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

Jie He

Anhui Province Urban Construction Design & Research Institute Co., Ltd., Jiangxi Branch, Nanchang, Jiangxi, 330003, China

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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 highway bridge engineering is an important part of urban transportation system construction quality and quality is also closely related to the development of urban construction. Hanging basket construction is a kind of mature construction technology, which does not need to erect scaffolding and has great spanning advantages, so it is widely used in municipal road and bridge constructions. The common sense of hanging basket construction is complicated, and the safety hazards in construction are easy to appear. BIM technology can integrate the information of various elements in that cycle into one environment during the project construction and provide reliable technical support to realize life-cycle planning, construction, operation, and maintenance of municipal road bridge projects. It is a must-do work that will 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

The hanging basket construction of municipal road and bridge projects has many potential safety risks, and the combination of building information modeling (BIM) technology can significantly reduce the probability of such risks. During the early construction stage of hanging basket, BIM technology can be applied to realize the three-dimensional model display of complete elements such as surrounding environment and hanging basket equipment, and then solve conflict problems in advance based on the simulation effect of multidimensional visualization during the installation and removal process of hanging basket. Moreover, BIM technology can build a virtualized hanging basket construction scene that allows the construction personnel to intuitively know the risk elements and operation points of each link in order to eliminate hidden dangers caused by human operational errors from the source.

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2.2 Minimizing Process Conflicts

With the development of BIM technology, we believe that by putting it into the hanging basket construction of municipal road and bridge projects can avoid conflicts between different construction links. As the construction progresses, the dynamically updated construction progress is mapped to the three-dimensional model. This mapping allows managers to grasp how process steps are proceeding in real time, and thus respond better and faster when conflicts occur. Once problems are found, which can avoid future problems in the course of construction, construction layout and human resource allocation can be adjusted in time to create favorable conditions for the smooth progress of construction [1]. More vigorously, in hanging basket construction, the BIM model can be adopt with different categories of information. When conflicts arise among construction processes, it can be analyzed documentation-based and solutions are rationally prepared on behalf of the information in the model to ensure more effective decisions in construction management process.

2.3 Improving Construction Collaboration Efficiency

The reasonable use of BIM technology in the hanging basket construction of municipal road and bridge projects can effectively improve the efficiency of construction collaboration. 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. As for the detection of process conflicts, dynamic conflicts in terms of time sequence can be detected, such as detecting whether there is a collision between the extension boom of surrounding concrete pump truck and the monitoring equipment under construction or at some time, there are overlapping motion envelope between adjacent hanging baskets. Inspection results are output as a visual report that identifies the position, nature and impacted process of the clash points to assist technicians in optimizing hanging basket design, amending construction plans or coordinating the work sequence between multiple works types.

3.3 Construction Progress and Dynamic Resource Management

Based on BIM technology, the dynamic resource management and construction progress of hanging basket composite simulated construction process simulation realize a comprehensive integration of digitization, visualization and refinement. Establishing a 4D-BIM model which contains geometric information and time attributes of elements, can adequately connect important processes such as assembly, preloading or segmental concrete pouring of the hanging basket with progress plan; allows construction time sequence flow simulation in dynamic three-dimensional visual forms;display project imagery progress at a certain temporal node intuitively; realize conflict identification among statistical results during control implementation period; optimize construction sequence and keep controlling on key path nodes. For example, from the perspective of resource management, linked with the progress plan, the BIM model can automatically generate relative plan on required labor, materials and mechanical equipment, as well as dynamic simulation and visual query based on time [2]. The BIM model realizes the integration of resources information (manpower, material and mechanical equipment), in conjunction with the progress plan, can automatically output resource demand curves to intuitively show the dynamic change data of construction resources such as quantity of workers, concrete volume and number of hanging basket equipment needed at each construction stage; achieve deviation warning by comparing with real-time actual progress. What is more, the BIM technology allows also to work together with a few participants in management. Design, construction, and supervision and other units can also share the same platform to view real-time progress and resource dynamics as well as real time transparency of information so that the process will be more timely optimized, thus achieving full informatization benefits for municipal road and bridge projects hanging basket construction in all aspects from design phase construction stage supervision offer a new way of thinking about design management coordinate.

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 this study, the refined design strategy including parametric model construction and full-process collaborative management was established based on BIM technology for the technical improvement of hanging basket construction in municipal road and bridge projects. Construction units are required to rely on the BIM model for virtual rehearsal to find in advance the spatial conflicts between the guide beam system and ballast system so that it can shorten the hanging basket assembly cycle. Therefore construction units should carry out simulation calculation and visual simulation of the stress distribution, deformation deflection and stability of hanging basket facing various most unfavorable working conditions in virtual environment based on BIM technology combined with finite element analysis software to optimize structural weak links actively. The design data, calculation sheets and simulation animations of all general engineering

projects are integrated into a unified BIM collaborative platform to realize the seamless flow and sharing between the links of design, calculation and construction preparation with data, so as to provide support for subsequent digital prefabrication, automated monitoring and lean project management.

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

The construction process and risk early warning of the 4D visual simulation of freestanding basket construction in municipal road and bridge projects based on BIM technology require a deep integration between the three-dimensional model and the time dimension, thus achieving dynamic simulation of the construction process. Construction units should utilize Revit, Civil 3D and other software to build accurate three-dimensional models of the main bridge body, hanging basket system, temporary supporting structure, surrounding environment. Dynamically change parameters like "hard seal vision", associate construction parameters with the model; follow with integrity simulation of states of work respectively. Through risk screening, the major hazard sources in the BIM model are clearly marked, and through the combination with Internet of Things sensors to achieve early warning of risk visualization. Structural cycle of the hanging basket construction Construction unit It decomposes each cycle of the hanging basket construction into a detailed process with precise time and spatial association,doing time attribution modeling on individual components of BIM model and forming four-dimensional (4D)constructing simulation animation. The establishment of a collaborative work mechanism is essential to ensure the effectiveness of dynamic simulation, and clear data delivery standards for various parties should also be defined. This can turn the traditional experience-based penetration model of construction management into a data-driven intelligent decision-making model, greatly enhancing the construction management level of municipal road and bridge projects.

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

The deep integration of BIM technology and sensors is carried out in the hanging basket construction of municipal road and bridge projects. It mainly takes the BIM model as the data carrier, collects key parameters in real time through sensor, and combines algorithm analysis to realize dynamic early warning. The audit recommendation is that construction enterprises base the BIM platform to build a high-precision model for hanging basket construction, including core components such as load-bearing system, anchoring system and suspension system, and associated sensor points. Real-time monitoring of the structural stress response at key nodes in the main truss framework of a hanging basket can be achieved with implementing strain sensors [3]. The displacement sensor is also mounted in the traveling system to monitor the hanging basket movement trajectory. The BIM platform consists of showing early warning information in image form by color rendering and animation simulation. Limit exceed sensor data should automatically be marked in red and flash, model components that are seen have exceeded their limit. This triggers a pop-up early warning window to populate with the relevant parameters, locations and suggested countermeasures. Provide a three-level intelligent early warning mechanism for construction units: Level 1 Early Warning when the monitored data does not exceed the limit, but with over 80% of the theoretical calculated value. The system will send an auto single and reminder to the technicians regarding paying attention for trend change. Level 2 early warning is triggered when the data reaches a range greater than 90% of the theoretical value or when the rate of change is abnormal, and identifies the abnormal point through the BIM model. Level 3 EWS (emergency warning system) is issued when the data approaches or exceeds its design allowable value, and at this point, an audible alarm and visual alarm of the highest level is immediately activated to suspend related high-risk operations automatically with precious time for emergency decision-making and personnel evacuation. The BIM-associated database enables storage of all monitoring data, early warning records and disposal measures in a traceable electronic archive. Project participants can work on a single platform, subject to their permission, making management more efficient.

4.4 Collaborative Management Based on BIM Technology

Multi strategy central collaborative management can realize the deep integration of design, construction, monitoring and other links in municipal road and bridge projects constructed with widespread hanging baskets by constructing a digital collaborative platform for all elements based on BIM technology. 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. In the quality acceptance stage, fast-location out-of-limit deviations based on comparison and analysis of the model and on-site measured data; generation and push-repair task orders to construction personnel. Based on this, for construction units, it is necessary to apply Internet of Things technology to fuse the data monitored by stress sensors and displacement monitoring points with the BIM model in real time. The model performed in real-time stress and deformation monitoring data for key parts under the exerted forces: Traveling and pouring of the hanging basket compared to theoretical calculated values. It can quickly locate the problem points when abnormal data is found, so as to help the technicians conduct remote diagnosis and decision-making, so that the construction process can be controlled.

4.5 Dynamic Resource Management Based on BIM Technology

BIM technology shows a new way for the dynamic management of manufacturing resources in the hanging basket construction of municipal road and bridge projects. Based on the high-precision geometric information of the BIM model and construction process parameters, construction units are encouraged to establish a database of resource requirements for each stage of hanging basket construction. In addition, they should also operate the while making full use of the integration advantages of Internet of Things sensors as well as the BIM platform to achieve real-time and dynamic perception about on-site resource statuses [4]. The big data of construction formed by BIM technology provides decision support for resource management, simulating the economic situation of different resource allocation plans and providing quantitative basis for project decision-making. So construction units can even monitor resources in real-time through RFID, QR codes, sensors and other IoT technology. The cloud-based BIM model provides owners, supervisors, construction units and subcontractors with collaboration capabilities on the same platform. Where on-site updates, design changes or weather influences make alterations to the plan, it can register any updates easily onto the model and progress. This configuration can make some changes to automatically analyze the impact of future resource requirements and provide early warnings and adjustment suggestions. This empowers managers to make scientifically-backed decisions and adjust plans for procuring, supplying and allocating resources on the fly.

5. Conclusion

To sum up, the technology of constructing hanging baskets in municipal road and bridge construction can effectively enhance the quality & efficiency of project construction. The application of BIM technology in municipal road and bridge projects hanging basket construction can let the construction personnel to avoid the hidden trouble link construction problem in advance, thus when constructing avoids repeated work and delays on the time, fundamentally optimize the efficiency of building. This paper explores technical optimization strategies for the construction and development of municipal road projects under BIM technology, in order to provide a strong support for the intelligent development of municipal road construction industry in the future.

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