Process Simulation and Technical Improvement of Hanging Basket Construction in Municipal Road and Bridge Projects Based on BIM Technology

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Abstract: Against the backdrop of the accelerating urbanization process, the scale of municipal road and bridge construction has expanded accordingly, and the technical difficulty of construction has also increased. Hanging basket construction is a key technology in municipal road and bridge construction, and its complexity and riskiness pose high requirements for project management. With its advantages of visualization and collaboration, BIM technology can simulate the hanging basket construction process and optimize the technology. This paper takes BIM technology as the core of discussion, analyzes the importance of BIM technology in the hanging basket construction of municipal road and bridge projects, and proposes process simulation plans and technical improvement strategies for hanging basket construction in municipal road and bridge projects under BIM technology, such as refined structural design, 4D visual simulation of the construction process, construction early warning, and dynamic resource management, providing clear guidance for the intelligent construction of municipal road and bridge projects.

1. Introduction

Municipal road and bridge projects are an important part of the urban transportation network, and their construction quality is closely related to urban construction and development. Hanging basket construction is a commonly used construction technology that does not require the erection of scaffolding and has strong spanning advantages, making it widely applied in the field of municipal road and bridge construction. However, the traditional hanging basket construction process is complex, and safety hazards are prone to occur during construction. The application of BIM technology can integrate various types of information throughout the project construction cycle, providing reliable technical support for the planning, construction, operation, and maintenance of municipal road and bridge projects. It is a necessary measure to improve the construction quality and efficiency of municipal road and bridge projects.

2. The Importance of BIM Technology in the Hanging Basket Construction of Municipal Road and Bridge Projects

2.1 Reducing Construction Safety Risks

There are many potential safety risks associated with the hanging basket construction of municipal road and bridge projects, and the use of BIM technology can effectively reduce the probability of such risks. At the initial stage of hanging basket construction, BIM technology can present complete elements such as the surrounding environment and hanging basket equipment through precise three-dimensional models, and identify conflict issues in advance during the simulation of the installation and removal of the hanging basket. In addition, BIM technology can create a virtualized hanging basket construction scene, enabling construction personnel to intuitively understand the risk elements and operation points of each link, thereby reducing safety accidents caused by human operational errors from the source.

2.2 Minimizing Process Conflicts

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The application of BIM technology in the hanging basket construction of municipal road and bridge projects can eliminate conflicts between various construction links. By associating the construction progress with the three-dimensional model, managers can understand the progress of each process in real time through the continuously updated construction progress, promptly identify process conflicts, and effectively deal with them. After discovering problems, the construction plan can be adjusted immediately and resources can be reallocated, creating favorable conditions for the smooth progress of construction [1]. Furthermore, the BIM model can integrate various types of information in the hanging basket construction. When process conflicts occur, targeted solutions can be formulated with reference to the model information, improving the efficiency of construction management decision-making.

2.3 Improving Construction Collaboration Efficiency

The reasonable application of BIM technology in the hanging basket construction of municipal road and bridge projects can effectively improve construction collaboration efficiency. Hanging basket construction in municipal road and bridge projects requires close cooperation among various specialties and work types. With the support of the visualization advantages of BIM technology, an integrated construction information model can be established, helping construction personnel to identify design conflicts in a timely manner. Under the supervision of multi-party collaboration, the construction period of the hanging basket in municipal road and bridge projects can be shortened and cost investment can be reduced, truly improving construction collaboration efficiency.

3. Process Simulation of Hanging Basket Construction in Municipal Road and Bridge Projects Based on BIM Technology

3.1 Three-Dimensional Model Construction and Visual Process Instruction

In the process simulation of hanging basket construction in municipal road and bridge projects based on BIM technology, the construction of a three-dimensional model and visual process instruction are core links. The BIM platform can establish a three-dimensional digital model of the main body of the road and bridge and the hanging basket system through high-precision surveying and mapping data and structural parameters. The model integrates key elements such as bridge alignment, prestressed system, hanging basket traveling track, and anchoring nodes, achieving precise reproduction of geometric dimensions, material properties, and spatial relationships. Visual process instruction can be carried out through virtual pre-assembly using the BIM model to check for spatial conflicts between various components and solve problems such as the interference between prestressed pipes and steel bars in advance. During instruction, software such as Navisworks or Fuzor can be used to create construction animations, simulating the entire set of process flows including the traveling, anchoring, formwork adjustment, concrete pouring, prestressed tensioning, and forward movement of the hanging basket, enabling construction personnel to clearly understand the operation essentials, safety key points, and spatial relationships of each step. Construction personnel can use mobile terminal devices to check the information at any time, ensuring construction accuracy and safety and safeguarding construction quality and fine management level.

3.2 Construction Process Clash Detection

In the process simulation of hanging basket construction in municipal road and bridge projects, clash detection based on BIM technology is mainly achieved through the construction of a high-precision three-dimensional model for full-process dynamic review. Navisworks software is used for comprehensive analysis of hard and soft clashes, and the Timeliner function is used to simulate dynamic construction processes such as the traveling of the hanging basket and concrete pouring to detect temporal and spatial conflicts between the tower crane's operating radius and the hanging basket structure, avoiding mechanical collision risks. This technology has shortened the pre-assembly time of the hanging basket from 20 days in traditional methods to 10 days, reduced

on-site communication errors through visual instruction, and cooperated with the BIM platform to achieve closed-loop management of quality and safety issues, significantly improving the safety and economy of the construction of bridges with irregular structures. In terms of process clash identification, dynamic conflicts in the time sequence can be detected, such as the overlap between the extended boom of the concrete pump truck and the monitoring equipment under construction or the motion envelope of adjacent hanging baskets at the same time. The inspection results are output in the form of a visual report, highlighting the location, type, and affected processes of the clash points, guiding technicians to optimize the hanging basket design, revise the construction plan, or coordinate the work sequence of multiple work types.

3.3 Construction Progress and Dynamic Resource Management

In the process simulation of hanging basket construction in municipal road and bridge projects based on BIM technology, construction progress and dynamic resource management achieve a deep integration of digitization, visualization, and refinement. By establishing a 4D-BIM model containing geometric information and time attributes, key processes such as the assembly, preloading, and segmental concrete pouring of the hanging basket can be closely associated with the progress plan, simulating the entire construction time sequence flow in a dynamic three-dimensional visual manner, and intuitively displaying the project image progress at different time nodes, thereby identifying progress conflicts in advance, optimizing the construction sequence, and ensuring that key path nodes are under control. At the resource management level, by linking with the progress plan, the BIM model can automatically generate resource requirement plans for labor, materials, and mechanical equipment, and achieve dynamic simulation and visual query based on time [2]. The BIM model integrates resource information such as manpower, materials, and mechanical equipment, and can automatically generate resource demand curves in combination with the progress plan, dynamically displaying resource data such as the number of workers, concrete volume, and the number of hanging basket equipment required at each construction stage, and achieving deviation warnings through comparison with the actual progress. In addition, BIM technology also supports collaborative management among multiple participants. Design, construction, supervision, and other units can view the progress and resource dynamics in real time through the same platform, achieving information transparency and ultimately improving the overall efficiency and economic benefits of the hanging basket construction in municipal road and bridge projects.

4. Technical Improvement Strategies for Hanging Basket Construction in Municipal Road and Bridge Projects Based on BIM Technology

4.1 Refined Structural Design of the Hanging Basket Based on BIM Technology

In the technical improvement of hanging basket construction in municipal road and bridge projects, the refined design strategy based on BIM technology focuses on building a parametric model and full-process collaborative management. Construction units should use the BIM model for virtual rehearsals to identify spatial conflicts between the guide beam system and the ballast system in advance and shorten the hanging basket assembly cycle as much as possible. On this basis, construction units should use BIM technology in combination with finite element analysis software to conduct simulation calculations and visual simulations of the stress distribution, deformation deflection, and stability of the hanging basket under various most unfavorable working conditions in a virtual environment, thereby proactively optimizing structural weak links. All design data, calculation sheets, and simulation animations are integrated into a unified BIM collaborative platform, achieving seamless data flow and sharing among design, calculation, and construction preparation links, and providing guarantees for subsequent digital prefabrication, automated monitoring, and lean project management.

4.2 4D Visual Simulation of the Construction Process Based on BIM Technology

The 4D visual simulation of the hanging basket construction process in municipal road and bridge projects based on BIM technology requires a deep integration of three-dimensional models and the time dimension to achieve dynamic simulation of the construction process and risk early warning. Construction units should use software such as Revit and Civil 3D to establish refined three-dimensional models of the main bridge structure, hanging basket system, temporary supports, and surrounding environment. Associate construction parameters with the model and simulate different working conditions through dynamic parameter adjustments. Clearly mark major hazard sources in the BIM model and achieve risk visualization early warning in combination with Internet of Things sensors. Construction units should also decompose each cycle of the hanging basket construction into detailed processes and precisely associate the decomposed processes with the corresponding BIM model components in terms of time,assign the model with time dimension attributes to form a 4D construction simulation animation. To ensure the effectiveness of dynamic simulation, a collaborative work mechanism should be established, and clear data delivery standards for all parties should be defined. This can transform the traditional hanging basket construction management model that relies on experience into a data-driven intelligent decision-making model, significantly improving the construction management capabilities of municipal road and bridge projects.

4.3 Hanging Basket Construction Early Warning and Monitoring Based on the Combination of BIM Technology and Sensors

In the hanging basket construction of municipal road and bridge projects, the deep integration of BIM technology and sensors mainly takes the BIM model as the data carrier, collects key parameters in real time through sensors, and combines algorithm analysis to achieve dynamic early warning. First, construction enterprises should build a high-precision model of hanging basket construction based on the BIM platform, covering core components such as the load-bearing system, anchoring system, and suspension system, and associate sensor points. Deploy strain sensors at key nodes of the hanging basket main truss to monitor structural stress in real time [3]. Displacement sensors can also be installed in the traveling system to track the movement trajectory of the hanging basket. The BIM platform visually presents early warning information through methods such as color rendering and animation simulation. When sensor data exceeds the limit, the corresponding model components should be automatically marked in red and flash, and a pop-up early warning window should display specific parameters, locations, and suggested measures. In addition, construction units should establish a three-level intelligent early warning mechanism: Level 1 early warning occurs when the monitored data exceeds 80% of the theoretical calculated value but does not exceed the limit. The system automatically sends a prompt to remind technicians to pay attention to trend changes. Level 2 early warning is initiated when the data exceeds 90% of the theoretical value or the rate of change is abnormal, and the system locates the abnormal point through the BIM model. Level 3 early warning is issued when the data approaches or exceeds the design allowable value, and the system immediately sends out the highest-level audible and visual alarms and automatically suspends relevant high-risk operations, providing a critical time window for emergency decision-making and personnel evacuation. All monitoring data, early warning records, and disposal measures are permanently stored in the BIM-associated database, forming a traceable electronic archive. Project participants can collaborate on a unified platform according to their permissions, improving management efficiency.

4.4 Collaborative Management Based on BIM Technology

In the hanging basket construction of municipal road and bridge projects, the collaborative management strategy based on BIM technology can achieve a deep integration of design, construction, monitoring, and other links by constructing a digital collaborative platform for all elements. Construction units should carry out Revit modeling and Midas-Civil mechanical simulations to accurately predict the stress and strain changes at each construction stage and identify in advance the anchoring risks between the hanging basket traveling system and the poured beam sections. During the hanging basket assembly stage, virtual assembly rehearsals can be

carried out using the BIM model, and animation demonstrations of the assembly sequence of the main truss, traveling system, and anchoring system can guide on-site workers in standardized operations. During the concrete pouring stage, the model can automatically calculate the concrete volume of each section and generate a dynamic procurement plan in combination with material inventory data to avoid construction stoppages due to material shortages. During the quality acceptance stage, by comparing and analyzing the model with on-site measured data, areas with out-of-limit deviations can be quickly located, and rectification task orders can be generated and pushed to the construction team. On this basis, construction units should use Internet of Things technology to integrate real-time data from stress sensors and displacement monitoring points with the BIM model. During the traveling and pouring of the hanging basket, the model dynamically displays the stress and deformation monitoring data of key parts and compares them with theoretical calculated values. When data abnormalities are found, the problem points can be quickly located to assist technicians in remote diagnosis and decision-making, keeping the construction process under control.

4.5 Dynamic Resource Management Based on BIM Technology

In the hanging basket construction of municipal road and bridge projects, BIM technology provides an innovative path for dynamic resource management. Construction units should establish a resource requirement database for each stage of hanging basket construction based on the high-precision geometric information and construction process parameters of the BIM model. They should also use the integration advantages of Internet of Things sensors and the BIM platform to perceive the on-site resource status in real time and make dynamic adjustments [4]. The construction big data accumulated by BIM technology provides decision support for resource management, simulating the economy of different resource allocation plans and providing quantitative basis for project decision-making. In addition, construction units can use RFID, QR codes, sensors, and other Internet of Things technologies to monitor key resources in real time. The BIM model based on the cloud platform enables owners, supervisors, construction units, subcontractors, and other parties to work collaboratively on a unified interface. When on-site progress, design changes, or weather factors cause plan changes, the platform can quickly update the model and progress. The system can automatically analyze the impact of changes on subsequent resource requirements and generate early warnings and adjustment suggestions. This enables managers to make scientific decisions and dynamically adjust resource procurement, supply, and allocation plans.

5. Conclusion

In conclusion, the hanging basket construction technology in the field of municipal road and bridge construction can effectively improve the quality and efficiency of project construction. The application of BIM technology in the hanging basket construction of municipal road and bridge projects can help construction personnel understand potential problems in the construction links in advance, effectively avoiding rework and delays in the construction process, and fundamentally improving construction efficiency. Therefore, the hanging basket construction of municipal road and bridge projects should deeply explore technical optimization strategies under BIM technology to provide strong support for the intelligent development of the municipal road and bridge construction industry.

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