BIM Forward Design Collaboration and Dynamic Construction Error Correction Technology for Highway Bridges

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Abstract: At present, in the process of highway and bridge construction in China, there are some problems such as low cooperation efficiency of various specialties, fault of information transmission, lag of error management and control in construction stage, and unclear positioning of industrial correction plan. This study takes BIM as the core, constructs information rules and standardization system of BIM model, and studies conflict detection and hierarchical processing methods. Then, the BIM model is combined with data acquisition to build a multi-dimensional construction error analysis and hierarchical early warning mechanism, which provides a rapid generation and optimization method for dynamic correction based on BIM. The research results will provide technical support for the digital control of the whole life cycle of highway bridges in China, and it is of great significance to improve the construction quality and accuracy of highway bridges.
***Keywords*:** highway bridge; BIM forward design synergy; construction error correction technology

1. Introduction

BIM technology is an important support to realize the digital transformation of engineering, and it has been widely adopted in recent years. Compared with the traditional two-dimensional drawing design mode, BIM technology takes three-dimensional parametric model as information carrier, which can integrate multi-dimensional information in the whole project, which lays a good foundation for multi-disciplinary collaborative work. However, at present, most of the applications of highway and bridge construction in China are still in the stage of reverse "flipping" of BIM, which does not play the role of BIM information, but also has problems such as poor information transmission, low collaboration efficiency, errors and omissions among various majors in the design stage, collision and deficiency discovery lag, which leads to the increase of design change cost. After entering the construction stage, the connection between the field measurement data and the design model is less and less. It is often after the handover or completion of the process that the error can be detected, and it is difficult to carry out dynamic control. At present, due to the lack of accurate data support, materials are wasted, the project schedule is delayed, and even the long-term safety of the bridge is threatened. Under this background, the research of forward design and construction error dynamic correction method based on BIM is in line with the technical characteristics of highway bridge engineering, and has very important practical significance for promoting the digital upgrading of highway bridge engineering and improving the construction quality.

2. BIM forward design collaboration technology for highway bridges

2.1 Construction of full-professional collaborative design process based on BIM

Building a full-professional collaborative design process based on BIM is the core link of forward design of highway bridges, which breaks through the information islands between various fields in traditional design, and realizes high integration and high efficiency collaboration. The process is based on BIM technology, and clarifies the division of responsibilities and collaborative interfaces of multi-disciplines (route, subgrade, pavement, bridge, tunnel, drainage, traffic safety facilities, electromechanical, etc.). In the design and planning stage, BIM technology is used to establish unified project standards, design schemes and final results, so as to ensure that all majors work together under the same framework. In the design and realization stage, the method of "central file + local file" or "end-to-end collaboration" is adopted, and professional designers design in parallel according to a unified BIM model, and upload the updated results in real time, so as to avoid the data delay caused by traditional serial design. In the design phase, develop the collaboration model of multiple phases, for example, complete the determination of the overall model in the scheme design phase, and carry out preliminary collaboration with various specialties [1]; In the preliminary design stage, in-depth modeling and comprehensive coordination of various specialties; During the design planning phase, patterns and information can be improved.

2.2 BIM model information depth and standardization system

The information depth and standardization system of BIM model is an important support to ensure the quality and efficiency of BIM forward design of highway bridges. It specifies the information content, detail level, information structure and expression method that BIM model should contain. For depth of information (LOD), geometric detail and geometric accuracy need to be measured. (Material properties, physical parameters, construction technology, technical specifications, cost, etc.) BIM model and application requirements (such as crash test, cost calculation, construction simulation, operation management, etc.) in various stages of highway and bridge engineering (scheme planning, preliminary planning, construction planning). For example, in the scheme design stage, LOD100-200 model focuses on the overall planning and large volume of the overall structure, while ROD300-400 requires the specific dimensions, connection methods and reinforcement information of components in the construction drawing design stage. The structure of standardization system mainly includes model naming specification, component classification coding specification, information parameter definition specification, model transfer specification, etc. Pattern names and category codes should be refined according to relevant national or industry norms and combined with engineering characteristics to ensure the uniqueness and identifiability of each module [2]. When defining information parameters, it is necessary to unify the names, data types and numerical ranges of general process parameters in order to achieve efficient information transmission and communication.

2.3 Conflict Detection and Management in Collaborative Design

In order to ensure the quality of BIM model and reduce design errors, false reports, collisions, etc., conflict detection and management in collaborative design is the key. The key is to identify and solve the design contradictions between different majors actively and in real time through BIM visualization and parameterization. In collision detection, there are rigid collision (physical geometric interface) and soft collision (insufficient distance, insufficient load, etc.). In terms of technical realization, the professional crash test software and modules are integrated on the BIM collaborative platform, and the corresponding test specifications are given. In terms of technical realization, the collision detection software and modules of each specialty are integrated on the BIM collaboration platform, and the collision detection criteria of each specialty (the minimum spacing between each specialty, the spacing required by the specification, etc.) are established, and the collision detection of the integrated model of each specialty is carried out on a regular basis or at key nodes. After the detection is completed, the system will generate a detailed conflict report containing the conflict location, conflict components, conflict types and severity, and accurately find the conflict points in the BIM model, which is convenient for designers to browse and analyze. Conflict management is a systematic process of identifying, classifying, evaluating, resolving and tracking conflicts. First, categorize the conflict reports and find out the factors causing the conflict, such as design errors, different understanding standards, unclear professional interface, etc.; Organizing relevant professional designers to evaluate them, clarify the priority of conflicts, and put forward corresponding solutions [3]; Communicate and collaborate on the platform, make corrections to relevant modules, and review the changes to ensure that conflicts can be handled effectively.

3. Dynamic correction technology of highway bridge construction error

3.1 Construction process BIM model and site data acquisition

The BIM model and on-site data acquisition in the construction process are the premise and foundation of dynamic correction of construction errors, aiming at establishing real-time data connection between virtual BIM model and physical construction process. Based on the BIM model, combined with the construction organization design, construction plan and the actual situation of the site, the BIM model of the construction process is established and adjusted. This model is also called "4D building simulation model" and "building execution model". The model contains the details of construction schedule, resource allocation, process arrangement, etc. It can simulate the whole construction process. On-site data acquisition uses a variety of advanced measurement means and sensing devices to acquire the key parameters in the project in real time. Commonly used measurement methods include total station, GNSS, 3D laser scanning, UAV surveying and mapping, Internet of Things sensors and mobile terminals. The method can accurately collect parameters such as geometric dimensions, spatial positions, installation accuracy, stress state, material properties and construction environment of components. The collected data is transmitted to BIM collaboration platform or special data management system through data interface, wireless network, etc., and compared with the design data in BIM model.

3.2 Construction error analysis and early warning mechanism

The analysis and early warning mechanism of construction error is the core link of dynamic correction technology of construction error. The main research contents include: through the comparative analysis of on-site measured data and

BIM model design data, identify the deviations in the construction process, warn the possible deviations in time, and ensure the construction quality and safety. Firstly, according to the characteristics of different structural forms (beams, columns, foundations, bridge decks, etc.) and construction (formwork assembly, rebar binding, concrete pouring, component hoisting, etc.), a scientific error analysis and evaluation index system is constructed, and suitable tolerance error range and deviation threshold are given. On this basis, the collected measured data (such as three-dimensional coordinates, dimensions, positions, etc.) are compared with the theoretical calculation results in BIM model, and the deviation size, direction and change trend of each monitoring point are obtained. Through statistical analysis, trend analysis and influencing factors analysis, the main causes of errors (such as measurement error, template deformation, improper design process, material shrinkage, environmental impact, etc.) are found out. When the deviation degree reaches or exceeds the preset alarm threshold after analysis, the system will issue a warning to project managers and farmers through platform information, SMS, e-mail, etc. The early warning data should include the early warning location, deviation value, deviation type, possible causes and suggested emergency measures, etc., so that the affected people can respond quickly, conduct verification and disposal, and avoid further spread of errors [4].

3.3 Dynamic Modification Scheme Generation and Optimization Based on BIM

The generation and optimization of dynamic correction scheme based on BIM is based on construction error analysis and early warning, and BIM technology is used to help formulate and optimize the adjustment scheme for construction deviation, so as to minimize the influence of deviation and ensure that the project meets the design requirements. After the early warning mechanism is activated, the technician will pinpoint the error in the BIM model and combine it with the failure analysis results to identify the kind of error. Decide the magnitude of the deviation. On the basis of the BIM model, the actual correction and documentation were carried out. Through real-time correction of the position, size, angle and other parameters of corresponding components in BIM model, and using BIM visualization function, the corrected results are visually displayed. At the same time, multiple schemes can be compared and selected, for example, the influence of different adjustment paths and different construction processes on the subsequent processes and the overall structure can be compared. In the process of scheme optimization, we should also consider the feasibility, cost-effectiveness, safety and impact on the whole project. The BIM model can quickly estimate the number of buildings required, material consumption, and the change of construction cycle, thus providing support for enterprise decision-making.

4. Conclusion

To sum up, highway bridge BIM is developing in the direction of multidisciplinary information interaction and efficient linking. Using standardized models and pre-conflict management as means, it can effectively solve the problems of information fracture and missing errors in traditional design, and greatly improve the design quality and efficiency. The dynamic correction technology of construction error combines the design model with the site construction data link to identify, warn and optimize the error in real time, and provide digital support for the construction precision control. The combination of the two technologies can provide new ideas and methods for the intelligent construction of highway bridges in China, and can also provide reference for the digital application of similar projects.

References

[1] Liu Nanmao. Three-dimensional real-life modeling of highway and bridge projects based on BIM [J]. Architecture Technology, 2025,56 (S1): 19-21.

[2] Shao Yuanhong. Application of BIM technology in highway bridge design system [J]. Engineering Technology Research, 2025,10 (21): 215-217.

[3] Yang Xiaochao. Exploration of full life cycle application of highway bridge based on BIM technology [J]. China Water Transportation, 2025, (17): 136-139.

[4] Wei Dong. Whole Process Practice of Highway Bridge Construction Based on BIM Technology [J]. Intelligent Building and Smart City, 2025, (07): 80-82.