Practical Exploration of BIM Technology in Construction Quality Control of Building Engineering

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Abstract: Based on the actual requirements of construction quality control in building engineering, this paper analyzes the application process of BIM technology in quality control (including establishing a BIM model for construction quality control, conducting pre-construction quality pre-control simulation analysis, implementing dynamic quality tracking during construction, and performing quality acceptance and archiving at the completion stage) and practical optimization strategies (optimizing the model data update mechanism, strengthening integration with quality inspection technologies, improving the closed-loop management of quality issues, and optimizing quality control permission allocation). It examines how BIM technology resolves issues such as scattered data and insufficient risk prediction in traditional quality control through digital and visual means. The paper summarizes key operational points for the practical application of BIM technology and expounds on its practical value in enhancing the precision and efficiency of construction quality management, aiming to provide references for the modernization and upgrading of construction quality control in building engineering.

1. Introduction

Currently, building engineering is developing towards large-scale and complex directions. The traditional construction quality control model, which relies on manual inspections and paper-based records, is gradually facing challenges such as difficulty in predicting quality risks, imprecise process control, and low efficiency in problem tracing, making it difficult to meet the demands for high-quality construction. As a digital management and control tool, BIM technology offers new paths for construction quality control with its advantages of parametric modeling, visual simulation, and data-driven collaboration. This paper focuses on the specific application process and practical optimization strategies of BIM technology in construction quality control, aiming to clarify the operational logic of BIM technology implementation, address pain points in practical applications, promote the full integration of BIM technology into the entire process of construction quality management, and contribute to improving the quality level of building engineering.

2. Application Process of BIM Technology in Construction Quality Control of Building Engineering

2.1 Establishing a BIM Model for Construction Quality Control

During the data integration phase, it is necessary to collect basic data such as design drawings, current construction quality acceptance specifications, and material performance parameters. Use data format conversion tools to uniformly incorporate scattered data into BIM modeling software to avoid data discontinuities. Define parameters by adding quality control parameters for each component in the model. For example, for wall components, define the allowable value of thickness deviation and the error range of verticality; for pipeline components, specify the pipe diameter specifications and interface sealing grades, ensuring that parameters fully correspond to acceptance standards. Embed quality control nodes by setting quality inspection points at key parts of the

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model and annotating inspection items, inspection methods, and pass criteria. Conduct model validation by organizing a joint review of the model by the design, construction, and supervision parties, focusing on verifying the accuracy of component parameters and the completeness of quality nodes. Promptly correct any parameter errors or node omissions discovered to ensure that the model can directly serve as a digital benchmark for subsequent quality management and control, avoiding quality management and control failures due to model deviations.

2.2 Pre-construction Quality Pre-control Simulation Analysis

Screen key processes by sorting out processes with high technical difficulty and significant quality risks based on project characteristics and prioritizing simulation analysis to ensure that resources are concentrated on high-risk links. Set simulation parameters by inputting process construction parameters into BIM software and associating them with quality acceptance standards to create a simulation environment consistent with actual construction scenarios. When simulating pipeline layouts, input the sizes and installation elevations of pipelines from various disciplines to ensure that simulation results closely match reality. Conduct simulations and risk identification by using the dynamic simulation function of the software to restore the process construction process, focusing on identifying design conflicts, construction difficulties, and potential quality risks, and marking and analyzing the causes of problems discovered during the simulation. Formulate pre-control plans by developing solutions based on identified risks, combining construction experience and technical specifications. Optimize pipeline routes for pipeline collision problems and formulate temperature control measures for concrete crack risks. Embed pre-control plans into the BIM model and synchronize them with all participating parties to ensure that all parties are aware of risk prevention and control points before construction.

2.3 Dynamic Quality Tracking during Construction

Build a data collection channel by equipping on-site management personnel with devices loaded with BIM mobile applications. Use the scanning function of the mobile applications to associate with model components and collect quality data on-site. When collecting data, simultaneously upload on-site photos or videos as evidence to ensure data authenticity. Then, conduct real-time data comparison by having the mobile applications automatically upload the collected on-site data to the BIM platform. The platform generates deviation analysis reports by comparing the measured data with the standard parameters in the model using built-in algorithms. For example, when the measured value of steel bar spacing exceeds the allowable deviation range, the system automatically marks the component and indicates the deviation value. Subsequently, initiate deviation warnings by having the system issue graded warnings for quality issues that exceed allowable deviations, clearly specifying the problem location, deviation situation, and rectification requirements in the warning information to ensure that the responsible party is promptly informed. Implement rectification closure by having construction teams formulate rectification measures based on warning information and carry them out. After rectification, upload the rectified data and image materials through the mobile applications. Supervisory personnel conduct online reviews, and the system eliminates warnings after the review is qualified to avoid the accumulation of quality issues.

2.4 Quality Acceptance and Archiving at the Completion Stage

Conduct model-entity comparison by having acceptance personnel locate the parts to be accepted through the BIM model and compare the actual engineering with the model one by one, including component dimensions, installation positions, and material specifications. Mark the comparison results in the model during the comparison process and record the deviation situations of non-conforming items in detail and require rectification. Implement special quality acceptance by conducting special inspections on key indicators such as structural safety and usability in conjunction with the BIM model. Use the structural component coordinates exported from the model for total station instrument verification and use the pipeline parameters in the model to check pipeline pressure test results to ensure that acceptance data is consistent with model parameters. Generate acceptance reports by having the BIM platform automatically generate digital acceptance reports based on the comparison results and test data. The reports should include the acceptance scope, acceptance items, test data, pass situations, and rectification situations, and the report format should comply with archival management specifications and can be directly used for completion acceptance filing[1]. During the data archiving phase, associate the quality data throughout the entire construction process with the corresponding components in the BIM model to form a digital model archive containing complete quality information. At the same time, export paper and electronic archives according to archival management requirements. Electronic archives should be stored in an encrypted manner to ensure the completeness, security, and traceability of the archives and provide data support for subsequent engineering operation and maintenance.

3. Practical Optimization Strategies for BIM Technology in Construction Quality Control of Building Engineering

3.1 Optimizing the BIM Model Data Update Mechanism

Formulate data update rules by clarifying scenarios that require updates such as construction changes (design drawing modifications, process adjustments) and material replacements (main material brand changes, specification adjustments), and specifying data update time limits for different scenarios. For urgent changes, complete updates within 24 hours, and for general changes, complete them within 48 hours. Unified change notice forms should be associated with model component IDs and annotate change content and basis and other data update formats[2]. Set up update trigger mechanisms by building a change application module in the BIM platform. When the construction party initiates a change application, automatically trigger the model update process, and the system simultaneously notifies the design and supervision parties to participate in the review to avoid update delays caused by manual transmission. Conduct review and validation by having the design party be responsible for verifying the compliance of change content and the supervision party for verifying the impact of changes on quality. After the review is passed, modeling personnel update the model data in the platform, and the system automatically generates data change logs after the update, recording the updater, update time, and change content[3]. Achieve synchronous feedback by having the platform automatically send update reminders to all participating parties after the model update is completed and simultaneously open the viewing permissions of the updated model to ensure that on-site personnel such as construction and supervision personnel promptly obtain the latest model data and avoid quality management and control deviations due to data lag.

3.2 Strengthening the Integration of BIM and Quality Inspection Technologies

During the technology adaptation phase, select appropriate inspection technologies according to quality inspection requirements, such as the rebound method for structural entity inspection, total stations for geometric dimension inspection, and ultrasonic flaw detectors for concealed work inspection. Confirm the data output formats (XML, CSV) of inspection equipment to ensure compatibility with the data interfaces of the BIM platform. If necessary, realize data format conversion by developing middleware[4]. Build data docking channels by establishing wireless transmission links (Wi-Fi, Bluetooth) between inspection equipment and the BIM platform. After inspection, the equipment automatically uploads the original inspection data (rebound values, coordinate deviations, flaw detection images) to the platform, which associates the inspection data with the model according to component IDs to form a one-to-one correspondence between "components - inspection data". Conduct automatic comparison and analysis by having the platform built-in comparison algorithms for inspection data and model standard values to compare the coordinates of components measured by the total station with the design coordinates in the model and calculate position deviations; compare the concrete strength values detected by the rebound method with the standard values corresponding to the concrete strength grades in the model to determine whether they meet the standards. After comparison, generate visual inspection reports[5]. Implement result application by marking "pass" for qualified components and archiving the data;

for non-conforming components, the system automatically associates the model to locate the problem location and pushes it to the construction party to formulate rectification plans. Re-inspect until qualified after rectification.

3.3 Improving the Closed-loop Management of BIM Quality Issues

Standardize the problem reporting process by requiring on-site personnel to upload photos and videos of quality issues when discovering them through the BIM mobile applications, annotate the model components where the problems are located, the problem types (dimension deviations, material defects, installation errors), and the severity levels (general, relatively severe, severe), and submit them. The system automatically generates a unique problem number and simultaneously pushes it to the responsible unit[6]. Implement classified and graded disposal by formulating disposal priorities according to the severity of problems, responding within 24 hours for severe problems, 48 hours for relatively severe problems, and 72 hours for general problems. Clarify responsibilities at all levels, with construction teams responsible for rectifying general problems, project departments responsible for coordinating relatively severe problems, and companies responsible for disposing of severe problems to avoid responsibility shirking. Track rectification progress by having the responsible units submit rectification plans in the platform, including rectification measures, completion time limits, and responsible persons. During the rectification process, regularly upload progress photos. Supervisory personnel view the rectification situation in real-time through the platform, and the system automatically upgrades warnings for problems that are overdue without rectification[7]. Conduct review and archiving by having the responsible units apply for review after rectification is completed. Supervisory personnel conduct on-site reviews and upload the review results in the platform. If the review is qualified, mark the problem as "closed-loop" and archive all process data such as reported records, rectification plans, and review results to the BIM model; if the review is unqualified, return it for re-rectification until the problem is completely resolved.

3.4 Optimizing BIM Quality Control Permission Allocation

Sort out the responsibilities of all parties by clarifying the specific work of participating parties such as construction, supervision, design, and other parties in quality control. The construction unit is responsible for overall supervision, the construction unit is responsible for problem rectification, the supervision unit is responsible for review and acceptance, and the design unit is responsible for technical support. List the types of quality data required by each participating party, such as construction parties needing to view component standard parameters, supervision parties needing to view inspection data and rectification records, and construction parties needing to view overall quality status reports[8]. Conduct refined permission division by setting permissions in the permission management module of the BIM platform according to the three-level structure of "participating party - role - permission". The construction team role only has permissions to view quality data and report problems for the components in the areas they are responsible for; the supervision engineer role has permissions to view quality data for the entire project, review problems, and approve rectifications; the management personnel role of the construction unit has permissions to view quality reports and receive warning information. At the same time, set permission validity periods to avoid long-term permission idleness[9]. Implement dynamic adjustments by having permission administrators promptly update platform permissions when the roles of participating parties change or work scopes are adjusted, reclaim the permissions of the original roles, and assign permissions of new roles to ensure that permissions match actual responsibilities.

4. Conclusion

Based on the above analysis, it can be seen that the application of BIM technology in construction quality control of building engineering should take full-process management and control as the core and realize value implementation through standardized application processes and targeted optimization strategies. At the application process level, from BIM model establishment and pre-control simulation before construction to dynamic tracking during construction and then to quality acceptance and archiving after completion, a quality management and control chain covering the "pre-event - in-event - post-event" stages has been formed, resolving the issue of data fragmentation in various stages of traditional management and control. The practical optimization strategies complement the shortcomings in BIM applications from four key dimensions: data update, technology integration, problem management, and permission allocation. For example, ensuring data timeliness through the model data update mechanism, improving inspection precision through integration with inspection technologies, ensuring problem rectification in place through closed-loop management, and balancing data sharing and security through permission allocation. These strategies jointly promote the transformation of BIM technology from "tool application" to "systematic management and control", effectively improving the efficiency of construction quality control.

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