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Smart Construction Site Management System Based on BIM

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Abstract: Zhuhai Port Project of Hong Kong-Zhuhai-Macao Bridge is the key node of "Super Project". During the construction of 1.07 million square meters artificial island, it faced complicated supervision and management problems. Huagong Supervision takes BIM technology as the core driving force to create a model of smart site management. In terms of technical application, using Revit software to create a three-dimensional model and realize the deepening design of special-shaped structures, the amount of on-site cutting is reduced by 37% and the construction period is shortened by 18 days; With the help of 4D dynamic monitoring system, the accuracy of construction progress control is improved by 80%; By means of stress simulation and stress monitoring, the safety risk of high formwork was pre-controlled, and the rectification rate of hidden dangers decreased from 62% to 9%. From the perspective of management efficiency, the multi-party collaborative platform shortens the design change cycle by 72%, the "BIM+measured quantity" method improves the qualified rate of concrete components to 98%, and the completed BIM model saves more than 8 million yuan for operation and maintenance. Aiming at the problem of insufficient construction capacity and inconsistent data standards, it is solved by "BIM+QR code" technology and compiling interactive standards. Practice has proved that BIM technology has formed a "data-driven collaborative governance" model by integrating the data of design, construction and supervision.

1. Introduction

Under the general trend of transformation and upgrading of the construction industry, digital technology is bringing profound changes to the traditional project management model [1]. South China, Guangdong Huagong Engineering Construction Supervision Co., Ltd. (hereinafter referred to as "Huagong Supervision"), as a leading enterprise in the supervision industry in South China, took the lead in exploring smart site management system based on BIM in projects such as Zhuhai Port of Hong Kong-Zhuhai-Macao Bridge, and contributed valuable practical experience to the whole industry. The construction industry in China has been plagued by low efficiency, serious waste of resources and high security risks [2]. According to "China Construction Industry Development Report", the labor productivity of construction in China is only 60% of that of manufacturing industry, and the safety accident rate is more than three times higher than that of industrial field. The traditional management mode mainly relies on two-dimensional drawings, and

the information transmission lags behind, which leads to the disconnection between design and construction, and the supervision work is often in a passive error correction situation [3].

With the help of three-dimensional model, BIM technology realizes the data integration of the whole life cycle of buildings, and integrates with technologies such as the Internet of Things and GIS, which gives birth to a new management form, namely "smart construction site" [4]. It promotes the supervision work from "rectification afterwards" to "pre-control beforehand", which greatly improves the management efficiency [5]. For example, after Huagong Supervision introduced the BIM collaborative platform in a complex structural project, the response period of design change was shortened from 72 hours to less than 24 hours, and the accuracy was improved by more than 60%.

In the Zhuhai Port Project of the Hong Kong-Zhuhai-Macao Bridge, Huagong Supervision has built a BIM supervision mode of "model first, data driven and coordinated linkage". In the design stage, 137 pipeline conflicts were found through collision inspection, which effectively avoided the later demolition and modification; In the construction stage, the 4-D progress simulation is used to optimize the process connection and identify potential safety hazards in advance; In the operation and maintenance stage, BIM model including equipment parameters was delivered, which improved the property efficiency by more than 40%. BIM also reconstructed the relationship between the supervision unit and other contractors [5]. In a commercial complex project, Huagong Supervision synchronized the construction progress and investment data through BIM model to help the construction unit accurately control the investment, and the project duration compliance rate increased from 78% to 92%.

Although remarkable achievements have been made, the promotion of BIM smart construction site still faces some challenges, such as insufficient technology integration, shortage of talents, lagging standards and high cost. Huagong Supervision actively responded by customizing the development interface, developing compound talents, and participating in the formulation of local standards, and called for policy support, such as special subsidies and green finance.

2. Core theory and technical foundation

BIM is the building information model, which builds the virtual mapping of the whole life cycle of the building by digital means and breaks the traditional management information barrier. It integrates multidimensional data, supports real-time design linkage, and lays the foundation for dynamic management of smart construction sites. Smart construction site is an integrated scene of BIM and multi-technology, and a closed loop is built based on BIM [6]. The two are coupled, BIM solves digital expression, and intelligently focuses on data flow applications. For example, Huagong Supervision combined BIM with QR code and APP in the project to shorten the response time of defect rectification.

Traditional supervision is often in an "after-the-fact" dilemma, and BIM reconstructs its business from multiple dimensions [7]. Visual precontrol realizes from "passive inspection" to "active simulation", and eliminates hidden dangers before construction [8]. Data integration breaks the "information island" and relates multi-source data to improve the acceptance efficiency. Process reengineering builds a full-cycle chain, and the role of supervision changes to "full-cycle manager".

Smart site technology is divided into "perception-platform-application" three layers. The perception layer collects data in real time, and the supervisor adjusts the scheme accordingly. The platform layer integrates data with BIM as the carrier to form a visual kanban to assist emergency. The application layer develops modules for supervision business to realize quality, safety and investment control.

BIM and smart construction site application have new requirements for supervision enterprises

[9]. The promotion of technology integration work requires the cultivation of a composite talent team with cross disciplinary abilities; The construction of a collaborative management system should establish a collaborative work mechanism that covers multiple stakeholders; The promotion of industry standardization process requires active participation in the formulation of industry technical guidelines and normative standards.

The theory of life cycle management is in line with the concept of BIM to realize data communication. Collaborative management theory emphasizes organizational collaboration, and supervision breaks down barriers of all parties through BIM platform to improve industry efficiency.

3. Huagong Supervision intelligent site management system

In the field of engineering construction, Huagong Supervision has deeply applied BIM technology by relying on innovative management mode, and achieved outstanding results in the Hong Kong-Zhuhai-Macao port project.

From a technical point of view, Huagong Supervision always adheres to the concept of "model first". At the beginning of the project, a special team was set up to carry out fine modeling work for key units such as the passenger inspection building and the transportation center. In view of the complex geological conditions of the artificial island, a three-dimensional geological model is constructed by using the integration technology of BIM and GIS, and the distribution of silt layer and the change of groundwater level are presented intuitively, which gives strong support for the optimization of deep foundation pit support scheme. In the deep design of steel structure, BIM is used to simulate the assembly of special-shaped column formwork, so as to detect and deal with the structural conflicts of nodes in advance, which effectively avoids the technical contradictions that are easy to occur in traditional two-dimensional drawings.

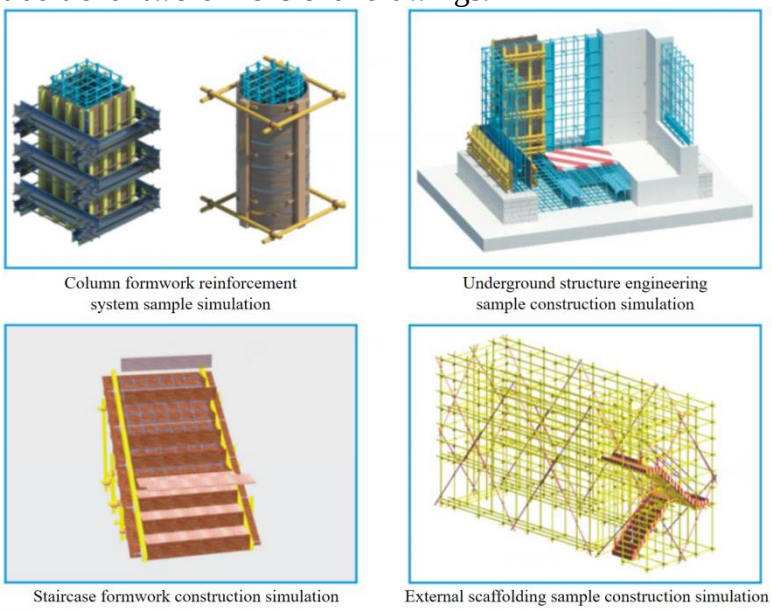

Figure 1 BIM construction simulation of special-shaped column operation frame

In terms of process management, Huagong Supervision has achieved multi-stage innovation and change. In the design stage, we break through the inherent mode of "passive audit" and actively participate in BIM collaborative design. Navisworks software is used to carry out full-professional collision inspection, and pipeline conflicts are found and solved in time, which significantly reduces the on-site demolition rate and shortens the construction period. In the construction stage, the BIM

model is combined with the schedule to form a 4D dynamic deduction system, and the construction process is simulated by software to identify and resolve the process contradictions in advance, thus reducing the slowdown. Futhermore, the quality control mechanism of "model guide+measured quantity" is established. First, the instruction book is generated by simulating the construction process, and then the physical project is tested, which greatly improves the dimensional qualification rate of concrete members. In the operation and maintenance stage, BIM model with rich equipment information was delivered, which facilitated the property management, greatly shortened the fault response time, and achieved the "integration of construction and maintenance".

In organizational construction, Huagong Supervision is committed to cultivating the ecological environment of collaborative governance. With the BIM collaborative platform as the core, the mechanism of "supervision leading and multi-party governance" is established. Through regular BIM meetings, technical disputes are solved by model sharing, and the construction scheme is optimized, thus saving costs. The development of BIM data responsibility matrix can clarify the data responsibilities of all parties, ensure the traceability of quality responsibilities, and ultimately reduce the occurrence of visa disputes. In terms of personnel training, the implementation of the "Digital Supervision Talents Incubation Plan", through internal certification and special training, has created a compound talent team, and the BIM modeling ability of supervision engineers has been greatly improved. Figure 1 shows the concrete application of BIM technology in the deepening design of special-shaped column formwork, which significantly improves the construction accuracy through three-dimensional simulation.

4. Case application: Hong Kong-Zhuhai-Macao Port Engineering Practice

(1) Scene application of BIM technology

The structure of "double-deck traffic diversion" in area A of the tourist inspection building is complex, and it is difficult for traditional two-dimensional drawings to accurately express the spatial relationship. Huagong Supervision used Revit to build a 3D model with 12,800 members. Aiming at the joint between arc glass curtain wall and steel grid structure, BIM was used to simulate the mechanical performance of different anchor arrangement schemes, and the structure of "3D adjustable joint" was determined (see Table 1). Compared with the original design, this scheme reduces the field cutting amount by 37% and shortens the installation period by 18 days.

Table 1 Comparison of Curtain Wall Node Solutions

Solution Type	Number of Anchors	On-site Cutting Rate	Construction Period (days)
Traditional Solution	2,860 units	45%	35
BIM Optimized Solution	2,210 units	8%	17

The team associated the BIM model with Primavera schedule and established a 4D dynamic monitoring system. In the construction of basement structure, the system identifies the conflict point between excavation and pile foundation construction, and adjusts the mechanical configuration to improve the efficiency of cross operation by 25%. The data show that the deviation of key line construction period is controlled within 3 days after BIM is used, which improves the accuracy of traditional management by 80% (see Table 2).

Table 2 Comparison of Key Process Schedule Deviations

Construction Phase	Traditional Management Deviation (days)	BIM Management Deviation (days)	Accuracy Improvement
Pile Foundation	±10	±2	80%
Basement Structure	±15	±3	80%
Steel Structure Lifting	±8	±1.5	81%

The construction risk of high formwork is high, and the team used BIM to simulate the stress of the frame, and found that the distance between vertical poles in the original scheme was too large and the risk of local instability was too large. After adjusting the layout of vertical poles and increasing diagonal braces, the stress value in the whole construction process is controlled within 85% of the design value through real-time monitoring of stress sensors. This technology reduces the rectification rate of hidden dangers in high formwork construction from 62% to 9%.

(2) Improvement and innovation of management efficiency

The multi-party collaborative platform has reduced the design change response period from 72 hours to 24 hours. For example, the mechanical and electrical pipeline of the inspection building is adjusted, the construction unit uploads the BIM change model, the supervisor completes the compliance audit within 4 hours, and the design unit updates the drawings simultaneously, saving 56 hours compared with the traditional process and avoiding the loss of about 400,000 yuan.

The mode of "BIM+measured quantity" improves the qualified rate of dimensional deviation of concrete members from 89% to 98%. In masonry engineering, the brick arrangement diagram is generated by BIM first, and then the finished surface is scanned by laser scanner, and the deviation analysis report is automatically generated, which can guide the improvement efficiency by three times. The overall leakage rate of the project is reduced from 15% to 3%, which meets the quality standard of Daruban Prize. Guangdong South China University of Technology Engineering Construction Supervision Co., Ltd. has introduced the combination technology of BIM and GIS in some projects, and generated digital 3D models through aerial photography of drones, as shown in Figure 2. This improves the efficiency of on-site management and provides more intuitive and accurate data support for risk identification and monitoring.

Figure 2 Integration of BIM and GIS

The completed BIM model contains 12,000 pieces of equipment information, covering the whole

life cycle data of facilities such as elevators and water supply and drainage pipelines. The property management team can scan the two-dimensional code of equipment to view relevant records in real time, which improves the efficiency of equipment fault handling by 60% and is expected to save more than 8 million yuan for later operation and maintenance.

5. Conclusions

BIM is not just a simple visualization tool, but an intelligent core that runs through the whole process of the project. It solves the bottleneck problem of special-shaped structure design through three-dimensional modeling, realizes the precise control of schedule deviation in millimeter level by means of dynamic data linkage, and transforms safety risk prevention and control into pre-control by means of simulation. In fact, this kind of "technical empowerment" is to bring the scattered elements such as space, time and risk in traditional management into a unified data framework, and achieve accurate mapping and intelligent deployment of all elements of the project.

On the level of management innovation, the project broke the collaborative barrier between traditional participants and built a cross-disciplinary "common language" through BIM model. The response efficiency of design change is improved by 72%, which is behind the process reengineering caused by data standardization; The key to improve the quality control accuracy to 98% lies in the closed-loop feedback mechanism of "model-guided construction-measured verification model"; The significant reduction of operation and maintenance costs benefits from the accumulation and application of life cycle data. This "data-driven collaborative governance" is essentially to shift engineering management from relying on experience to relying on scientific decision-making, and from fragmented management and control to systematic integration.

The challenges faced by the project and the coping strategies have universal application value. The technical gap at the construction end has been made up by the lightweight application of "BIM+QR code"; The data barriers of the contractors are compatible with the standardization construction, which shows that the technology landing needs to give consideration to both advancement and adaptability.

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