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Application Strategy of BIM Technology in the Forward Design of Bridges

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Abstract: Bridge engineering is highly specialized and has spatial characteristics, which puts forward higher requirements for design work. The advancement of information technology has provided ample tools to facilitate bridge design work, with building information modeling (BIM) technology being one of them. BIM technology ensures the efficiency and quality of the forward design of bridges, while also reducing construction costs. This article starts with defining the concept of BIM technology, followed by a discussion on its advantages in bridge design and application process, which serves as a reference for other bridge designers.

Keywords: BIM technology; Bridge; Forward design; Application strategy

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1. Introduction

In bridge design, BIM technology is utilized to analyze building information and create a digital model that represents the building's life cycle. This involves simulating the physical structure through a digital model by analyzing data, building and analyzing the model, performing calculations in three-dimensional space, and integrating building information. This information is then transferred through the design, construction, and maintenance phases. The use of BIM technology is crucial for the forward design of bridges.

2. Related concepts

(1) BIM technology

BIM technology involves using information tools to create a building model, update drawings in real-time, analyze design data, and manage drawing information. This technology significantly enhances the efficiency of construction projects. As BIM technology rapidly evolves, its scope and capabilities continue to expand and become more sophisticated. Currently, BIM technology is often used in the three-dimensional modeling of construction projects. It integrates project design, construction, operation, maintenance, and data into a comprehensive 3D model. By collecting, storing, analyzing, and providing feedback on information, BIM offers an information platform for project construction and management. This ensures timely information acquisition throughout the construction process and aids in project execution through visualization. BIM technology is widely used in road, bridge, and integrated pipeline projects [1].

(2) Forward design

As the name suggests, forward design is a concept in contrast to flip design, leveraging BIM to conduct proactive engineering design. This involves using a BIM 3D environment to analyze the construction needs of engineering projects, compare design solutions, assess the reasonableness of design choices, and evaluate component dimensions. Additionally, it can be used to visualize and simulate construction processes, optimize designs, and output results. Forward design provides robust support for the advancement of BIM design in 3D, centralizing engineering information to enhance and support design work.

3. The advantages of applying BIM technology in the forward design of bridges

(1) Design information sharing

BIM technology enables the sharing of design information, which improves team collaboration and accelerates the design process. It enables the integration and coordinated management of bridge information, allowing designers to use a cloud platform to update and share design data, ensuring the coordination of design schemes across multiple disciplines. The visual model improves the communication of design issues and strengthens the rationality of design decisions. The BIM platform automatically records design changes, helping designers review and track modifications, thereby ensuring design quality. Additionally, the BIM platform's support and interaction with other systems boost work efficiency. Through standardization and modularization, the design team can flexibly create bridge component models and efficiently complete design tasks via information sharing [2].

(2) Ensuring design quality

Applying BIM technology to bridge design significantly enhances design quality. Traditional design software is prone to mistakes in analyzing spatial intersections of plane models in the design stage. In contrast, BIM technology employs three-dimensional modeling for bridge information, visualizing design content, and helping designers identify structural defects. The clash detection function in BIM allows for the identification and resolution of design issues through repeated modifications, thereby improving design quality. Additionally, BIM enables visualization of the geometric space of the bridge structure, supporting designers in analyzing structural forces, simulating the construction process, providing construction guidance, and ensuring the overall design quality of the bridge.

(3) Improving design efficiency

In the bridge design stage, the application of BIM is crucial for ensuring design efficiency. Due to its modularity, parameterization, and visualization features, BIM can present design information through three-dimensional models, allowing designers to understand design schemes intuitively and facilitate communication. Additionally, BIM supports collaborative design across different disciplines, enabling timely information updates and reducing the error rate. Design parameterization allows designers to flexibly modify model parameters and optimize design schemes. Furthermore, the automatic detection function helps identify and resolve design issues early in the process, advancing the threshold for engineering quality control. Designers can use pre-configured modular components and standardized components to reduce repetitive design. By adopting the BIM software, the design information is concentrated in one model, which facilitates the tracking of project design and ensures design efficiency.

4. Application of BIM technology in bridge forward design

(1) Establishing a three-dimensional model

The process of forward design of bridges begins with the establishment of a three-dimensional model. This model visually represents the bridge's structure and frame size, allowing engineering designers and other personnel to gain a comprehensive understanding of the project. In bridge engineering modeling, emphasis is placed on creating models of points, lines, surfaces, and volumes, which can be combined to construct complex geometries. In the design stage, data related to the bridge are input into the software according to the specifications. Given the linear nature of bridge models, designers can use Civil3D to process the three-dimensional route and construct the model with the assistance of the Dynamo software, transforming two-dimensional data into a three-dimensional model. We can build adaptive families using Revit software. Adaptive families can be built using Revit software, and Dynamo can locate components based on specified elevations and distances, leveraging the advantages of software parameterization to create the bridge's superstructure efficiently. For the substructure, Revit parameters can also be utilized for modeling. Dynamo software facilitates batch placement of component models, enhancing modeling speed and obtaining precise component positioning information. After completing the modeling, the design scheme and component positioning data are compared to verify the feasibility of the positioning, ensuring accuracy and consistency in the bridge design [3].

(2) Model calculation and analysis

When applying BIM for forward design, designers need to determine key position information such as prefabricated structures, cast-in-place structures, expansion joints, and piers of the bridge based on the actual bridge conditions. This information is then imported into the software to create a three-dimensional model. Once the modeling is complete, the entire model is calculated to analyze the effectiveness of the key node model establishment. Due to the complexity of bridge components, repeated design during modeling can increase the model's computational load and impact design effectiveness. To address this, it is essential to use three-dimensional software to simplify the design process and reduce modeling effort. For instance, when using SolidWorks to build the bridge structure and prestress model, data from the NADS/MIDAS software can be imported to automatically generate the structural model. Designers can then input information such as the number of steel sections and materials into the platform, enabling quick generation of the structural model. This approach ensures that the analysis of the bridge structure aligns with the real model and software calculation results, thereby improving design efficiency and ensuring consistency.

(3) Statistical work volume information

BIM technology allows the virtual splicing of the bridge design. By creating a splicing model within BIM and adjusting it based on information collected on-site, the construction process can be fine-tuned accordingly. BIM serves as a comprehensive database rich with bridge information, providing detailed project quantity information to construction participants and aiding various construction stages. In contrast to traditional design methods, which often rely on manual calculations for engineering quantities, forward design with BIM allows for computerized quantity tracking. This method ensures accurate engineering quantity statistics and reduces the error rate associated with manual operations by using classification extraction based on the information database. For example, in the design of Block 0 of a prestressed box girder bridge, utilizing BIM technology for forward design allows for precise and efficient management of project quantities and facilitates accurate on-site construction adjustments. Given that prestressed steel beams, concrete, and ordinary steel reinforcement are the primary materials for bridge construction, BIM technology facilitates efficient quantity counting by categorizing materials based on their attributes within the model. By leveraging these attributes, the system can automatically generate quantity information in a clear and organized format. This information can be presented visually, aiding in rapid statistics and ensuring compliance with design program requirements. Additionally, the system can generate sample drawings automatically, further enhancing clarity and facilitating accurate quantity calculations [4].

(4) Model data interaction

Data interaction is crucial in bridge design, construction, and maintenance. Through BIM model data interaction, multi-party collaboration and information sharing can be realized. Utilizing cloud platforms, participants in bridge engineering can share, access, and update bridge data models in real-time, fostering efficient communication in a collaborative environment. This setup enables the flexibility to update design solutions as needed. During data interaction, strict screening and management of model data are implemented to prevent the loss of design information. Software versions are meticulously managed to assist users in tracking the history of data changes. This approach allows different professional design teams to closely cooperate, update, and share information within the same model, promoting collaborative design efforts. BIM software facilitates data exchange, enabling integration of the bridge model with other systems such as cost estimation and structural analysis. This integration streamlines the sharing of professional data and ensures multi-party interaction throughout the design process, enhancing overall efficiency and effectiveness.

(5) Model positioning verification

To verify the accuracy of BIM model positioning, field measurements can be conducted to obtain data on bridge beams, plates, piers, and other components at different positions. This data includes component size, elevation, and coordinate information. Subsequently, this information is compared with the corresponding components in the BIM model and the disparities between the modeled and real information are analyzed. Adjustments are then made to the model based on the results to enhance its accuracy. Model adjustment may involve modifying the shape, position, and size of components. After optimization, the model undergoes re-verification. Through iterative correction processes, modeling accuracy is improved to ensure that the verified results are applicable to construction. Feedback on the verification results is then provided to the design team, guiding the subsequent application of BIM technology in modeling tasks. This feedback loop ensures continuous improvement and refinement of the BIM model for accurate representation of the bridge structure.

(6) Clash detection

As bridge structures grow increasingly complex and design requirements become more stringent, traditional two-dimensional design drawings may struggle to capture all necessary details. This can lead to undetected defects in the design, necessitating changes during construction [6]. However, by adopting BIM technology for forward design in bridge engineering, on-site bridge models can be created using advanced technical tools. Furthermore, clash detection can be conducted to identify potential conflicts within the bridge structure, such as clashes between steel bundles and rebars. Clash detection enables prompt adjustments of the modes and further optimization of the plan to prevent structural clashes during construction, thereby ensuring both quality and safety. This integrated approach enhances overall project management and minimizes risks associated with complex bridge structures [7].

(7) Sorting out component information

To facilitate component search and management in bridge design, a component library is organized based on bridge types and structural compositions. Structural components of bridges, such as prestressed elements, caps, upper and lower structures, and basic structures, are categorized accordingly. These components are then developed into parametric models within BIM applications, capturing connection relationships, materials, and shapes. Parametric modeling allows for convenient adjustments and demonstrates the model's versatility [8]. For efficient component search and management, designers must name and encode all components in the library to ensure that the model accurately reflects component materials, sizes, and types. Additional attribute information, such as design years, materials, and manufacturers, should be incorporated to provide team members with a comprehensive understanding of component characteristics. This facilitates informed component selection during engineering design, construction, and management processes, with 3D model preview diagrams aiding in component visualization [9]. During the construction of the component library, integration of component models, classifications, attributes, and preview diagrams is essential. This integrated information is typically presented through spreadsheets, BIM software component libraries, and databases. Regular updates to the component library are necessary to ensure that information remains current, meeting the diverse needs of different personnel involved in bridge projects.

(8) Output design results

In the initial application of BIM technology, it is necessary to establish standardized templates and output standards, covering fonts, drawing formats, and table styles, to ensure professional and consistent output content. BIM software is used to extract model information such as plane, component, and elevation, which is used as the basis for the generation of two-dimensional drawings or documents. Standardized templates are then formulated based on these output results to meet the needs of all departments involved. Output results can be presented in various formats such as DWG, PDF, and IFC, among others. Before finalizing the output results, thorough review and proofreading should be conducted to ensure the completeness and accuracy of the design outcomes [10]. During the model inspection, the design specifications and standards should be shared with other teams to ensure that can access and share design results. Additionally, timely backup and archiving of design data should be carried out for future modifications or reference.

5. Conclusion

Bridge engineering design is relatively complex, and the application of BIM technology to carry out forward design can reduce the risks involved and ensure the safety of the bridge structure. In the forward design of bridges, designers are required to establish a three-dimensional model for the bridge, analyze and calculate the model, count the engineering quantity information, complete the interaction and verification of the data model, analyze whether there are defects in the design through clash detection, comprehensively sort out the component information, and finally output the design results to provide support for the bridge construction.

Disclosure statement

The author declares no conflict of interest.

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