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Information-based Smart Construction Management of High Rise Building Under the Complex Surrounding Environment in City Core Area

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Abstract

With the development of urbanization, the increase of building density in urban core areas have resulted in the complexity of construction environment. While high-rise landmark building has always been preferred in the construction of urban core areas, super high-rise building construction is facing construction management difficulties due to its complex working conditions and enormous building system, as the construction management of super high-rise buildings in the area requires higher, refined and detailed standard, especially with the complex surrounding environment of the urban core area. Based on a super high-rise project in a core area of Shanghai which has 370 m building height and 772,643 m2 building area, with complex surrounding environment, narrow construction site and many super-high-altitude crossing works. With the application of BIM technology, the Internet of Things, the LAN communication and other various intelligent mechanical equipment, the information management systems as well as the efficiency and refinement of construction management have improved, ensuring the smooth implementation of the project while effectively controlling the impact on the surrounding environment.

Keywords: Urban core area, super high-rise buildings, Construction management, Information-based smart construction, General contract management

1. Introduction

With the acceleration of urbanization, the renewal of the core areas of large cities has accelerated, and there are more and more large-scale complex construction projects in the central urban area. In order to meet the business needs, such projects often choose the construction model of 'super high-rise with large-area commercial and rail transit cover, which can maximize commercial benefits, but lead to the huge and complex building system. In addition to the extreme complex surrounding environment, which puts forward higher requirements for project construction management.

A high rise building project in Xujiahui core area of Shanghai is taken as example, in which various digital management systems are applied to improve the professionalism and refinement of general contracting manage-ment to ensure the orderly construction of super high-rise projects in the complex core area of the city. Further development direction of intelligent construction is put forward based on the application result in project implementation.

1.1. Project Overview

1.1.1. Project profile

The super high-rise complex is located in the core area of Xuhui District, Shanghai. As a large-scale urban high-end complex, the project will become a new urban landmark after completion. The total land area of the project is 66,017 m^2. The project consists of three towers and commercial podiums, with a total construction area of 772,643 m^2. The building height of T1 tower is 220 m, and the building height of T2 tower is 370 m with 70 floors above the ground. After completion, the T2 tower will be the tallest building in the west of Huangpu river in Shanghai.

The surrounding environment of the project is extreme complex, with serried underground pipelines, the subway line on the north side passes through the foundation pit of the project and the subway station on the east side shares the basement exterior wall with the project. Figure 1 shows the surrounding environment. In addition, the podium is basically fully occupy the site result in the cramped construction space.

1.1.2. Key difficulties in super high-rise construction in the complex environment of urban core areas

1) The integrated management of design and construction is difficult due to the complicated design modification.

There are dozens of professional engineering design units involved in the project. The general contractor will face the issue that how to coordinate and manage dozens of design units and nearly hundreds of professional construction contractor, which put forward high request

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Figure 1. Surrounding environment sketch.

to the integrated project management.

2) Superimposed safety risks caused by the complex surrounding environment of the urban core area and the super-high-altitude intersection operations

The urban core area project has complicated surrounding environment with various buildings such as schools, office buildings, hotels, shopping malls, and residential areas scattered within 50 m surrounding scope, which cause the huge pressure of civilized construction management. As the east side basement shares the exterior wall with the subway, the east side area of the project cannot be used as large components transport corridor. While the cloth-filled podium has a superimposed impact on the transportation and stacking of on-site building materials, which cause more three-dimensional crossing operations that increase on-site safety risks.

3) High pressure of employment management under the normalization of the COVID-19 epidemic situation,

The project has a 4-5 years peak period of construction labor during the entire project construction process. In this period, there will be nearly 3,000 workers work at the construction site. With the normalization of COVID-19 epidemic control during the construction process cause huge challenges to on-site management and even the normal operation of the project that how to better manage workers and the flow information of labor force.

4) High requirement of general contracting schedule, quality, safety overall management

How to coordinate and master the progress, labor force and building materials information of each subcontractor on the basis of ensuring the progress, quality and safety under the condition of narrow construction site and tight schedule pose huge challenge for general contracting management.

1.2. Key technologies for intelligent management of super-large project construction sites

In order to safely, high-qualitily, and efficiently complete a super-large scale project with huge construction volume, numerous large-scale equipment and complicated construction workers. The technology of drones, remote monitoring, Internet of Things, two-dimensional codes and other methods is applied to conduct on-site intelligent management.

1.2.1. Construction site information collection technology based on oblique photography technology

Due to the large number of on-site construction working place, integrated floor plan of the site which is shown in Figure 2 is created by drone aerial oblique photography

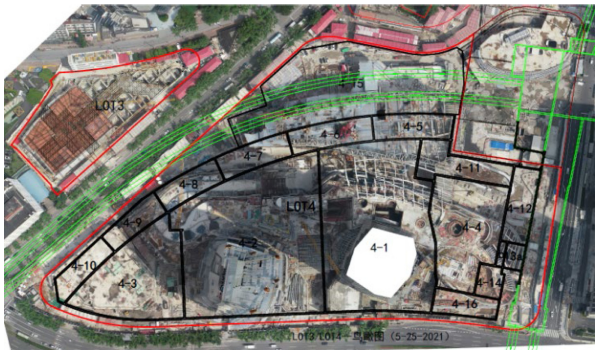


Figure 2. Construction site progress plan.

combined with software processing to achieve a clear and simple expression of on-site construction progress.

This kind of visualization scheme makes the on-site progress presentation more intuitive, and also gives a more comprehensive understanding of the overall road, site layout and other information on the site to the on-site management, which provides strong support for the construction planning of the project implementation phase.

1.2.2. Remote real-time monitoring technology for operating areas with high risk of accidents

The high-definition cameras and network monitoring platforms are applied to remotely monitor and manage key areas with high incidence of accidents. For example, the steel platform which is a main work area, nine panoramic network high-definition cameras are installed on the steel platform crane (the specific arrangement is shown in Figure 3). The real-time monitoring allows management to intuitively and timely realize the quality, safety and progress on work platform, and further improve the level of refined construction management.

1.2.3. Real-time monitoring technology for on-site construction equipment operation status

Due to the tight schedule, the podium and the tower are constructed at the same time, and the podium is SRC concrete structure with large amount of steel structure components and concrete civil works lifting. During the peak period of the construction process, there are 12 luffing jib tower cranes operating at the same time on site, which cause high safety risk. In response to such situations, an intelligent anti-collision system for the tower crane group is applied on site, which use sensor to calculate the boom projection length, and the adjacent tower crane boom parameters are sent to the host installed in the cab. The system can make the driver more intuitively understand the collision situation of the tower crane.

1.2.4. Information management technology of processing, transportation and construction of prefabricated components

The steel structure hoisting capacity of this project is 22,000 tons per year. The steel structure hoisting

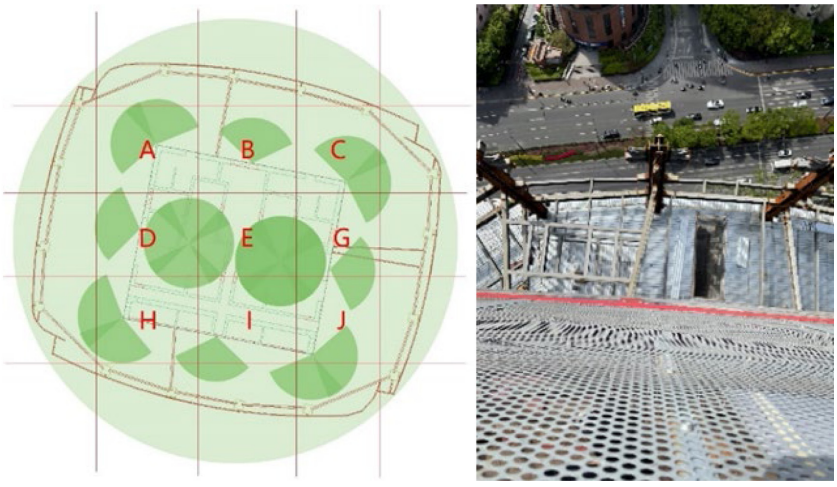


Figure 3. Panoramic camera figure.

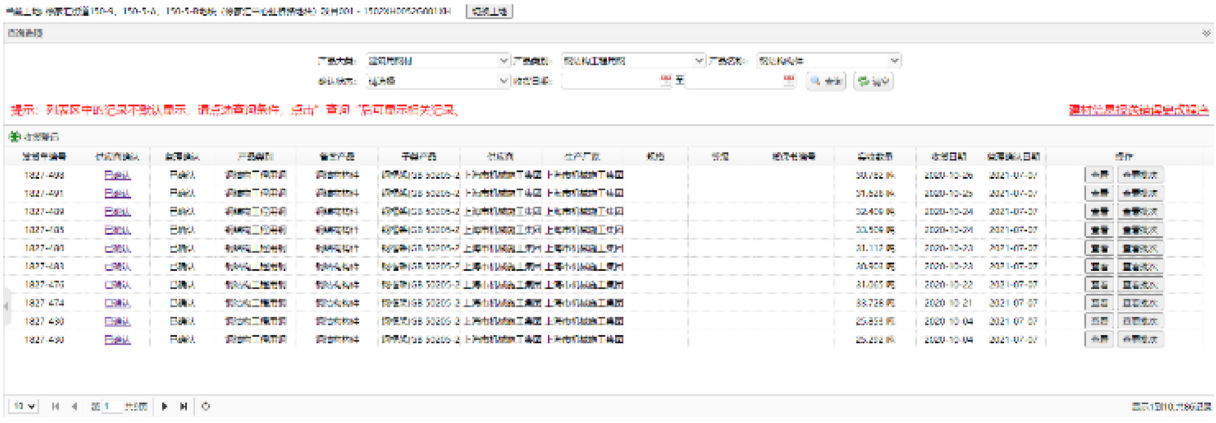


Figure 4. The internet of things platform.

operation area is distributed in all the construction areas on the site. Due to the complex form of the steel structure, the detailed design, processing, transportation and hoisting management meets higher requirements. Accordingly, the Internet of Things platform is applied to monitor the factory's material preparation, processing and transportation conditions in real time. Suppliers, construction units, and supervisors can confirm the components status on the cloud platform, as shown in Figure 4.

1.2.5. On-site inspection management technology based on QR code technology

1) Safety inspection

The construction equipment parameter information, record information, personnel qualifications and safety disclosures are integrated by using QR code technology. On-site safety management can verify the relevant information on-site by scanning the QR code. The general contracting management can confirm the on-site safety management situation through the safety inspection records.

2) Technical disclosure

The required documents such as technical disclosure and construction scheme are exhibited on the construction work surface in the form of QR code, which make workers to scan the QR code before operation to review the key points of construction and reduce on-site safety issues.

3) Management of fire operation permits

The fire operation time, workers and the surrounding environment are summarized by the QR code. In addition, the on-site fire operation points are integrated by BIM model. Managers can use the model to confirm the fire operation area and conduct a targeted inspection. During the inspection, the QR code can be scanned to confirm whether the fire operation condition meets the requirements.

3. Key construction technologies based on intelligent mechanical equipment

3.1. Key technologies for vertical transportation in super high-rise building construction

The T2 super high rise tower has a huge building volume, which result in a large demand for vertical transportation of building materials, electrical equipment and construction workers during the construction process. Therefore, the research and innovation of vertical transportation construction technology will significantly improve the construction efficiency of the project. The main technology of this project adopts the following schemes.

3.1.1. Integrated climbing construction system of large tonnage tower crane and steel platform

The integration of the crane and the steel platform change the from that the tower crane attached to the structural surface alone into the form that tower crane is installed on the steel platform truss, which makes the relevant safety management responsibilities more clear and avoids safety risk that the cross-climbing of the tower crane and the steel platform. The integrated system have greatly improved the safety of on-site construction.

3.1.2. Jumper elevator construction technology

Jump elevator technology is a advanced vertical transportation scheme in super high-rise construction. The anticipate of permanent fire elevator can be achieved by the climb of elevator machine room. The use of the jump elevator scheme enables the fire elevator to be anticipated by about 60 weeks. Compared with the construction elevators, the permanent fire elevators have huge advantages in stability, transportation speed, and transportation tonnage. The use of jumper elevators brings greater convenience to the material vertical transportation of secondary structure and decoration engineering.

3.2. Key technology for high-performance concrete construction

3.2.1. Smart concrete pouring technology of super high-rise building

One-key calibration of pouring points, automatic pouring path planning and automatic fixed-point pouring can be achieved by using the latest intelligent concrete distribution spreader which is unmanned operation with positioning accuracy within 200 mm. The integrated technology of monolithic steel platform formwork and concrete distributing machine is also adopted in the project to solve the problems of low control accuracy and low intelligence of existing distributing equipment mounted on the monolithic steel platform and realize the precise positioning and pumping of concrete. The specific content parameters are shown in Figure 5.

The Internet of Things platform is introduced in the program to monitor and manage the concrete distribution spreader. The combination of local monitoring and remote monitoring carry out the comprehensive management of on-site concrete pouring.

3.2.2. Super high-rise concrete pumping technology

The digital rapid connection technology of the spreader with pumping pipe is applied in the project. The concrete pipe is lifted hydraulically to ensure that the concrete pipe can be raised quickly, and the laser automatic distance measurement and self-compensating flexible pouring pipe is used to achieve precise connection.

3.3. Intelligent controlled integrated steel platform formwork and large construction machinery integrated building equipment

The T2 tower is the first to use intelligent controlled integrated steel platform formwork and large construction



型号			单位	HG35A-5Z
性能	最大布料半径		m	35
	独立高度(至臂根铰点)		m	3.5
	臂架回转角度		°	±270
	整机重量		kg	13000
	电机功率		kW	30
控制方式			/	近控/无线遥控
臂架	形式		/	五节液压Z型卷折
	输送管径		mm	DN125
	末端软管		°×mm	5°×3000
	第一节臂	长度	m	12.73
		转角	°	0~90
	第二节臂	长度	m	7.85
		转角	°	0~180
	第三节臂	长度	m	7.88
		转角	°	0~240
	第四节臂	长度	m	2.64
		转角	°	0~180
	第五节臂	长度	m	3.9
		转角	°	±60

Figure 5. The application of intelligent concrete distribution spreader.



Figure 6. Monitoring management system of concrete distribution spreader based on the internet of things.

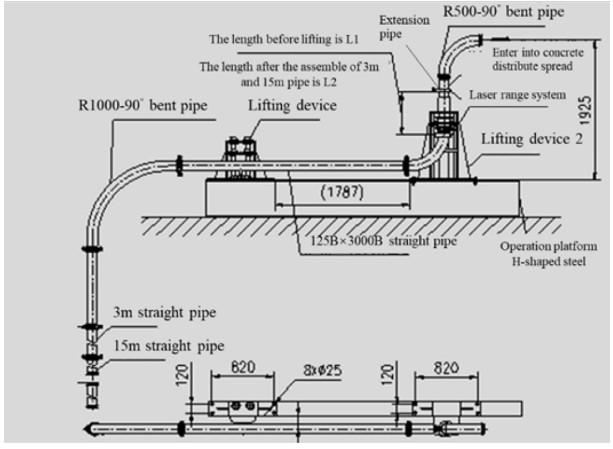


Figure 7. Composition of concrete.

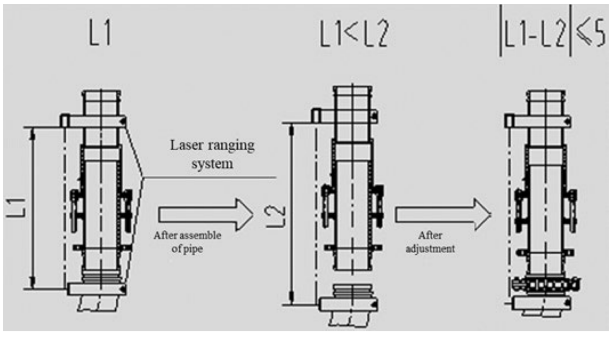


Figure 8. Principle of automatic compensation.

machinery integrated building equipment. The integrated building equipment is composed of six parts: steel platform system, hanging scaffold system, steel beam climbing system, tube support system, large load-bearing tube support system and formwork system. By integrating large capacity system, integrated steel platform formwork, large tower crane, new intelligent distributing system, and construction elevator, the platform is able to realize the collaborative work of various mechanical equipment on the construction site and greatly improve the efficiency.

In the process of construction, intelligent detection technology is used by build equipment, to monitor the stress, deformation and environmental parameters of key parts. The remote monitoring of the climbing status of integrated building equipment is realized through the real-time collection and analysis of large amounts of data

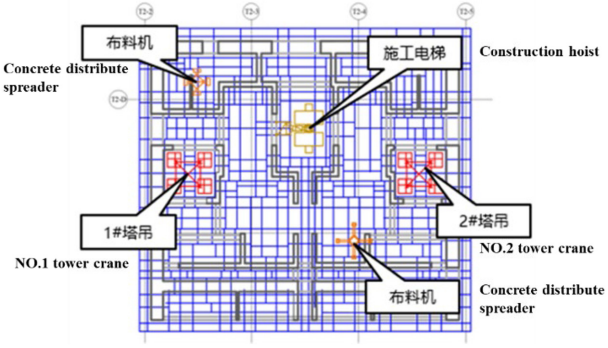


Figure 9. Location diagram of construction equipment on steel platform.

and information during the construction process.

4. Digitalization of general contract management

By integrating advanced information technology into daily management, the management level in terms of cost, schedule, quality and safety is improved, the efficiency of on-site project management is increased, and the comprehensive refined project control is achieved.

4.1. On-site management techniques based on BIM

As a representative of digital tools, BIM technology has played a significant role in the planning, design, construction and management of this project.

4.1.1. Research on BIM-based construction schedule management techniques

The construction process of super high-rise buildings is relatively simple and has a high degree of modularity. During the construction of this project, BIM model is used for visualized manage of the construction process. The construction process and corresponding color are set and marked for different specialties and construction sections in the general contracting platform. And the process can be updated by scanning the code via mobile phone, which makes the progress control more intuitively. Details are shown in Figure 10.

4.1.2. Collaborative work management techniques based on BIM technology

During the uploading of the BIM visual management model, if the construction progress is delayed, all professionals need to submit the schedule delay documents and bind them to the corresponding construction section. Under the unified and coordinated management of general contracting, construction delays can be traced back, and the ability to claim compensation can be better retained.

4.2. Informatization management of labor status based on Internet

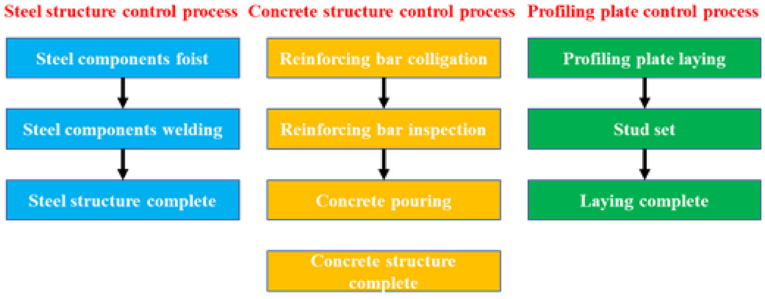
Due to the normalized management during the epidemic, the labor management of on-site construction workers has become a key factor in the progress of on-site construction. Under the premise that the problem of labor mobility cannot be completely solved, this project uses the Internet to carry out informatization management of workers, thereby improving the level of on-site management. The key points are as follows.

4.2.1.Informatization of labor real-name management

The general contractor and the subcontracted laborers are responsible for real-name registration of all the on-site personnel.

4.2.2. Informatization management APP

Customized Apps are developed by third-party software vendor. Each personnel will get an independent account after real-name registration and specialties assignment. The worker can enter the site with the generated QR code.



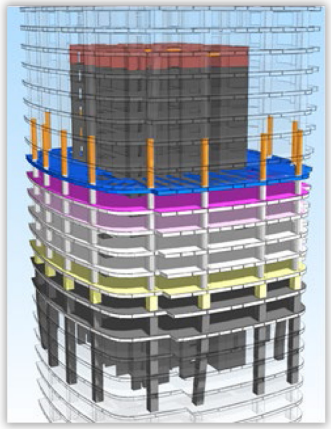


Figure 10. BIM visual management model.

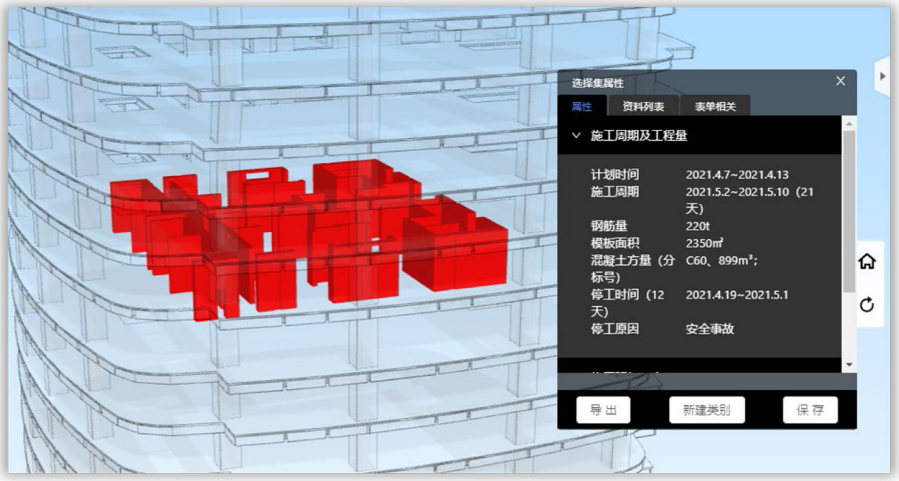


Figure 11. BIM schedule management and tracing platform.



Figure 11. On-site labor force dynamic statistics

4.3.3. Regional real-time personnel statistics and admission management

For the entire construction site, closed-off management is carried out through the use of turnstiles. For key construction areas, QR code is adopted. In this way, the number of various personnel on site can be better counted, and the progress can be controlled comprehensively.

5. Conclusions and direction of smart construction

5.1. The application outcome of smart-construction

The complex environment in the core area of the city has brought huge challenges to the construction of super high-rise buildings. Under great management pressure, the on-site management team proactively chose new technologies, processes, and methods, making a great breakthrough of smart construction. In general. The smart construction brings following advantages to the project:

5.1.1. Improvement in technical planning and management

In terms of project technical planning, technologies such as BIM and drones are used to better grasp the on-site situation, and coordinate facilities such as on-site storage yards and roads, therefore guaranteed the orderly operation of the project. Through the design of the large-capacity steel platform and the integration of various mechanical equipment, the technical management level and safety of super high-rise construction have been improved.

5.1.2. High degree of digitalization of safety management

By introducing a variety of digital methods such as panoramic cameras, QR codes, and anti-collision systems, the management and control of the 700,000 square meter construction site are strengthened. The on-site labor management is enhanced through the use of real-name system and the Internet. This enables the management team to have a more comprehensive and in-depth understanding of the on-site personnel flow.

5.1.3. Enhancement in cost management and management efficiency

If the management staff is deployed in accordance with normal project, the total number of the management team of this project will far exceed 1,000. It is precisely because of the adoption of digital and intelligent management technology that the on-site management cost and communication cost are effectively reduced, and the management efficiency and management level are greatly improved.

5.2. Future development direction

Digitization is developing rapidly in the field of engineering construction. However, through the implementation of this project, pain points are also revealed.

5.2.1. Labor force management

The popularity of real-name and face recognition has

brought project labor management to a new level, but separated management among different projects often results in repeated management of labors. Each worker will encounter different real-name management methods at each construction site, which will greatly increase the cost. How to have a more unified management method for real-name system is a issue that needs to be solved urgently.

5.2.2. Object management: further development of the Internet of Things in the 5G era

In the 5G era, the Internet of Things has entered a new field. The Internet of Things this project applied is still in terms of component information transmission. How to better improve the management level of the Internet of Things, such as the management of the entire process of admission, processing, assembly and acceptance of network monitoring components of raw materials, is still a process of continuous development.

5.2.3. Data management:

The large-scale application of BIM model, digital technology and equipment has effectively promoted on-site management. However, due to the numerous BIM model management platforms, the relevant digital solutions focus on different professions. Three-dimensional technology is also far from two-dimensional CAD technology to do "one model to the end". How to integrate various digital modules to form a completed digital control plan is a key part of smart construction from the icing on the cake to the indispensable.

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