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Enterprise-Level BIM Technology Application in Guangxi Lebai Nongyi Tunnel (Postprint)

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Abstract

Guangxi Lebainongyi Tunnel is an extra-long tunnel. During the construction process, quality and safety control are extremely stringent due to exceptionally complex geological structures. Geological forecast data for tunnel excavation is of paramount importance, necessitating the elimination of adverse geological and hydrogeological conditions ahead of the working face. Meanwhile, quantity statistics for over-excavation and under-excavation during tunnel excavation have become a notable difficulty in conventional construction. Additionally, real-time recording and updating of tunnel uneven settlement monitoring data, as well as on-site progress, quality, and safety management, urgently require new project management tools to enhance collaborative management efficiency. To address the aforementioned key difficulties in tunnel construction, the team conducted multiple comparative analyses of different BIM software suites and adopted a BIM solution integrating Revit+Dynamo+Civil3D+BIM5D, which can resolve management application challenges from BIM model establishment to various project phases, such as: bill of quantities statistical analysis, construction progress management on a daily basis, per-linear-meter stationing positioning to assist in resolving construction quality and safety issues, etc. Utilizing this tunnel BIM solution enables model deepening based on actual site construction information data and provides multi-perspective assistance in solving various difficulties associated with traditional tunnel construction. The research outcomes of this project can provide professional technical solution references for BIM applications in similar highway engineering projects.

Full Text

Preamble

Application of Enterprise-Level BIM Technology in Guangxi Lebai Nongyi Tunnel

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Abstract: Guangxi Lebai Nongyi Tunnel is a super-long tunnel. Due to the exceptionally complex geological structure, quality and safety control is extremely stringent during tunnel construction. Geological forecast data for tunnel excavation is particularly critical, requiring elimination of adverse geological conditions and hydrogeological factors ahead of the excavation face. Simultaneously, statistical analysis of over-excavation and under-excavation quantities has become a major challenge in traditional construction practice. Furthermore, real-time recording and updating of uneven settlement monitoring data, as well as on-site progress, quality, and safety management, urgently require new project management tools to enhance collaborative management efficiency. To address these key construction challenges, the team conducted multiple comparative analyses of different BIM software suites and adopted a comprehensive BIM solution integrating Revit, Dynamo, Civil 3D, and BIM5D. This solution addresses management and application challenges from BIM model creation through all project phases, including bill of quantities statistical analysis, daily-basis construction schedule management, and quality/safety issue resolution through per-meter pile number positioning. This tunnel BIM solution enables model deepening based on actual site construction information and provides multi-dimensional assistance in solving various traditional tunnel construction difficulties. The research results of this project can provide professional technical reference solutions for similar highway engineering BIM applications.

Keywords: Super-long tunnel; Per-meter-level model accuracy; Geological structure simulation; Tunnel over-excavation and under-excavation quantity statistics; Surrounding rock geological simulation; Uneven settlement monitoring; BIM5D collaborative management; Construction stage

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1.1 Research Background and Significance

BIM technology (Building Information Modeling), first proposed by the "Father of BIM" Charles Eastman in 1975, has evolved through embryonic, emergence, and development stages. Since its introduction to China over a decade ago, BIM has matured in building and municipal engineering applications, demonstrating powerful technical and management advantages in numerous EPC and PPP projects by breaking down the "information silos" inherent in traditional project management. BIM has gained widespread recognition from owners, designers,

supervisors, contractors, and consultants, establishing itself as one of the most influential new technologies in the engineering construction field. Its integration with various engineering domains leverages its advantages in informatization and intelligent project management across all phases.

1.2 Research Content

Tunnel construction involves numerous excavation processes, stringent safety control requirements, and significant challenges in monitoring geological rock strata and hydrogeological conditions, as well as managing feedback from blasting excavation processes. This research focuses on addressing these critical tunnel construction management challenges by introducing BIM technology and BIM management platforms to effectively control key project elements, substantially improving production performance. Additionally, by enabling interoperability between enterprise management platforms and BIM big data, the research enhances enterprise-level project management oversight, effectively monitoring dynamic information across all new projects within subsidiary companies and reducing enterprise management costs. Centered on the Baise Tunnel as the research subject, this project utilizes BIM technology and BIM project management platforms throughout the entire lifecycle from pre-construction to final delivery, exploring BIM application points and project management implementations in tunnel projects to provide a complete and referenceable BIM technology application system for highway engineering development, thereby accelerating BIM technology advancement in the highway engineering sector.

2.1 Project Introduction and Engineering Characteristics

The Nongyi Tunnel of the Guangxi Leye to Baise Expressway spans 3.8 kilometers, comprising KG and KH sections with eight pedestrian cross-passages and four vehicle passages, making it the longest tunnel on the Lebai Expressway. The project faces substantial pressure regarding overall construction safety, quality, and schedule, with numerous inspection requirements. Control of tunnel progress, safety, and quality constitutes the primary management focus and challenge.

This super-long tunnel project represents the first application of BIM technology, combined with the BIM5D collaborative management platform. Through BIM technology application and management during tunnel construction, the project aims to further enhance the technical application and management capabilities of the Lebai Expressway project department in tunnel projects, effectively safeguarding construction progress, quality, and safety.

2.2 Engineering Difficulty Analysis

The Nongyi Tunnel of the Guangxi Leye to Baise Expressway is a super-long tunnel totaling 3.8 kilometers. During the initial project phase, serious deficiencies in preliminary design documentation, including original geological exploration

data, tunnel main structure design, and hydrogeological conditions, prevented determination of critical engineering information data for the BIM model. This resulted in insufficient model detail that could not meet project management requirements.

During the construction phase, significant challenges emerged: the tunnel' s main structure exhibited substantial variations in curvature, longitudinal and transverse slopes, and surrounding rock geological information, with numerous design changes during the process. Creating a BIM model suitable for construction process management became a major difficulty. Additionally, with multiple subcontracting units involved, project quality, safety, and progress management became increasingly complex. Introducing new technologies to improve project management levels and reduce construction costs became a key priority. In summary, the project BIM R&D center needed to address these challenges through a comprehensive and feasible BIM implementation strategy to resolve project management difficulties.

3.2 Implementation Plan

To meet the requirements of the project' s BIM application objectives, the BIM R&D Technology Center organized multiple seminars and, according to relevant criteria in the *National Unified Standard for Building Information Model Application* and considering the particularities of this tunnel project, formulated the project' s *BIM Implementation Standards for Construction Phase*, *Highway Modeling Specification*, *Tunnel Modeling Specification*, and the *BIM5D · All-Discipline · Modeling Standard* for use with the BIM5D collaborative management platform during the pre-planning phase. These documents provide technical guidance and requirement measures for subsequent BIM implementation during the construction phase.

3.4 Application Measures

Following completion of preliminary preparations, the BIM project team concentrated on constructing the Nongyi Tunnel main structure model, 3D geological model, construction site model, tunnel settlement monitoring model, and over/under-excavation model. Upon model completion, the team launched BIM implementation applications and BIM5D collaborative management platform applications. BIM implementation applications include: BIM design drawing review reports, material quantity statistics, construction site planning, 3D geological simulation, tunnel settlement monitoring simulation, and construction process simulation. BIM5D collaborative management platform applications include: document collaboration, quality and safety management, production progress tracking, material extraction, process library management, and early warning management.

During project BIM implementation, the BIM project team tracked the implementation process and researched innovative BIM application points. Through

stage-based BIM meetings, the team tracked BIM application progress, resolved implementation feedback issues, and explored innovative BIM application points for the project.

After project application implementation, the team organized a BIM implementation summary conference where implementers presented summaries and reflections on the BIM application process and discussed prospects for BIM application in future highway engineering projects.

3.3 Team Organization

To address traditional tunnel project construction management challenges and ensure efficient achievement of project BIM objectives, this project involved not only establishing a project BIM team but also engaging all project management departments and members in the research application. Various disciplines, departments, and teams collaborated to jointly discuss and resolve BIM application challenges during the construction phase.

This project appointed the chief project engineer and BIM chief consultant as overall BIM implementation leaders, primarily responsible for guiding and controlling the overall BIM technology application implementation. The deputy chief project engineer and BIM engineers served as project BIM implementation managers, mainly following up on BIM technology application status and progress while controlling BIM technology application results. Project construction engineers, technical engineers, safety officers, quality inspectors, document engineers, and commercial cost control managers all participated in project BIM collaborative management, assisting in collecting and processing project process data, substantially improving implementation rates.

3.5 Software and Hardware Environment

To resolve Nongyi Tunnel project management challenges and achieve project BIM application objectives, the project BIM team conducted multiple BIM seminars during the construction phase and ultimately selected primary BIM application software as shown in Table 1 .

The project BIM team conducted comprehensive analysis of BIM software operation configurations. Based on the actual management requirements of the Nongyi Tunnel project and under the premise of meeting data processing, data storage, graphics workstation, and graphics computing requirements, the team ultimately determined primary BIM application hardware as shown in Table 2 .

4.1 Parametric BIM Model Establishment

Based on tunnel design and construction drawings, this project conducted component breakdown and family library establishment for the tunnel model. Com-

bining 3D coordinate data, pile numbers, and elevation points, the team employed adaptive family modeling methods integrated with Dynamo to establish parametric models with per-meter model accuracy, providing accurate model data for subsequent refined BIM model applications and various BIM implementations.

4.2 BIM 3D Design Drawing Review

After constructing the parametric tunnel model and simulating the tunnel construction process, the team reviewed design drawings and prepared BIM drawing review reports for identified design issues. These reports were promptly fed back to the design institute and participating units for review, ensuring construction schedule adherence and project quality.

4.3 Bill of Quantities Statistical Analysis

Through refined BIM model establishment combined with design engineering material measurement parameters, the team extracted quantities for tunnel concrete, waterproofing boards, water stops, steel frames, and other materials by route, mileage section, and lining type dimensions. This guided on-site construction material preparation and assisted in project quantity verification.

4.4 3D Geological Structure Simulation

Based on geological survey reports and related data, the team simulated the main geological structure of the overall mountain in the design master plan, providing preliminary project geological information for subsequent advanced geological forecasting and surrounding rock grade identification. Additionally, the overall mountain terrain provided reliable basis for project construction site layout, including site selection for the project department, material storage areas, and living quarters, enabling the most rational and optimized construction site layout.

4.6 Surrounding Rock Geological Structure Simulation

Based on geological exploration data, the team simulated geological structure morphology and relationships to predict surrounding rock conditions ahead of excavation. Combined with tunnel advanced geological forecasting, the surrounding rock geological model was updated in real-time for comparative analysis and documentation against the original design exploration model, enabling early warnings to reduce construction safety risks and safeguard personnel and property safety.

4.5 Over-Excavation and Under-Excavation Quantity Statistics

During tunnel blasting excavation, the team utilized a full-section scanner to scan the blasted tunnel section and generate over/under-excavation CAD section drawings. These drawings were then used to construct over/under-excavation BIM models for comparative analysis with design BIM models, calculating quantity differences to continuously control on-site construction process standards and reduce project material costs.

The over-excavation/under-excavation rate and quantity calculation formula: Over-excavation/under-excavation rate = (Actual secondary lining volume - Design secondary lining volume) / Design secondary lining volume

4.9 Construction Process Simulation

Based on tunnel settlement monitoring data, the team promptly imported data into BIM software to construct tunnel settlement models, recording and analyzing tunnel section uneven settlement detection data. This enabled intuitive comparison of real-time settlement conditions and construction early warnings for corresponding pile number sections, improving tunnel construction safety.

Integrating BIM models with construction process plans, the team simulated various surrounding rock excavation process flows and structural construction methods through construction process animation. This provided 3D visual technical briefings for on-site construction personnel, guiding field operations.

4.8 Construction Site Layout Optimization

Utilizing BIM technology for construction site planning and scheme simulation comparison, the team optimized construction site layout to improve site utilization, reduce secondary material handling, facilitate transportation, accelerate construction progress, and reduce production costs. The specific BIM implementation approach combined: drone aerial photography of surrounding mountain conditions + Civil 3D model analysis + BIM model site layout optimization solutions.

4.11 BIM5D-Quality and Safety Management

When on-site construction personnel identify quality or safety issues, they can photograph, record audio, and document issues via mobile phones, transmitting them to responsible personnel for timely rectification. Simultaneously, data is statistically aggregated and analyzed through cloud and PC platforms, assisting leadership across all project participants to review overall project quality and safety conditions and adjust work plans accordingly.

4.14 BIM5D-Production Progress Tracking

Through the BIM5D platform, the team divided construction flow mileage tasks and arranged weekly and monthly production tasks. Construction personnel recorded and fed back on-site construction conditions in real-time via mobile phones, promptly resolving construction issues, improving construction progress management efficiency, and ensuring timely project completion.

4.15 BIM5D-Material Extraction

This project employed the BIM5D platform to import tunnel models and associate them with progress plans. Project personnel statistically analyzed model material quantities by mileage section, progress time, and component type dimensions, exporting material reports for material planning reference. This enabled advance material procurement and preparation, reducing material supply risks and ensuring orderly project construction.

4.17 BIM5D-Advanced Geological Forecast Warning

The PC platform established tunnel advanced geological forecast warning tracking plans associated with advanced geological forecast schemes. On-site geological forecast personnel collected and recorded advanced geological forecast data via mobile phones, filling in relevant geological forecast descriptions and treatment recommendations. When forecasted surrounding rock conditions differed from design classifications, early warnings were issued to safety and engineering departments for timely measures, ensuring tunnel construction safety.

4.19 Enterprise System Management Platform Application and Utility Analysis

Through the enterprise-level management system platform, effective engineering management, basic data management, centralized procurement management, labor resource management, enterprise standard management, budget management, fund management, asset management, business management, and financial management can be achieved. This platform provides: Enhanced single-project control capability by unifying project quality, safety, fund, and schedule status data for group-level effective project implementation control; Improved data storage and retrieval efficiency through centralized cloud storage of project documentation, financial data, and industry information, preventing data loss; Precise high-level decision support by providing effective data support for major decisions by enterprise or project leadership; Improved resource allocation by controlling human resources, mechanical equipment, and fund distribution across projects based on enterprise operational data.

5.1 Innovation Points

1. **3D Surrounding Rock Geological Simulation and Early Warning**: Combining geological exploration data to simulate geological structure morphology and relationships, predicting surrounding rock conditions ahead of time. Real-time updates to surrounding rock geological models based on tunnel advanced geological forecasting enable comparative analysis with original design models for early warning and improved on-site construction safety.
2. **Over-Excavation and Under-Excavation Quantity Statistics**: Integrating measured tunnel over-excavation and under-excavation data into BIM software to construct models, analyzing over/under-excavation position data, and conducting quantity statistics to provide BIM model data for surrounding rock excavation quantity verification.
3. **Tunnel Settlement Monitoring Simulation and Early Warning**: Combining tunnel settlement monitoring data with BIM software to construct tunnel settlement models, recording tunnel section settlement data, intuitively displaying settlement conditions, and issuing construction early warnings for corresponding pile number sections to improve tunnel construction safety.

5.2 Experience Summary

1. **Regarding BIM Technology Application Implementation Strategy**: As the first tunnel construction project to apply BIM technology, this project summarized tunnel BIM technology applications and innovations through continuous technical discussions and application expansion, establishing a mature tunnel BIM technology application solution.
2. **Regarding Main Structure Model Construction Technology**: Based on tunnel design drawings and site construction techniques, the project conducted multiple model construction iterations through BIM modeling software. Through continuous modeling tests and technical optimization, a comprehensive tunnel BIM model construction technology was summarized.
3. **Regarding BIM Implementation Application Mode**: This project' s BIM implementation adopted a mode led by the chief project engineer to establish BIM application content, assisted by BIM engineers. Through continuous improvement and innovation of results, BIM implementation was gradually rolled out across the entire project.
4. **Regarding BIM5D Project Collaborative Management**: Since introducing the BIM5D project collaborative management platform, this project adopted a pilot operation mode initially implemented by the engineering, quality inspection, and safety departments. After demonstrating

stability and benefits, the platform was gradually promoted to the entire project department for management application.

5.3 BIM Research Results Benefit Summary

1. **Promoting BIM Development in Highway Engineering**: BIM establishes digital engineering models that accumulate to form an information database for the highway industry, becoming critical foundational data for national security information management.
2. **Promoting Informatization in Highway Engineering Management**: BIM technology provides powerful data support and technical backing for refined project management, enterprise intensive management, and enterprise informatization management in highway engineering projects, promoting lifecycle project informatization management across the entire highway industry.
3. **Internetization of Highway Engineering Industry**: BIM drives the internetization of the highway industry. Through virtual cloud technology, all project data is integrated on the BIM cloud platform, enabling management decision-makers to monitor project implementation dynamics in real-time through the data platform and achieve remote collaborative management of highway projects.

References

[1] Chen Guojia. Road 3D Design Method and Application Based on BIM Technology[J]. Urban Architecture, 2016, 04: 282.
[2] Li Chong. Application of BIM Technology in Highway Engineering Management[J]. *Transportation World*, 2016(17): 94-95.
[3] Cao Jiliang. Exploration of BIM Technology Application in Highway Engineering Cost Management[J]. *China Science and Technology*, 2015(22): 88-89.

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