction process of “partitioned rotation + overall lifting” of large-span curved surfaces.

According to the on-site construction conditions and civil structure layout, combined with the structural characteristics of the roof steel structure, which is high in the middle and low on all sides, and has a large height difference between the bottom chords, the “partitioned rotation + overall lifting” construction technology is used to divide the overall structure into the left partition, the middle partition, and right partition. The left and right partitions are rotated to the design posture respectively, and then joined with the middle partition using supplemental rods; then the whole is raised to the design elevation, and finally, supplemental rods are installed and unloading is performed to complete the roof installation.

Since the entire construction process requires high precision in rotation and lifting, high synchronization in multi-point lifting, and monitoring of changes in stress, displacement, etc., BIM technology is used to simulate, calculate and optimize the partitioned rotation and lifting motion processes. The rotation and lifting scheme for the steel structure roof is shown in Figure 5.

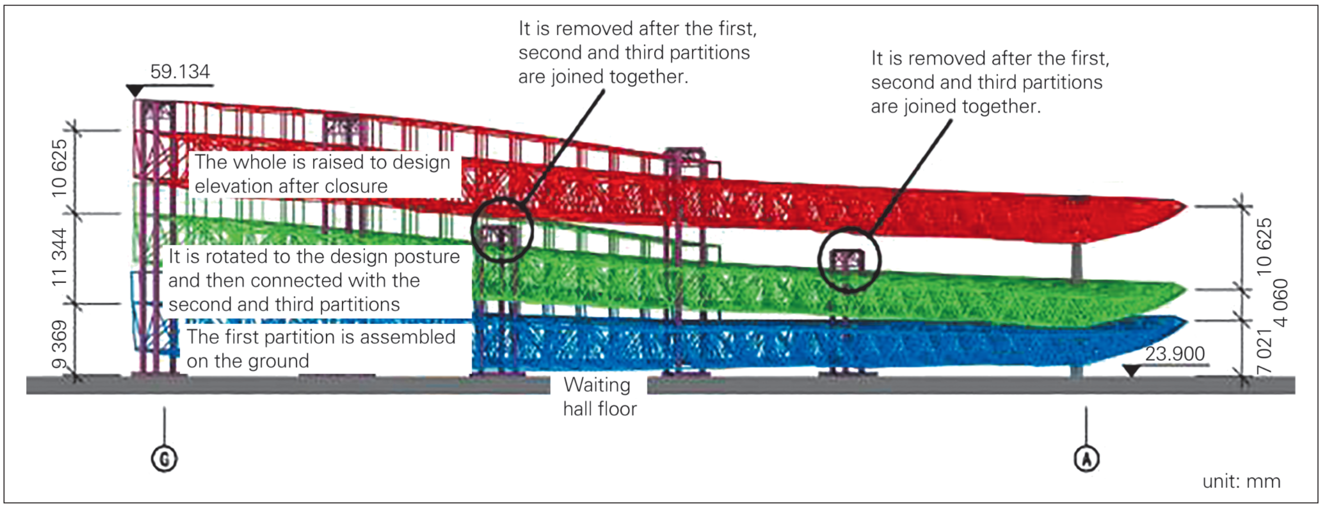
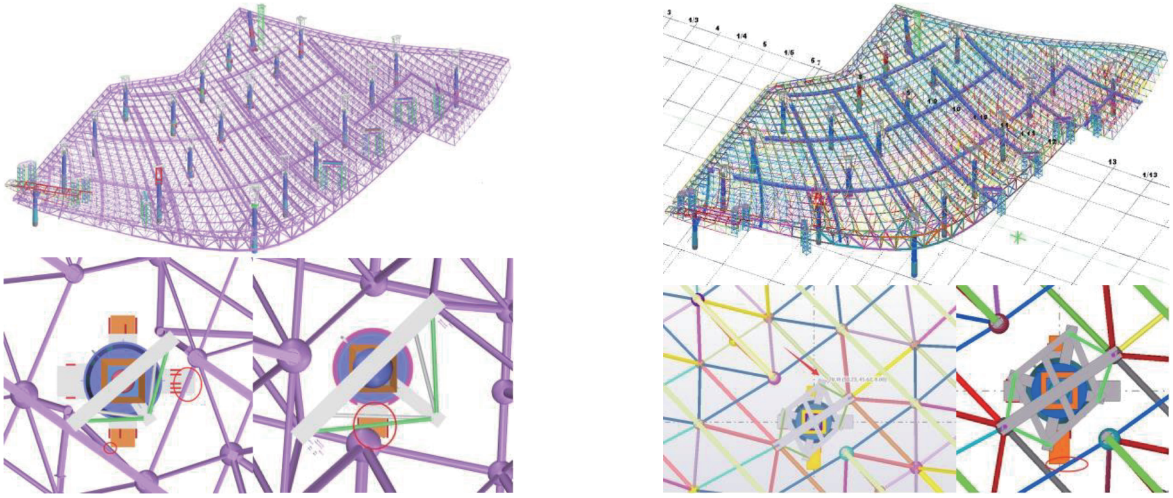


Figure 5 Diagram of the rotation and lifting scheme for the steel structure roof

BIM technology is applied to perform laying-off analysis of roof structure rotation, BIM models are used to extract the spatial coordinates of bottom chord nodes, the difference between each node and the ground is calculated in real time through motion simulation, and the difference between nodes and the position and angle of minimum rotation axis are obtained through testing. In order to achieve the goal of synchronous lifting of multiple lifting points, a hydraulic calculation control system is re-developed; by defining the total lifting stroke of all lifting points as S_1 - S_N, and the lifting rate corresponding to S_N as v_n, it can be obtained that the lifting speed at any other lifting point is $(S_i/S_n)\times v_n$; the lifting rate and unit stroke corresponding to each lifting point are input into the hydraulic calculation control system to achieve equal proportional lifting of multiple lifting points at different rates and avoid non-synchronization of the lifting points during the rotation and lifting process.

During the rotation and lifting process of the roof structure, the structural shape gradually changes from the assembly posture to the design posture, and rod interference will inevitably occur during the process. Therefore, rod collision analysis is particularly important. Considering the complexity of on-site construction, for example, if column top lifting frames are arranged on the original structural columns, the structural columns may also include corbels, steel bars and other components, and the only use of traditional collision analysis may ignore the influence of other disciplines or construction measures. Using the BIM-based model combination technology for rotation and lifting states, Tekla software is used to conduct rod collision analysis on the lifted structure and other structures (lifting frames, steel columns, corbels, steel bars) in the assembled and lifted states, and a certain safety distance is reserved to prevent on-site assembly errors and displacement of the actually lifted structure, which may lead to collision of rods. The mold combination collision analysis for the assembly posture and the design posture is shown in Figure 6.



(a) Assembly posture

(b) Design posture

Figure 6 Mold combination collision analysis

(2) Three-dimensional laser scanning technology is used to monitor the deformation of long-span roof steel structure.

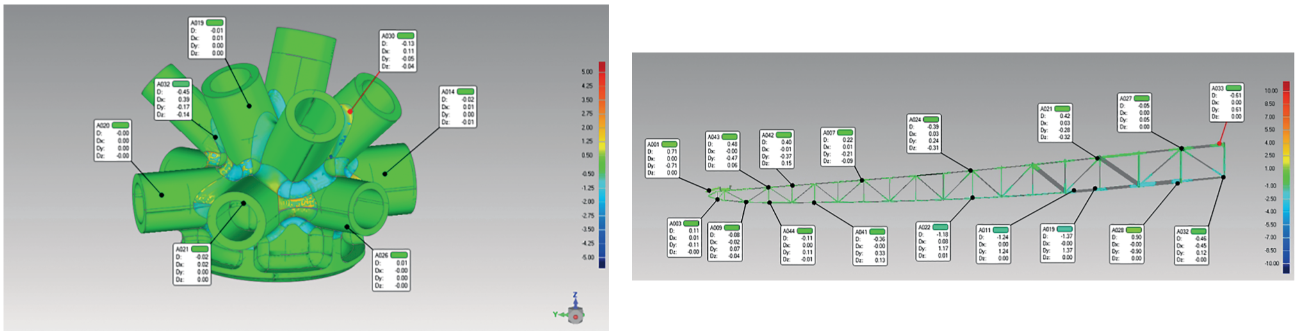
The roof steel structure of Hangzhouxi Railway Station is a hyperboloid as a whole, which is constructed by the "partitioned rotation + overall lifting" construction technology. Since traditional single-point measurement cannot effectively evaluate the posture in the process of rotation and lifting, and it is also difficult to express the shape and position of the structure after forming with the measurement results of local points, so three-dimensional laser scanning point cloud imaging measurement technology is used to conduct three-dimensional scanning and monitoring of the entire process from component processing, on-site assembly, rotation and lifting to structural unloading and forming to ensure the quality of project construction [11].

① Factory processing stage. Typical components and complex node components are selected for scanning, and the scanning results are compared with theoretical models to achieve geometric dimension detection of single components. For the roof steel castings, typical trusses in the central truss area and other nodes, a geometric model of the component is obtained through three-dimensional laser scanning (see Figure 7(a), Figure 7(b)), which fully demonstrates the manufacturing deviation of the component. Factory corrections are made according to the deviation analysis results, or engineering pre-adjustment is conducted for the components connected to it to avoid on-site trimming and installation failure.

② Virtual assembly stage. According to the on-site assembly sequence, the models are imported into the computer in sequence, the assembly process of solid components is simulated in the virtual environment, and problems that may arise during the installation process (such as misaligned interfaces of adjacent components, deviation of corbels, etc.) are analyzed. For those that do not meet the standard requirements, an adjustment plan for the components with deviations will be proposed during the factory processing stage.

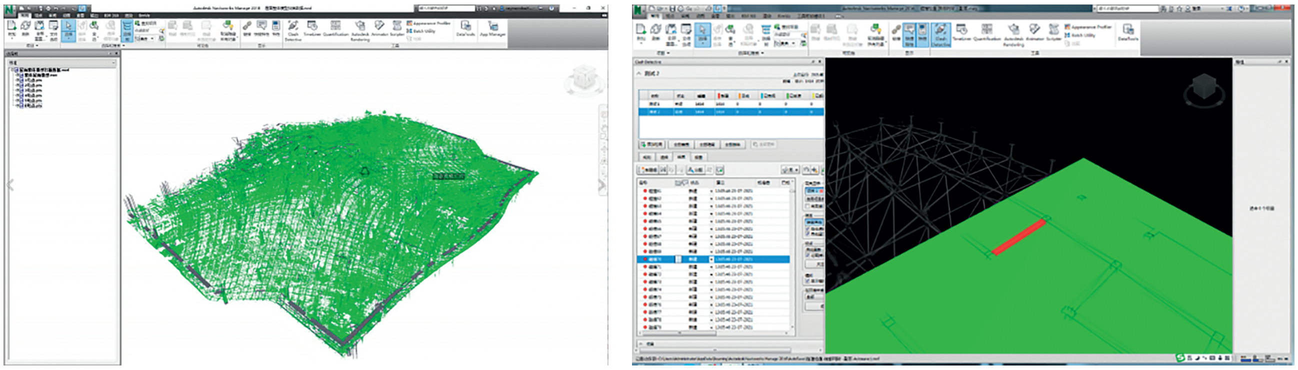
③ On-site installation stage. The junction position of the assembly blocks to obtain the on-site assembly errors. Based on the assembly errors, the deformation results of the construction simulation are accumulated and used as guidance data for processing of post-supplemental rods to avoid on-site secondary processing or repairs.

④ Structure forming stage. The point cloud model after structure forming is obtained by scanning (see Figure 7(c)), and the deviations of key points are analyzed and com-



(a) Steel casting nodes

(b) Typical trusses in central truss area



(c) Navisworks structure forming

(d) Roof model fitting

Figure 7 Deviation analysis results

pared with calculation results to verify and debug the simulation method. Meanwhile, the roof substructure deepening model and the structural forming model are fitted (see Figure 7(d)) to obtain the positions with large errors. The substructure is adjusted in the early stage to reduce on-site modification operations, improve installation quality, and speed up installation progress.

(3) Prefabricated construction technology is applied to plan the installation of the hyperboloid ticket check canopy and optimize the equipment layout of the machine room.

① Ticket gate in the waiting hall. The "hyperboloid glass + hyperboloid wood grain aluminum plate" canopy scheme is adopted to present the overall hyperboloid modeling effect (see Figure 8). Three-dimensional scanning is conducted for the steel keel and then deep modeling is carried out to better control the processing accuracy of the hyperboloid glass and the arc shape of the hyperboloid.

② Skirting boards of the ticket check canopy in the waiting hall. Hyperbolic arc skirting is used according to the overall appearance. The shape of the skirting is changeable, and in order to make the appearance color consistent with the stone, GRC skirting is selected after comprehensive comparison between stone and aluminum plate samples (see Figure 9). GRC skirting boards are prefabricated and have various shapes, and have good anti-fouling and anti-impact capabilities because they are made of fiber-added concrete.

③ Comprehensive overall layout of equipment and pipelines in the machine room. First, based on the two-dimensional drawings, three-dimensional sketch model is established by rationally planning and optimizing

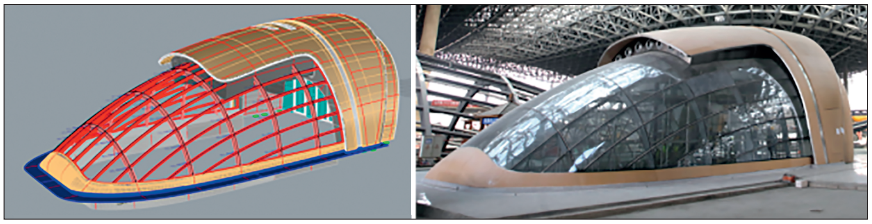


Figure 8 Detailed model and real scene of the ticket check canopy model

Figure 9 Detailed model and real scene of GRC skirting boards

the equipment layout and the pipeline arrangement. On this basis, a high-precision BIM model is formed by collecting manufacturers' technical indicators and specifications of the equipment, pipelines, valves, joints, flanges, etc. in the refrigeration machine room, measuring the installation environment of the machine room site, and taking into account civil construction deviations. On the basis of the detailed model, according to the on-site installation conditions and processing requirements, it is divided into pipe section modules and submitted to the processing plant for prefabrication. Taking the water pump as an example, its high-precision BIM model is shown in Figure 10.

The processed components are inspected to ensure that they meet the installation accuracy requirements. Before leaving the factory, the prefabricated pipe sections are protected properly and transported to the site, and an installation plan based on BIM technology is formulated based on the site conditions. After the plan is formed, technical disclosure is conducted on site, followed by installation, connection, commissioning, pipeline anti-corrosion and insulation, and finally submission for acceptance.

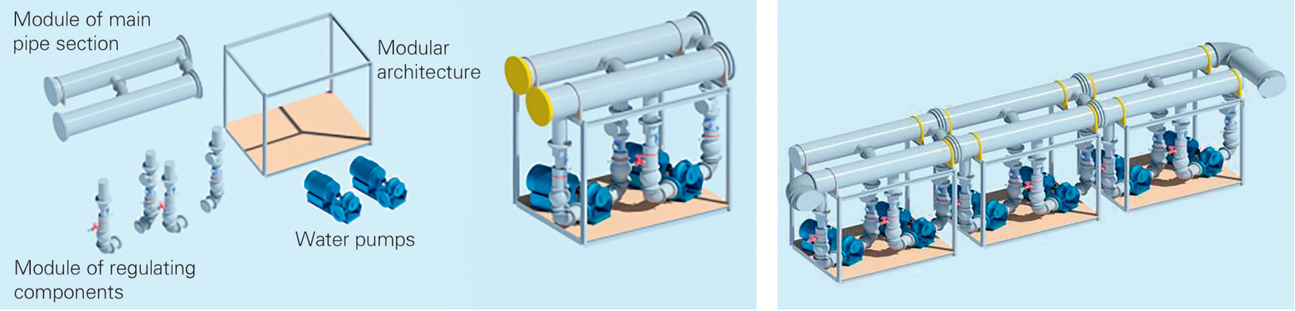
(4) Grid construction refined management technology.

According to the content and management needs of the Hangzhouxi Railway Station Project in different construction stages, it is divided into different grid units. Following the principles of balanced workload, fewer interfaces, full coverage, and relative fixation, the grid units are generally divided into six management stages: civil structure construction, steel structure construction, metal roof construction, curtain wall construction, mechanical and electrical installation, and decoration. According to the management level, each stage is divided into four levels: construction unit, construction bid section, construction team, and streamline section, and the relevant responsible persons are specified. A grid management platform is established to combine the components of BIM models of each grid unit, assign grid unit codes, establish the association between work tasks and grid units, and realize work flow section management [12]. The diagram of data association identification is shown in Figure 11.

In independent grid units, material allocation plans, labor demand plans, and construction plans are established, stimulated and optimized based on construction period goals. The grid management platform is used to track the progress of grid units and conduct progress deviation analysis to control unit construction quality, ensure construction period goals, ensure construction quality, and improve the management level.

5 Application Effects

(1) Economic benefits. Virtual assembly is used to replace traditional assembly to ensure the processing accuracy of steel components, which reduces the occupation period of 30 000 m^2 physical pre-assembly site by half a year, and saves RMB 600 000 Yuan in site rent. Virtual assembly eliminates the cumulative errors in the processing of individual components, reduces the construction period by



(a) Water pump single module (b) Water pump module connection

Figure 10 High-precision BIM model of water pump

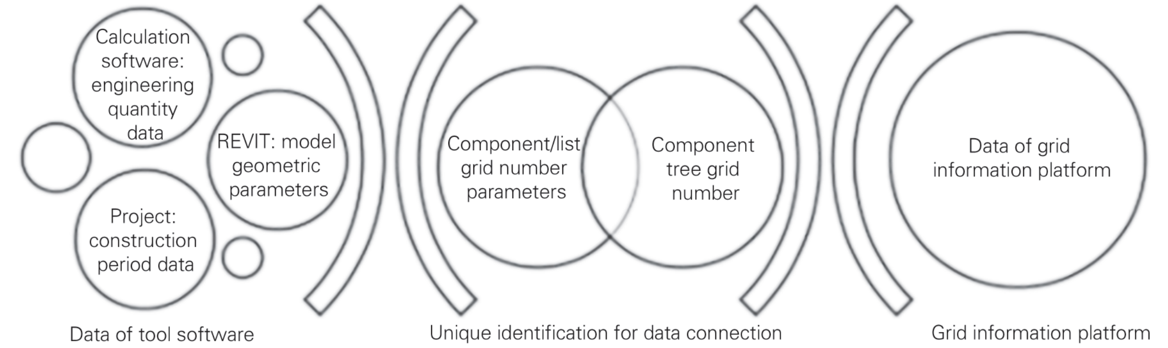


Figure 11 Diagram of data association identification

20 days, and saves more than RMB 5 million Yuan in additional expenses for rework materials; the three-dimensional laser point cloud scanning technology is used to improve the construction accuracy of assembly junctions and avoid on-site repairs, which reduces the inlay construction period by 5 days, and saves RMB 200 000 Yuan in additional expenses for materials; after the structure is formed, the overall point cloud scanning is conducted to effectively control the structural accuracy (mm level), and optimize the blanking of roof and curtain wall sub-components, which saves more than RMB 1 million Yuan in additional expenses for reworking; the visual deepening design of complex nodes is performed together with node construction simulation to discover and optimize more than 90 steel structure problems in advance, improve scheme comparison and selection, ensure the effect of technical disclosure, and avoid rework problems, which saves RMB 2.2 million Yuan in labor and material costs.

(2) Social benefits. As a supporting project for the 19th Asian Games in Hangzhou in 2022, Hangzhouxi Railway Station has an obvious regional demonstration effect and provides a reference for the intelligent construction of other station buildings in the region.

(3) Environmental benefits. The Project won the certificate of three-star green building design label.

6 Conclusions

Through the application of intelligent construction technology in Hangzhouxi Railway Station, a highly integrated BIM collaborative management platform was built. According to the key and difficult points of the Project, a technical route was developed for the intelligent construction of Hangzhouxi Railway Station, and research was carried out in such aspects as long-span curved surface structure improvement, steel structure construction monitoring, special-shaped ticket canopy construction, prefabricated machine room construction, and grid construction management, so as to gradually realize the digital, networked, and intelligent transformation of each business process of the Project, which has effectively improved the efficiency of construction management, achieved significant economic, social and environmental benefits, and provided reference experience for the construction of similar railway passenger transport hubs.

(Translated by QIAN Jun)

References

[1] LI Shengquan, ZHANG Qianghua. Discussion on the development model of large railway hubs in the high-speed railway era: from “transportation complex” to “urban complex” [J]. *Planners*, 2011, 27 (7): 26-30.

[2] XIE Bin, YANG Changqiong. Grid management of high-speed railway passenger station construction [J]. *Railway Transport and Economy*, 2015, 37 (9): 90-94.

[3] LIAO Yuping. Accelerate the transformation of the construction industry and promote high-quality development: interpretation of the *guiding opinions on promoting the coordinated development of intelligent construction and construction industrialization* [J]. *China Engineering & Consulting*, 2020 (9): 18-21.

[4] The Ministry of Housing and Urban-Rural Development of the People's Republic of China, the National Development and Reform Commission of the People's Republic of China, and the Ministry of Science and Technology of the People's Republic of China, etc. Guiding Opinions on the Coordinated Development of Intelligent Construction and Construction Industrialization: JSH. [2020] No. 60 [A]. Beijing, 2020.

[5] DING Lieyun. Intelligent construction promotes the transformation of the construction industry [N]. *China Construction News*, 2019-06-07 (8).

[6] XIAO Xuwen. Intelligent Construction Seeks Practical Results [N]. *China Construction News*, 2021-04-05 (4).

[7] QIAN Qihu. The field of engineering construction must move towards smart construction [J]. *Construction and Architecture*, 2020 (18): 17-18.

[8] MA Zhiliang. The way to highly intelligent construction [J]. *Construction Technology*, 2019, 48 (12): 1-3.

[9] XIE Yalong, WEI Qiang, WANG Wanqi, et al. In-depth research on the intelligent construction system of railway engineering [J]. *China Railway*, 2023 (1): 72-81.

[10] LIN Xin, TANG Binghong, PENG Hongliu. Application of intelligent management system and technology in railway construction engineering [J], *Railway Technical Innovation*, 2022 (5): 130-134.

[11] DU Liqiang, ZOU Haitao, TONG Yuchao, et al. Three-dimensional laser scanning deformation monitoring technology for long-span roof steel structure of Hangzhouxi Railway Station [J]. *Journal of Information Technology in Civil Engineering and Architecture*, 2022, 14 (4): 41-47.

[12] DU Liqiang, TONG Yuchao, YAN Xinjun, et al. Application of construction grid management based on 4D-BIM technology in Hangzhouxi Railway Station [J]. *Journal of Information Technology in Civil Engineering and Architecture*, 2022, 14 (2): 18-27.