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Research on Engineering Application based on BIM+ Intelligent Construction Technology

-- Taking the Yibin Start Square Project as an Example

Xiongzhi Cao [1], Maoli Lan [2], Siyu Wang [1], Yaxin Li [3], Lian Li [1], Li Zhao [1], Yong Hou [1],

Yujie Zhang [1, *]

[1] Chengdu Technological University, Chengdu 611730, China
[2] SI CHUAN HUA XIN (GROUP) CPA (LLP), Luzhou 646099, China
[3] China MCC5 Group corp. Ltd, Chengdu 610011, China

*** Corresponding author:** Yujie Zhang

Abstract: With the rapid development of the construction industry, Building Information Modeling (BIM) and intelligent construction technology have gradually become important means to improve project management and construction efficiency. This article takes the Yibin Start Square project as an example to discuss the specific methods and effects of BIM+ intelligent construction technology in engineering applications. By introducing BIM technology, the entire process of information management from design, construction to operation and maintenance has been realized, and the accuracy and visualization level of engineering data have been improved. Combining intelligent construction technologies, such as drone inspections, robot construction, and the Internet of Things (IOT), further optimizes the construction process and improves construction quality and safety. The research results show that the application of BIM+ intelligent construction technology in the Yibin Start Square project not only effectively reduced the project cost, but also significantly shortened the construction period, and has extensive promotion value. This article aims to provide reference for similar engineering projects to promote the digital and intelligent transformation of the construction industry. The direction of intelligent construction is of great significance to the modernization and upgrading of the construction industry, as well as to my country's infrastructure construction and urban modernization process.

Keywords: Building Information Modeling (BIM); Intelligent Construction; Information Management; Intelligent.

1. Introduction

1.1. Background

Since the beginning of the 21st century, countries around the world have incorporated intelligent construction into their national strategies to seize the commanding heights of industrial development in order to achieve high-quality, efficient and highly competitive development of their respective national industries. The construction industry is an important material production sector and pillar industry of the national economy, but the level of informatization and refined management is at a lower level compared with other important industries. The modernization and upgrading of the construction industry from the direction of intelligent construction is of great significance to the country's infrastructure construction and urban modernization process. With BIM+ intelligent construction technology as the core, intelligent production and construction as the development path, and low-carbon, energy-saving and environmental protection as the development goals, we will accelerate the transformation and upgrading of engineering construction and promote high-quality development of the construction industry.

1.2. Overview

In recent years, scholars from various countries have conducted relevant research on BIM and intelligent construction.

Rangasamy [1] used a three-step process of bibliometric search, quantitative analysis, and qualitative analysis to map research trends and knowledge gaps based on the latest research trends in BIM, AI, and IoT applications. Future research directions such as automated design and development, robotic manufacturing, application compatibility, strategic decision-making, and PC operation and maintenance were highlighted.

Iqbal; Fahad [2] developed an innovative framework using low-cost wireless sensors based on the Internet of Things (IoT) technology. The IoT-based data was further integrated with the building information model (BIM) model of the structure to develop its digital twin (DT) to increase digital capabilities for the construction industry, enabling relevant departments to remotely access concrete compressive strength parameters. It is possible to remotely monitor concrete strength parameters in real time in the BIM environment and use the ActiveBIM system to promote informed decision-making and optimize construction progress.

X Hu[3] proposed a novel digital twin framework to achieve real-time monitoring and visualization of indoor environments by integrating building information modeling (BIM), the Internet of Things, autonomous robot-based mobile mapping and sensing, and indoor positioning technology. The BIM digital twin model was used to intuitively visualize it, and the indoor positioning system based on ultra-wideband achieved near-centimeter-level positioning accuracy. In addition, they innovatively integrated structural analysis expertise into the BIM structure and visualized it, realizing the visualization of structural behavior at different locations of structural elements/components. The BIM-enabled DT framework was demonstrated and tested for real-time visualization of a prototype structural frame subject to bending forces and monitoring the structural deformation of key structural components [4].

YY Al-Ashmori[5] found that the implementation of BIM can significantly improve the productivity and performance of projects, and investigated the application of BIM technology. Statistical analysis shows that the advantages of BIM are quite prominent in terms of productivity, time, cost, conflict and communication.

Chen J[6] used the knowledge graph of scientific measurement technology, VOSviewer and CiteSpace software to analyze the literature data on BIM medical construction projects (BIM-MCP). The analysis found that the research focus of BIM-MCP includes model development, framework, implementation, system integration, application throughout the life cycle, application in emergency medical engineering projects, and intelligent management of medical facilities and smart buildings. It is proposed that the use of BIM medical facility management (BIM-MFM), the integration of BIM technology in sustainability assessment, and the application of BIM technology in emergency medical engineering and smart medical construction should be enhanced.

Wei Cui [7] proposed a study on intelligent building construction management methods based on BIM and information-based soft sensor monitoring technology, established a building construction model, and created an information database containing basic data and extended data. By establishing a BIM model and splitting it into various modules, the real-time dynamic database detected by the environmental monitoring sensor is grafted onto the BIM model. The entire construction process is simulated through the intelligent Internet, dynamic monitoring is carried out, and emergency plans are adjusted in real time to ensure the rationality of the entire construction phase of multiple blocks. Machinery, materials and manpower are scheduled and managed according to the expected construction process requirements. The study found that compared with the traditional management model, information sensors and monitoring intelligent management systems are more efficient, effectively improve resource utilization, achieve low-carbon construction, and significantly accelerate project progress.

A Mohammed [8] adopted a comprehensive approach to evaluate the impact of BIM and smart construction on sustainable structural development. The study found that there is a positive correlation between BIM and smart construction and sustainable structural development elements. BIM-driven environmental risk assessment has an important impact on sustainable and sustainable structural development. Smart construction has a significant impact.

The development of intelligent construction technology is constantly promoting the intelligence, efficiency and sustainability of modern buildings. At present, the intelligent construction technology formed by combining advanced technology has a profound impact on all aspects of construction engineering design and construction, and has realized the integration and transformation of information and intelligence. In terms of architectural design, through BIM+ intelligent construction technology, designers can more accurately display design concepts, optimize design solutions, and improve design efficiency. Secondly, in the construction process, intelligent construction technology can help realize intelligent production, improve construction efficiency and quality through the application of automated equipment and robots, and reduce labor costs and safety hazards.

2. Case Study: Yibin Start Square Project

2.1. Project Overview

The Qibu Plaza project is located on the east side of the north bridgehead of Minjiang Bridge in Yibin City. The project is surrounded by municipal roads on all sides, with a total land area of 77,003 square meters, a total construction area of 268,278.13 square meters, a ground construction area of 192,507.42 square meters, and a basement construction area of 75,771 square meters. The Qibu Plaza project is a key project in Yibin City. The project integrates office buildings, commercial buildings (new type of complex social commercial complex), hotels (five-star hotels) and residences (river view residences). After completion, it will become a new landmark in Yibin City, as shown in Figure 1.

The main functional divisions of the above-ground part are: 30 floors above ground and two underground floors. Among them, the commercial area is 23,113.30 square meters, the business office area is 89,280 square meters, the high-rise residential area is 76,263 square meters, and the supporting rooms are 1,307.12 square meters. The main functional divisions of the basement part are: underground garage is 72,999 square meters, and non-motor vehicle garage is 2,772 square meters. This project plans to use the commercial area (Phase II) as the scope of intelligent construction implementation. Phase II includes three high-rise office buildings (12#, 13#, 19#) and four multi-storey commercial buildings (15#, 16#, 17#, 18#), with a total construction area of about 160,000 square meters. This project takes large-scale intelligent construction robot construction and BIM forward design as the key tasks and highlights of intelligent construction implementation, which are used to fully demonstrate the changes brought about by scientific and technological innovation construction technology.

The overall effect diagram of the starting square   Phase II floor plan

Figure 1. Implementation scope of intelligent construction in the starting square

3. Practical Application

3.1. BIM Technology

Intelligent construction is an innovative method that makes full use of the new generation of information technology and runs through all stages of construction projects, including design, production, construction, and operation and maintenance. With the help of advanced technologies such as cloud computing, big data, Internet of Things, construction robots and artificial intelligence, intelligent construction aims to significantly improve the intelligence level of the construction process and achieve efficient, accurate and sustainable development of construction projects. This project mainly applies BIM technology, smart construction sites, IoT systems, intelligent robots and equipment and other fields.

The Yibin Starting Square project is a significant urban development project located in Yibin, China. It includes various commercial and public facilities designed to enhance urban living standards. BIM was implemented from the early design phase, enabling detailed planning and simulation. The BIM model was used throughout the construction phase for coordination and management, as shown in Figure 2 and Figure 3.

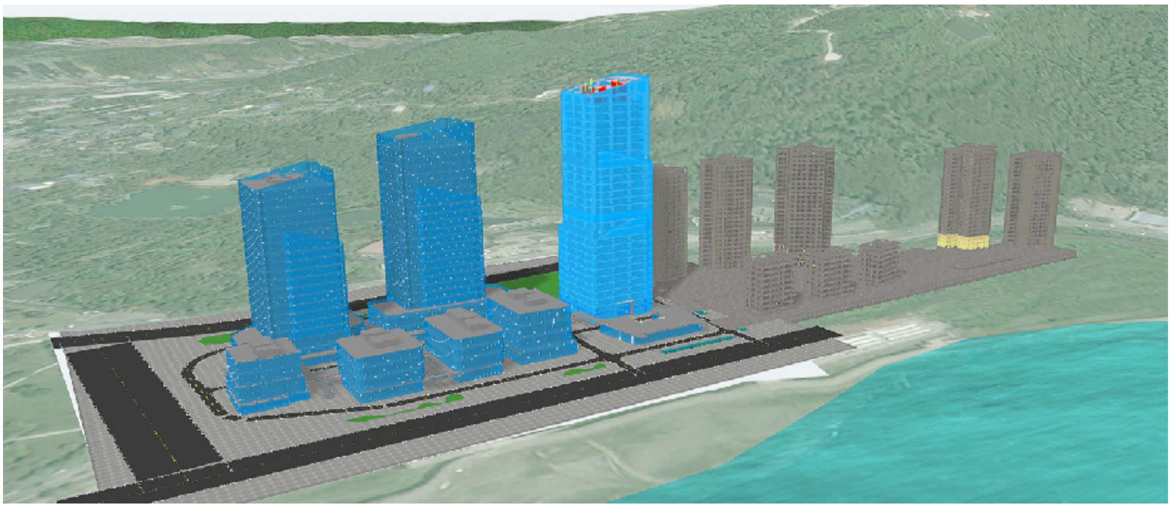

Figure 2. Phase II BIM Model

Figure 3. Phase II BIM model rendering

3.2. Intelligent Construction

3.2.1. Smart Construction Site Management Platform + IoT system

Smart construction sites can achieve real-time monitoring and control of construction sites through high-precision measurement and sensing technology, as shown in Table 1. Through smart construction sites, the combination of virtual and reality can be achieved, and integrated information management of construction sites can be carried out, as shown in Figure 4.

The smart construction site platform system of this project includes modules, such as digital command cabin, labor management, safety management, quality management, machinery management, progress management and IoT detection system as shown in Figure 5. At the same time, the robot monitoring system is integrated into the platform to realize automatic monitoring of the robot's working status, position and operation. In the IoT monitoring stage, a relatively complete intelligent monitoring system is established in combination with the current sensor system, and the smart construction site platform system is used to realize automatic early warning of the project's operating status.

Table 1. Management and control platform application

Serial number	Application Project	Main content	Completion
1	Project Display	Company introduction, project introduction and digital sandbox;	completed
2	Smart construction site integrated system	Smart construction site command center and other module applications;	completed
3	Environmental Monitoring	Monitor sewage, vehicle access, PM2.5	completed
4	Labor Management	Face recognition and entry and exit management;	completed
5	Video Surveillance	Video helmets, smart cloud broadcasting, thermal imaging fire prevention, tower crane monitoring, etc.	completed

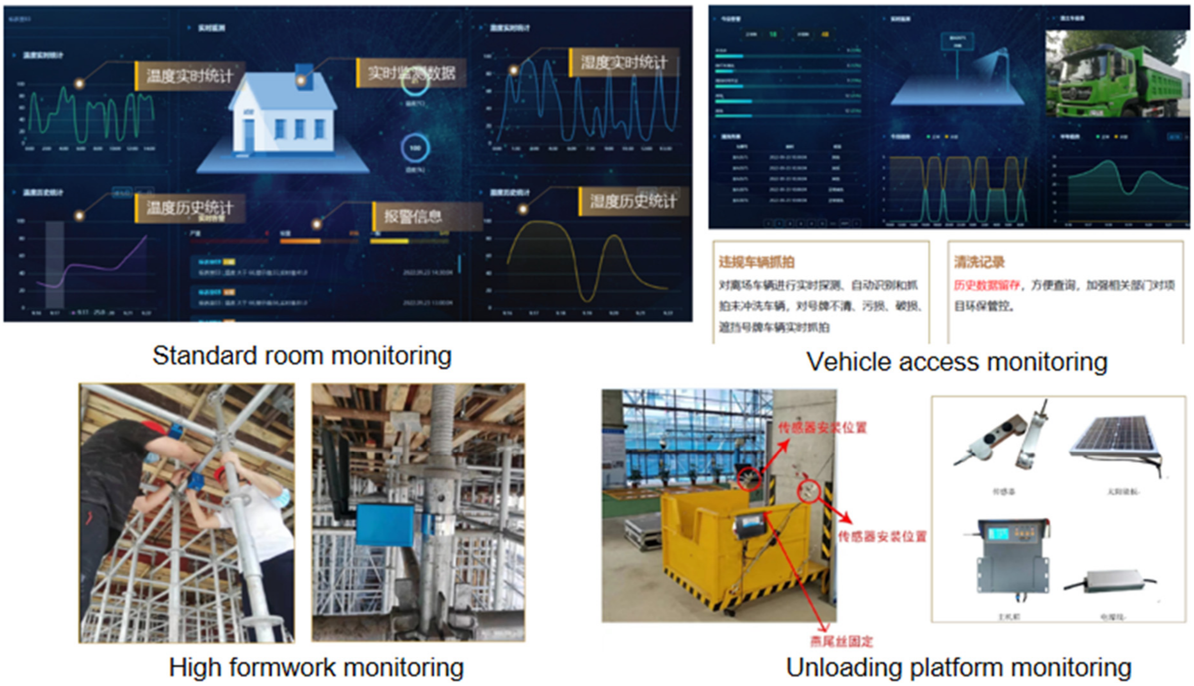

Figure 4. Integrated information management (Internet of Things system)

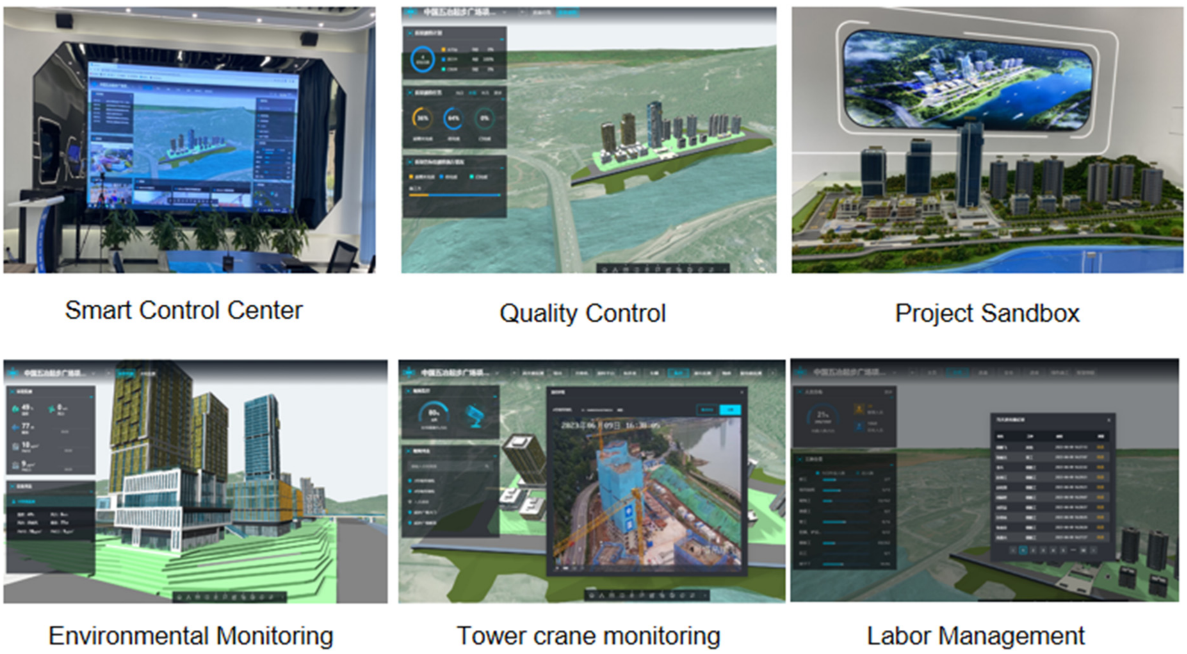

Figure 5. Smart construction site platform system

3.2.1.1 Machinery Management

1. Large machinery

The project uses the platform to check the operating safety status of large-scale machinery and equipment, safety inspection and maintenance, and the completeness of various internal plans and equipment and personnel information before it is put into use, and supervises hidden dangers with one click. The platform automatically generates disclosure materials based on illegal operation data to assist in safety education. Since the project applied the smart construction site + IoT system, the key safety risk sources of large-scale machinery on site have been effectively supervised, and no minor injuries or above accidents have occurred.

2. Tower base monitoring

The project uses the platform to view the operation status of the tower crane, and analyze the lifting operations with real-time images and data. When there are any illegal operations, the system will immediately issue an alarm message and push it to the tower crane operator and management personnel to strengthen the tower crane's self-control and management capabilities and ensure safety.

3.2.1.2 Labor Management

1. Real-name system for labor

By applying turnstiles + facial recognition to strengthen the real-name management of personnel, the information of labor personnel is effectively and quickly integrated to realize the systematization of labor personnel information management; the labor entry process is optimized, and the completion time of each labor entry management work is reduced from 2 hours to 0.5 hours, and the management efficiency is improved by 75%. So far, it has saved 320,000 yuan in labor costs.

2. Personnel attendance monitoring

The platform is used to view the status of each subcontract, work team, and type of work, and analyze whether the number of people on site meets the production requirements in combination with the current construction and production tasks. Video monitoring is then used to assist in viewing the implementation of the work surface and the progress of the project, and to strengthen control over key areas of the construction site to avoid the risk of delays due to insufficient work.

3. Employment risk reminder

In terms of on-site stability maintenance, when a person causes a malicious disturbance or violates the rules more than three times, the project will blacklist him. Blacklisted people cannot enter the construction site through the gate, and the platform will also register and warn when they are working on other projects of the company. In addition, the platform will push the information of personnel who have not yet entered the site for education, strengthen the process inspection of labor education, and ensure that the three-level education coverage rate of on-site workers is 100%.

3.2.1.3 Quality and Safety Management

Table 2. Management and control platform application

Application Project	Reasons for application	Application Purpose
High formwork monitoring	There are large areas of high formwork in the basement and the first floor	Timely reflect changes in the high-rise formwork support system to prevent accidents and monitor the stress, settlement and displacement of the support system
Tower crane intelligent monitoring	There are multiple tower operations and it is a dangerous project	Real-time monitoring of tower crane data, driver face recognition, tower crane collision warning, and automatic braking control; real-time monitoring of overload.
Intelligent monitoring of elevators	Large quantity, frequent use and dangerous projects	1. Accurately locate the position and operation status of the elevator, real-time load monitoring, overload warning 2. Fully connect with the real-name system, collect driver identity information in real time, and monitor the number of people in the cage
Intelligent monitoring of unloading platform	The standard floor area is large, and multiple unloading platforms need to be arranged on each floor.	Solve safety risks such as difficult supervision, serious overloading and lack of knowledge
Standard room	The total amount of concrete is large and there are many standard test blocks.	1. Real-time monitoring of the test block maintenance environment, over-limit alarm, automatic production maintenance records, etc. 2. Establish historical data storage function to provide a basis for quality problem tracing
Water/Electricity Usage Monitoring	High energy consumption	Through smart water and electricity meters, smart meter reading is completed and real-time monitoring is carried out. Quantitative analysis of budget quota water and electricity energy is carried out, and accurate statistical analysis of water and electricity energy consumption is carried out.
Vehicle Management Intelligent Monitoring	There are many construction vehicles and they come and go frequently.	It is convenient to detect, automatically identify and capture vehicles leaving the site; form historical data for easy query and environmental protection control; mark and alarm for vehicles that have not been cleaned and bypassed

1. Ensure a closed loop

In terms of quality management, through PDCAD process management, by the end of April, the project had initiated 196 quality inspection issues, with a rectification rate of 100%, a timely rectification rate of 90%, and all quality issues were resolved. In terms of quality acceptance, each construction process retains acceptance records. At present, the project's first acceptance pass rate is 99.33%, and the actual measurement pass rate is 100%.

2. Digital security management

The project enters the identified hazardous sources into the system every month, and issues inspection tasks after risk assessment. The responsible persons receive reminders of pending tasks on their mobile phones and carry out inspections, achieving an effective closed loop from the identification of hidden dangers to their execution. The problem rectification rate is 100%, and the management of the safety problem database is more standardized. So far, no safety accidents have occurred in the project.

In summary, safety management is combined with intelligent construction technology and the IoT system is adopted, as shown in Table 2. By issuing inspection tasks through key control points, the project safety management is listed, reducing unstable factors such as the experience of managers and the quality of the plan.

3.2.2. Construction Robot

Intelligent robots have shown significant advantages in the construction field. They can effectively replace manual tasks that are highly repetitive, cumbersome and dangerous. The application of this automation technology not only significantly improves construction efficiency, but also effectively ensures the safety of the workplace. It also significantly reduces the error rate that may be caused by manual operations and significantly reduces the labor intensity of workers. During the structural construction stage of this project, the project department plans to use concrete laser floor leveling machines, ground grinding machines, and ground troweling machines, as shown in Figure 6.

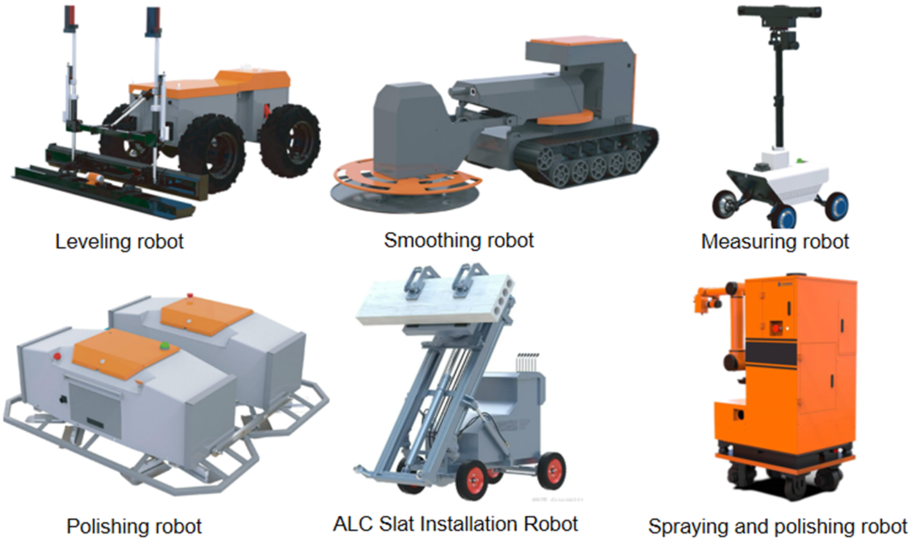

Figure 6. Construction robot

In combination with the project progress, the project also applied ALC strip installation robots, putty spraying robots, putty grinding robots, indoor spraying robots, measurement robots and building cleaning robots for combined construction, as shown in Table 3.

Table 3. Robot Application

Machine Type	Application	Reasons for application
Concrete	The total application area of concrete construction is about 160,000 square meters	It convenient for robots to plan construction paths and is particularly suitable for robot construction.
Secondary Structure	The total application area of ALC strip installation is about 50,000 square meters	1. High operating efficiency 2. Avoid manual handling and installation 3. High structural layer to avoid operating risks
Interior decoration	Structural layer grinding, putty and paint spraying, grinding, the total application area is about 50,000 square meters	1. Environmentally friendly construction, no dust 2. High construction efficiency, saving labor costs
Helper Class	Measuring/cleaning/transporting	1. Convenient and efficient measurement 2. Save labor costs
Supporting category	Cleaning station / Mixing station / Charging station	Essential

3.3. Application Effect

In terms of progress and economy, the project implements refined management and control through the implementation of BIM + smart construction site + IoT system - reasonable resource allocation of personnel, machinery, and materials, innovative design and application of methods, early prediction and real-time control of the environment, and quality control. Safe and efficient closed loop. So far, compared with the overall progress plan, it is 1-2 months ahead of the contract period, which indirectly saves about 630,000 yuan in rental fees for four tower cranes for two months and the labor costs of tower operators and signal workers. Through the in-depth design of visual nodes and the simulation method of node construction, the labor and material costs caused by rework were significantly reduced, with a total cost saving of 2.2 million yuan.

In terms of safety and quality, by utilizing video monitoring + hardware intelligent monitoring + comprehensive data analysis, we assist the project in the process management of large machinery. We conducted a month-on-month analysis of the number of tower crane alarms over three months, and the number of alarms decreased by 36%. Through problem tracking, project problems were closed-loop and controllable in a timely manner, and no safety accidents with minor injuries or above have occurred. The project's first-time acceptance quality pass rate was as high as 99.33%, with an error rate of less than 1%, and no quality accidents have ever occurred. In traditional labor entry management, there are many training items and the frequency of personnel entering and exiting the site is high. Each training session takes about 2 hours. Now, through the application of real-name labor management, it only takes 0.5 hours to complete the same amount of work, the entry process is optimized by 1.5 hours, and the information of labor personnel can be effectively integrated and systematically managed, with an efficiency improvement of 75%, saving the workload equivalent to that of two managers and saving 320,000 yuan in labor costs.

4. Results and Discussion

1. Improvements in Project Management

The integration of BIM and intelligent construction technologies significantly improved project management by providing accurate and timely information, facilitating better decision-making.

2. Enhancements in Construction Quality and Safety

The use of drone inspections, robot construction, and the Internet of Things (IOT) enhanced construction quality and safety by enabling precise execution and continuous monitoring.

3. Cost and Time Savings

The application of these technologies resulted in substantial cost and time savings, demonstrating their economic benefits.

4. Challenges and Solutions in Implementation

Despite the benefits, several challenges were encountered, such as resistance to change and technical issues. These were addressed through continuous training and technical support.

5. Conclusion

Intelligent construction technology makes full use of smart construction site platforms, the Internet of Things, big data, BIM, etc., through the application of intelligent systems, to improve the intelligence level of the construction process, significantly reduce dependence on people, reduce labor costs, and improve construction efficiency. Accurate data analysis and simulation improve the cost performance and reliability of the building and ensure the construction quality. Pay more attention to environmental protection, energy conservation and emission reduction, and reduce energy consumption and pollution during the construction process.

From an energy management perspective, the use of smart construction technology can significantly improve energy efficiency. The intelligent energy management system can accurately monitor the energy consumption of the building through sensing, control and optimization methods, and make adjustments and optimizations based on real-time data. Smart construction technology also shows its advantages in terms of material selection and quality control. Through big data technology, smart construction technology can analyze material performance, cost, environmental friendliness and other factors to help building designers and architects choose the optimal materials. At the same time, smart sensors can monitor structural changes, temperature, humidity and other indicators of the building in real time, and automatically detect and diagnose building quality problems. From the perspective of construction progress and safety, smart construction technology can be applied to the automation and intelligence of engineering construction. Real-time monitoring and control of the engineering site can be achieved through sensors and Internet of Things technology, and construction progress and quality can be automatically managed. At the same time, smart sensors and cameras can monitor construction site safety conditions in real time, automatically detect and diagnose safety issues, and reduce the risk of construction site accidents.

BIM+ intelligent construction technology will play an increasingly important role in the future construction industry. With the development of robots and automation technology, intelligent construction will achieve a higher degree of automation and intelligence. Robots will take on more construction tasks, reduce labor costs, and improve construction efficiency and quality. By applying BIM technology, data integration and sharing throughout the life cycle of a building can be achieved, thereby improving the efficiency of design, construction, and operation. It will also make building design and construction more accurate and reliable, reducing waste and errors.

Acknowledgments

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