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

At present, building engineering is going in the direction of scale and complexity. The good old construction quality control models that rely on expensive manual inspections and word-of-mouth checks are becoming less feasible with the emergence of a host of new challenges around unexpectedly high-quality risks, imprecise process controls, and sub-par problem tracing efficiencies from increasingly higher demand for high-quality construction. BIM technology, featuring parametric modeling, visual simulation and data-driven collaboration has opened up new avenues for construction quality control, as a digital management and control tool. This paper addresses the operational logic of BIM technology during the construction quality control process, combining practical optimization suggestions for application and management of BIM technology, with the aim to refine pain points in practical applications, promote the comprehensive integration of BIM technology into all aspects involved in construction quality management efforts, and assist in improving building engineering quality levels.

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

2.1 Establishing a BIM Model for Construction Quality Control

In the data integration stage, it needs to collect basic data such as design drawings, current construction quality acceptance specification and material performance parameters. Use data format conversion tool, to convert scattered data into an integrated model in BIM modeling software, and avoid data discontinuities. Define parameters by adding quality control parameters for individual components in the model. Such as for wall components, define the allowable value of thickness deviation and verticality tolerance; for pipeline components, clarify pipe diameter specifications and interface sealing grades to ensure parameters are fully mapped to acceptance standards. Insert the

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quality control nodes at key parts of your model through setting up quality inspection points, and respective annotations with inspection item(s), inspection method(s) and pass criteria. Perform a model validation through a collaborative review of the model by the design, construction and supervision parties to verify that component parameters are correct and quality nodes are complete Immediately correct any errors in parameters or omissions of nodes that are detected to make the model directly serve as a true digital reference point for future quality management and control, thereby avoiding quality management and control failures caused by deviations from the model.

2.2 Pre-construction Quality Pre-control Simulation Analysis

Either sort the key processes with high technical difficulty and serious quality risk according to project characteristics or emphasize simulation analysis to ensure that resources are concentrated on high-risk links. Simulation of engineering quality controls: Input the process construction parameters to be set into the BIM software, associate with quality acceptance standards in BIM software, and finally we can get an example simulation: simulate a process where we will have a near-perfect environment that more closely resembles actual construction scenarios. While simulating pipeline layouts, you should feed the dimensions and installation heights of pipelines from different disciplines so that simulation results closely reflect reality. Dynamic simulation function of the software to rebuild the process construction process, identify design conflicts, construction difficulties and potential quality risks, for problems discovered during the simulation to be marked and tracked analysis. Precontrol plans through the development of solutions based on identified risks (crossing construction experience and technical data). Establish pipeline routing optimization for pipeline collision issues and temperature control against concrete cracking threats. Integrating the pre-control plan into the BIM model and syncing it with all participants so that everyone knows about risk prevention and control points before construction.

2.3 Dynamic Quality Tracking during Construction

Create your data channel: Give them devices with BIM mobile application installed for onsite managers Use the mobile applications scanning function to pair with model components in order to obtain quality data at the site. For example, while captured data is uploaded all on-site photos or videos as evidence simultaneously to prove authenticity. At that point do a genuine time correlation of information by naturally sending the gathered on location information from the mobile applications to the BIM stage. Using built-in algorithms, the platform creates deviation analysis reports by comparing the measured data with standard parameters in the model. Taking the steel bar spacing as an example, if the measured value of the steel bar spacing exceeds the allowable deviation range when working, it will be automatically marked and display with the default devication vale. It is important to start issuing warnings for detections that deviate from target values/conformance based on quality issues, with clear delineation of the problem location, situation surrounding the deviation in a quantitative way and what steps need to be taken to remediate it so that the owner can take quick action. Construct rectification closure by requiring construction teams to establish rectification measures based on the warning information and perform them. Post adjustment, upload the modification information and manufacturers photos via cell phone applications. Online reviews conducted by supervisory personnel, and warnings are removed when the review is qualified to curb accumulation of quality issues.

2.4 Quality Acceptance and Archiving at the Completion Stage

Model-entity comparison: permit acceptance personnel to find the part information that needs to be accepted in the BIM model, and compare each actual engineering with a single model, including component dimensions, installation position, material type. In the comparison process, we compared the results in the model with those obtained from the comparison, and carefully identified all non-conforming items as well as their deviation situations and required that they be rectified. Conduct Special Inspections on critical parameters like structural safety etc. along with the BIM model to ensure special quality acceptance. Use the structural component coordinates imported from model to verify total station instrument and utilize pipeline fabricated parameters in model so that pipeline pressure test results can be reviewed closely with acceptance data for consistency with model parameters; Acceptance Reports Automated The BIM platform automatically generates digital acceptance reports based on the results of a BIM comparison, as well as test data. The reports include acceptance scope, acceptance items, test data, pass situations and rectification situation(s), the report format should meet archival management specification and it can be used directly for completion acceptance filing [1]. In the data archiving phase, combined good data throughout all construction processes with their corresponding BIM model components to form a digital model archive that includes complete quality information. Simultaneously, under the archival management requirements export paper and electronic archives. The electronic archive is stored in an encrypted form to ensure the integrity, security and traceability of the archive, so as to 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

Rules for data updates: Describe the scenarios that require an update (such as construction changes, design drawing in major modifications process changes, etc.; material replacements; main material brand change; specification change), and limit the time for data updates under different scenarios. Complete updates for urgent changes in less than 24 hours and less than 48 hours for others. Where each unified change notice form should be tied to model component IDs, and annotate change content and basis data update formats [2]. Create a change application module in the BIM Platform to trigger updates. When the construction party submits a change application, automatically trigger model update and notify design party and supervision party to conduct a joint review in parallel to prevent delays in updating due to manual transmission. Review and Validation: it includes design party responsible for verifying change content is compliant, while supervision party should be responsible for examining how the changes impact quality. When the review is passed, modeling personnel update the model data in the platform, and after all updates, the system automatically generates data change logs, recording who updated it (the updater), when it was updated (update time), and what were changed [3]. After the model is updated, all parties involved in the update automatically receive notifications to preview it and open permissions to view this version of the model at the same time. This makes it possible for on-site personnel such as construction and supervision personnel to obtain the latest model data nearby immediately after updating, avoiding quality management and control deviations caused by data lag;

3.2 Strengthening the Integration of BIM and Quality Inspection Technologies

In the process of technology adaptation, we should determine rational inspection methods based on quality inspection needs, for structural entity test can be selected rebounding method, and measuring geometric dimensions with total stations, as well as concealed work inspection can use ultrasonic flaw detectors. Verify Data Output Format of Inspection Equipment (XML, CSV) Compatibility with BIM Platform Data Interfaces If needed, convert between data formats by creating middleware [4]. Docking channels between information data crews: establish the wireless transmission links (Wi-Fi, Bluetooth) to dock the inspection equipment with the BIM platform. Upon inspection, the equipment automatically uploads the original inspection data (including rebound values, coordinate deviation and flaw detection images) to the platform. The platform associates the test data with the model in a one-to-one "component - inspection data" relationship based on component ID. Automatic comparison and analysis carry out, the platform to implement classification into inspection data and model standard value of built-in comparison algorithm, the coordinates of elements measured by total station needs with model design coordinates for contrast, calculate position deviation; Concrete rebound method detection strength values with the corresponding concrete strength grade in model standard value difference investigation to determine whether it meets standard. Create inspection reports based on comparison [5]. According to the application of result, qualified components are marked with pass, and the data is archived; while non-conforming components will automatically associate this model through the position where the problem occurs, push it out to the construction party for rectification plans. Re-inspect until qualified after rectification.

3.3 Improving the Closed-loop Management of BIM Quality Issues

When detection through BIM mobile applications, on-site personnel upload photos and videos of quality issues that have been discovered, annotate the model components where the problems are located, problem types (dimension deviations, material defects, installation errors), and severity levels (general, relatively severe; or severe) to standardize the form of issuing problems. The system generates a unique problem number automatically and then pushes it to the responsible unit [6]. Decomposed, graded disposal: develop disposal priorities according to the severity of problems: respond, solve severe problems within 24 hours; generally severe problems can be solved in 48 hours; general problems can be solved in 72 hours. Separation of Responsibilities at All Levels: Clarifying that construction teams at the lowest level of responsibility are responsible for problems in general yet project departments coordinate the solutions to relatively severe problems while companies solve and dispose of severe problems avoiding shirk. Unit responsible for submitting rectification plans in the platform, including rectification measures, completion time limits and persons responsible. Make updates on your progress by uploading photos throughout the rectification process. The rectification situation is seen by supervisory personnel on the platform in real time, and overdue prevention problems that have not been rectified are automatically upgraded to severe warnings [7]. Review and archiving responsible units apply for review after rectifying the problem Inspectors perform inspections and conduct the on-site evaluation after uploading the results to the platform. When the review is qualified, set the problem as "closed-loop", and all process data (reported records, rectification plans, review results) are archived to the BIM model; when unqualified they will be returned for re-rectification until eliminated.

3.4 Optimizing BIM Quality Control Permission Allocation

In quality control, specific work done by various participating parties (construction, supervision, design and other parties) shall be made clear to sort out the responsibilities of all parties. The construction unit overall supervision, the construction unit responsible for problem rectification; The supervision unit is responsible for review and acceptance; The design unit provides technical support. For example, what quality data will be needed by different parties to participate: construction parties need component standard parameters for viewing; supervision parties need inspection data and rectification records viewing; Construction parties require overall quality status reports Perform refined permission division [8]. Based on the three-level structure of "participating party-role-permission", set permissions in the permission management module of the BIM platform. The construction team role has permission to view quality data and report problems (if any) for the components in each area they are responsible for; the supervision engineer role has permissions to view quality data of the whole project, review problems and approve necessary rectifications; moreover, management personnel role of construction unit only have permission to view quality reports and receive warning information. Also, establish permission validity periods to prevent extended non-use of permissions [9]. Dynamic Adjustments: Permission administrators are encouraged to issue updates as soon as actual role changes or work scope adjustments between all parties involved occur (reverting permissions for former roles, assigning new role based permissions) to match assigned permissions with real life responsibilities.

4. Conclusion

According to the above research, we can see that BIM technology for construction quality control of building engineering, should take full-process management and control as the core to realize value implementation by way of standard application process and precise optimization strategy. At the level of the application process, it has formed a quality management and control chain covering "pre-event - in-event - post-event" through BIM model establishment and pre-control simulation before construction, dynamic tracking during construction and quality acceptance and archiving after completion, greatly solving the data fragmentation problem of traditional management and control in various stages. Practical optimization strategies have been proposed to ameliorate four main limitations of BIM applications, which are the update frequency and accuracy of data items, technology integration, problem solving capability and permission allocation. Such as through the model data update mechanism, ensuring the timeliness of the data;Through integration with inspection technologies to enhance inspection precision;The closed-loop management mode guarantees that problems will be rectified in place; And rights allocation balances data sharing and security. All these strategies could together promote BIM technology from "tool pervasion" to "systematic management and control", which can enhance the efficiency of quality control effectually.

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