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Application Strategies of BIM Support Technology in First-Class Highway Reconstruction and Expansion Projects

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Abstract: This article analyzes the application strategies of Building Information Modeling (BIM) support technology in a first-class highway reconstruction and expansion project based on its actual situation. According to the basic situation of BIM technology and its application goals in this project, it explores application strategies such as BIM model construction, BIM prefabricated structural model deepening and schedule simulation, BIM collision detection, and BIM tunnel pre-construction simulation. Through this analysis, it is hoped to provide a reference for the rational application of BIM support technology and ensure the high-quality and efficient completion of first-class highway reconstruction and expansion projects.

Keywords: First-class highway; Reconstruction and expansion project; BIM support technology; Model construction; Collision detection

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1. Introduction

In today's digital and information age, BIM technology has become a key support technology in the field of construction engineering. The reasonable introduction and application of BIM technology to first-class highway reconstruction and expansion projects, combined with the reasonable construction of BIM models, can effectively control their progress, quality, and safety. Under the premise of completing the reconstruction and expansion construction with quality and quantity guaranteed, it can reasonably save time and cost. Based on this, engineering units must have a sufficient understanding and attention to BIM technology, and adopt reasonable strategies to apply BIM technology based on the basic situation of first-class highway reconstruction and expansion projects and their actual application requirements. Only in this way can its application advantages be fully utilized, ensuring the implementation effectiveness of first-class highway reconstruction and expansion projects.

The subject of this study is the expansion and reconstruction project of the Xining-Huzhu first-grade highway, which has a total length of 42.78 km. Firstly, there is the in-situ expansion section, with a length of 25.75 km. According to the expansion design requirements, the engineering unit needs to expand the original 4 lanes in-situ to 6 lanes. Secondly, there is the newly built section, with a total length of 17.03 km, newly built in a 4 lane format. According to the overall construction arrangement of the project, the entire route needs to be divided into three sections. The first section is K5 + 300–K27 + 800 (XHSG-1), with a length of 22.5 km; the second section is K25 + 700 to K42 + 780.042 (XHSG-2), with a length of 17.08 km; and the third section is K0 + 000 to K5 + 300 (XHSG-3), with a length of 3.2 km. In this project, BIM technical support is mainly targeted at the design and construction of the second section (XHSG-2). This article mainly analyzed the application of BIM support technology in it.

2. BIM technology and its application goals

2.1. Introduction to BIM technology

BIM technology is an advanced technology and model that integrates and manages construction project information with the support of current advanced digital and visualization technologies. It comprehensively incorporates geometric information such as building project structure and equipment, as well as non-geometric information such as processes, costs, resources, and performance into BIM software. Through the construction and application of BIM models, it can provide digital technical support for various stages of the entire life cycle of construction projects, including structural design, construction plan formulation, material procurement, on-site construction management, and later operation and maintenance of construction projects [1].

2.2. Goals of BIM technology application

In this first-class highway reconstruction and expansion project, BIM technology serves as a crucial supporting technology with the following primary application goals.

During the engineering design phase, the main objective of BIM technology is to establish a comprehensive BIM information model for the second section (XHSG-2). This involves integrating three-dimensional information models of all bridges, interchanges, and tunnels into a unified model, including critical information such as location parameters, geometric parameters, and engineering materials. This digitizes the entire project foundation, providing information support for subsequent project management and maintenance. Additionally, it aims to further enhance the quality of engineering design through techniques like deep design of complex structures and three-dimensional visualization inspections.

In the construction phase, BIM technology is primarily used to carry out model refinement and progress simulation through prefabricated structure modeling. This clarifies the internal basics, reasonably adjusts and optimizes the design scheme through collision inspection, efficiently conveys the construction intent through three-dimensional clarification, provides guidance for on-site construction with the help of mobile terminals, reasonably improves construction quality, and shortens the construction cycle. In tunnel engineering, the main goal of BIM technology is to implement 4D simulation of the construction progress, analyze and grasp various construction difficulties, formulate targeted response plans, and improve the effect of tunnel construction.

During the operation and maintenance phase, the primary goal of BIM technology is to utilize the BIM models and all relevant parameters constructed during the project's design and construction as a foundation. By organically integrating various information such as energy consumption, assets, and monitoring, it aims to provide comprehensive and targeted data support for the subsequent operation and maintenance work of the project [2].

3. Application strategies of BIM technology in first-class highway reconstruction projects

3.1. BIM model construction strategy

In first-class highway reconstruction and expansion projects, the primary application strategy of BIM support technology is the reasonable construction of BIM models. During specific modeling, staff should use basic project information as a basis, combined with the initial design of various components in the project, to establish a comprehensive BIM model [3].

When constructing the BIM model for this project, the Bentley software supported by BIM technology was mainly used to establish a BIM model for the second section (XHSG-2) of the project. All professional information such as roads, bridges, tunnels, terrain, traffic safety, lighting, and drainage in this section was fully incorporated into the model. It included 17 large and medium-sized bridges, 2 interchanges, and 1 tunnel. The model construction mainly included location information, geometric information, and material information. The highway coordinate system was used as the plane coordinate system in modeling, the 1985 national elevation datum was used as the elevation system in modeling, and the Xi' 80 ellipsoid parameters and the central meridian of the 102° east longitude projection zone were used as the engineering coordinate system in modeling. The projection surface elevations were 2330 m and 2600 m, respectively. Finally, the coordinates under different projection zones were fully translated to the 2330 m projection surface, forming a complete set of highway coordinate systems. Based on this, combined with specific design parameters and on-site actual conditions, the refined establishment of each structural model was completed in the Bentley software platform support software.

During the construction of the bridge model, for instance, the route's horizontal, vertical, and transverse designs are first created using the Powercivil function in the platform, completing the construction of a three-dimensional route model. Constraint parameters are reasonably set to ensure an adaptive transition effect between various complex cross-sections. Then, using the Open Roads Designer function, a terrain model is established based on the bridge's centerline. With the help of the Open Bridge Modeler function, a parametric model of the overall bridge structure is quickly constructed, significantly improving modeling efficiency. Finally, the constructed bridge model is imported into the RM-Bridge module with one click to calculate structural performance, significantly improving design quality and efficiency. **Figure 1** shows a BIM 3D model of a bridge in the project.

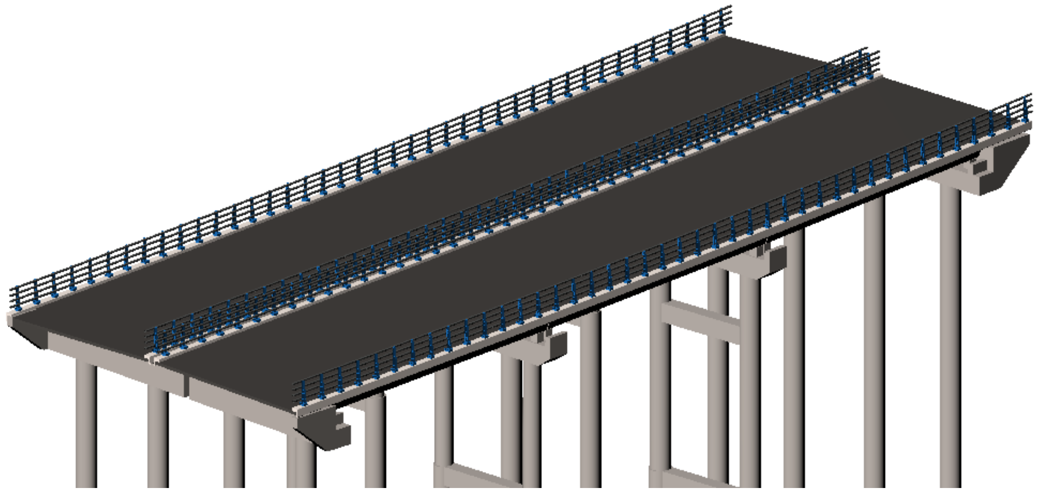

Figure 1. BIM 3D model of a bridge in the project.

3.2. BIM prefabricated structural model deepening and schedule simulation strategy

For prefabricated structures in first-class highway reconstruction and expansion projects, effective model deepening and schedule simulation can be implemented with BIM technology support to ensure the quality of structural design and schedule control effects.

In this project, the prefabricated structures were mainly including bridges, culverts, and retaining walls. To achieve good structural deepening and schedule simulation effects, based on the prefabricated design drawings of each structure, the detailed models of internal reinforcement and interfaces are constructed with the help of Bentley software supported by BIM. For unreasonable parts such as collisions between models, precise adjustments can be made in the BIM model [4]. At the same time, according to the determined prefabricated construction steps, the model construction is reasonably split, and the entire prefabricated structure's construction steps and timeline are simulated with the help of the schedule simulation software Synchro Pro.

During the BIM deepening and simulation of prefabricated retaining walls, a 1:1 model was created using Bentley software based on the design drawings. Key information such as concrete usage and arrangement rules for each structural type was extracted from the model. Pre-assembly simulation was carried out ahead of time using this software. After optimizing the simulation, the final model was sent to the construction unit, providing digital and visual guidance for on-site construction. Each prefabricated retaining wall component was modeled with detailed numbering and attribute information added, facilitating efficient model positioning, real-time viewing of component and on-site construction information. Additionally, with the help of Synchro Pro software, the construction of prefabricated retaining walls was simulated according to the construction schedule control requirements, and corresponding lifting animations were created. The visual and vivid display of the assembly process provided technical support for subsequent construction schedule control.

3.3. BIM collision detection strategy

In the expansion project of a first-class highway, collision detection is a key application direction of BIM supporting technology. Based on BIM model construction simulation, corresponding collision problems can be discovered in a timely manner. Reasonable optimization of the corresponding structural layout can be made based on the BIM model, which can effectively avoid collision problems in subsequent actual construction and ensure project progress and quality [5].

In this project, the ProStructures function in Bentley software was mainly used to perform collision detection on areas where installation conflicts occurred in prefabricated structures. Based on the specific detection results and combined with the actual structural layout, reasonable optimization was implemented to ensure the smooth progress of subsequent installation and construction [6].

During the BIM simulation analysis of the prefabricated structure of this project, it was found that the flange and vertical steel structure of a certain bridge were prone to collision conflicts. Therefore, with the support of ProStructures functionality, specialized collision detection and optimization processing were implemented for the bridge, comprehensively eliminating potential collision issues during the subsequent installation and construction of the prefabricated structure. This provided strong technical support for the efficiency, quality, safety, and cost control of the bridge installation and construction [7].

3.4. BIM tunnel pre-construction simulation strategy

For first-tier highway reconstruction and expansion projects, tunnels are a key and difficult engineering component [8]. Therefore, in the application process of BIM supporting technology, engineering units should also combine the actual situation of the engineering project and its design standards, and use BIM models to implement pre-construction simulations of tunnels. This allows for timely identification of potential problems in subsequent construction, makes reasonable optimizations based on the BIM model, and generates high-quality construction simulation animations to provide professional and visual guidance for subsequent tunnel construction operations.

There is only one tunnel in this project. During the pre-construction simulation, the ProStructures functional module in the Bentley software was mainly used to implement the pre-construction simulation for this tunnel section [9]. A 1:1 BIM model was established for the lighting, cable trench, and anchor rod systems in this tunnel section, and deep modeling was implemented for key parts such as road markings. At the same time, Synchro software was introduced to implement a 4D simulation of the tunnel construction progress. The simulation confirmed that there were no serious conflicts, collisions, or safety issues in the original construction plan, and the engineering unit could strictly follow the original plan for construction. On this basis, the specialized animation and rendering software 3Ds max was introduced. With the support of this software, high-quality simulation animations of the tunnel construction process were created and generated, enabling intuitive and vivid display of the overall tunnel construction process. This can provide professional and modern technical support for the smooth implementation of subsequent tunnel construction. **Figure 2** shows the BIM deep design model diagram of the tunnel section of this project.

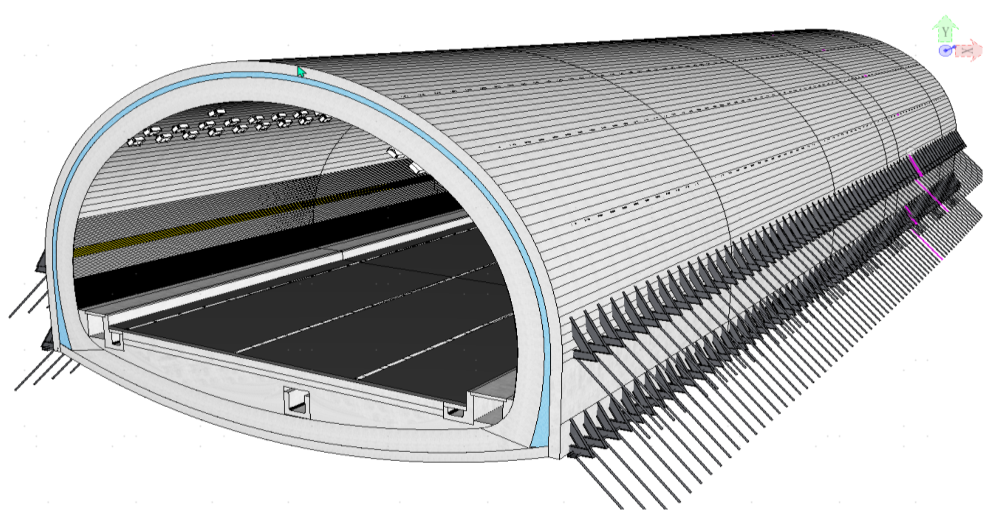

Figure 2. BIM deepened design model diagram of tunnel section of the project.

4. Application effects of BIM technology in the first-class highway reconstruction project

In this first-class highway reconstruction and expansion project, BIM technology demonstrated excellent application effects.

Firstly, with the support of BIM technology, the complete BIM foundation model construction of the second section (XHSG-2) of the project was completed. All structural information, basic information, and other critical information within the scope of this section were comprehensively incorporated into the BIM model, establishing a digital foundation for the overall engineering project and providing digital information support for subsequent construction, maintenance, and management work [10].

Secondly, with the support of BIM technology, deepened design was implemented for key structures such as prefabricated bridges, bridges and culverts, and retaining walls in the project. Through prefabricated construction simulation analysis, three-dimensional visual technical clarification was provided to the construction unit, enabling efficient communication of the design intent for the prefabricated structures in the project. This laid a solid technical foundation for improving overall construction quality and shortening the construction duration.

Finally, with the assistance of BIM technology support software, visual inspection and optimization of collisions during project construction were carried out. At the same time, pre-construction simulation was achieved for the key tunnel construction of the project. This enabled subsequent formal construction to proceed safely, orderly, and smoothly, successfully avoiding many quality and safety hazards, and effectively controlling overall construction and engineering costs.

Thus, it is evident that BIM supporting technology has significant advantages in the process of reconstructing and expanding first-class highways for this project. The rational application of this technology to subsequent similar projects can provide important support for controlling the quality, progress, safety, and cost of the entire construction process.

5. Conclusion

In summary, BIM technology is a critical supporting technology in modern construction engineering. The rational application of this technology to first-class highway reconstruction and expansion projects, through the reasonable construction of BIM models and digital simulation of various key processes, can reasonably optimize various aspects such as engineering design, construction organization plans, and on-site construction management, enabling the smooth implementation of first-class highway reconstruction and expansion projects.

In future first-class highway reconstruction and expansion projects, BIM technology will develop towards a more green and intelligent direction, thus better adapting to the reconstruction and expansion goals and development plans of first-class highway engineering.

Disclosure statement

The author declares no conflict of interest.

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