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Design of Construction Management System of Rotary Drilling Pile Based on BIM

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Abstract: Pile foundation engineering was a hidden work, it includes three processes: mechanical hole forming, reinforcement cage fabrication and installation, concrete pouring. Pile foundation construction was characterized by great difficulty in process management and high cost of remedy in case of quality problems. Besides, due to the uncertainty of the site stratum, it was difficult to accurately and timely feed back the final hole depth into the rock, and mechanical hole forming cannot create favorable conditions for subsequent processes. Rotary drilling pile has the advantages of high efficiency, good safety and strong stratum applicability, which was widely used in pile foundation construction. In order to improve the construction efficiency and information management level of pile foundation engineering, a set of rotary drilling pile construction management system was developed. The system was based on the key points of pile foundation engineering management to monitor the positioning, hole depth and drilling rate, verticality, current, noise and other parameters respectively. It uses 3D geology and BIM to display the relationship between hole depth and stratum in real time, otherwise it applies the multivariate data of monitoring to realize automatic rock-socketed judgment. The system could comprehensively monitor and manage the construction process information of rotary drilling pile, dynamically correct the potential quality problems in the process, which effectively reduces the difficulty of process management and saves construction time.

Keywords: Rotary Drilling, BIM, Construction Management, Internet of Things

1. Introduction

Most foundation works in infrastructure and house construction projects belong to hidden work, whose process management has always been the pain point and difficulty. In pile foundation construction engineering, it was necessary to manage the process of drilling, reinforcement cage production and installation, concrete pouring and so on. Among them, the most difficult part of management was drilling, and its main control parameters are: positioning, depth of drilling, rock-socketed depth, verticality. In the traditional construction management, many parameters were checked by manual. Because of the non-uniform standard and large error of manual judgment, which the result of pile foundation into the rock judgment often have a great controversy. In addition, the verticality which was a crucial parameter for engineering quality, cannot be monitored in real time, so there was a great lag in control, and follow-up problems were costly. Therefore, it was necessary to use the Internet of things technology to carry out information management on the tools of rotary drilling pile, which were most widely used in pile foundation engineering. At present, Cai Degou, Zhu Hongwei et al. [1-2] have studied and applied the pile foundation construction management system of CFG long auger in railway engineering, which has solved the data management of construction positioning, drilling depth, pile inclination and current of final hole and achieved good results. Rao Wubin [3] studied and applied the management and control system of mixing pile based on digital cloud platform, which achieved certain results in the quality and achievement control of soil-cement. Based on the drilling data of advanced drilling, Wang Yiming [4] et al. studied and applied the digital construction technology of punching pile, which reduced common problems such as hole collapse and slurry leakage. Ou Huabin [5] studied the real-time monitoring of on-site environmental information, such as support structure, hydrogeology and surrounding environment, and on-site management information, such as personnel and machinery, through sensors and Internet of Things positioning technology, to achieve project monitoring and management visualization. In addition, many scholars have studied the application of BIM (Building information modeling) in engineering. Parka C et al. [6], Kwow et al. [7] and Lijuan CHEN et al. [8] constructed an integrated information conceptual model of defect management and AR for passive defect management in the actual construction process, and actively reduced the problems of construction defects, missed inspection and rework. Chris Gordon et al. [9] analyzed the application of LiDAR and entity perception technology in construction and explored its role in construction supervision and quality control. Kwon et al. [10] used BIM technology, AR and image matching technology to improve the detection function of construction defects, and developed two types of defect management system, image matching system and mobile DM-AR application. Zhang Ailin et al. [11] constructed a BIM technology prefabricated building construction phase management system to solve the problem of the loss and misuse of prefabricated components and improve work efficiency. Zhang Jingjie et al. [12] Sun Wu et al. [13] integrated BIM and RFID technology to build an intelligent management system for construction workers, which has conceptually realized the functions of safety reminder and accident warning.

In this paper, design a set of rotary drilling pile construction management system, which use intelligent equipment to monitor positioning, hole depth, verticality and noise; and the integration of 3D geological information and real-time hole depth data was to dynamically analyze the rock-socketed situation; it makes the covert engineering datable and transparent, which was helpful to improve the management ability of construction process.

2. System Architecture Design

The system architecture was divided into perception layer, hardware layer, software layer and display layer, as shown in Figure 1.

(1) Perception layer: the operation information of on-site rotary drilling pile foundation was transmitted to the management system through a variety of sensors. The sensor equipment of the sensing layer mainly includes rotating counter, Beidou locator, verticality sensor, current and noise sensor. The rotary counter is mainly used to measure the depth of drilling. The real-time depth of drilling could be calculated by recording the number of turns of the pile machine hoist; Beidou locator was used to record the construction positioning of pile machine; verticality sensor was mainly used to monitor the borehole verticality; The current sensor was mainly used to monitor the dynamic current of pile foundation, through which the hardness state of pile machine and stratum could be deduced.

(2) Hardware layer: it mainly includes servers, networks, storage devices and security devices to ensure the normal operation of the information system.

(3) Software layer: geological information, BIM model, planning, concrete management, reinforcement cage management, front-end monitoring, data analysis, log management and other application modules were constructed on the basis of various basic data and business.

(4) Display layer: dynamic message warning, production simulation and business process control were realized mainly through large screens or mobile terminal devices.

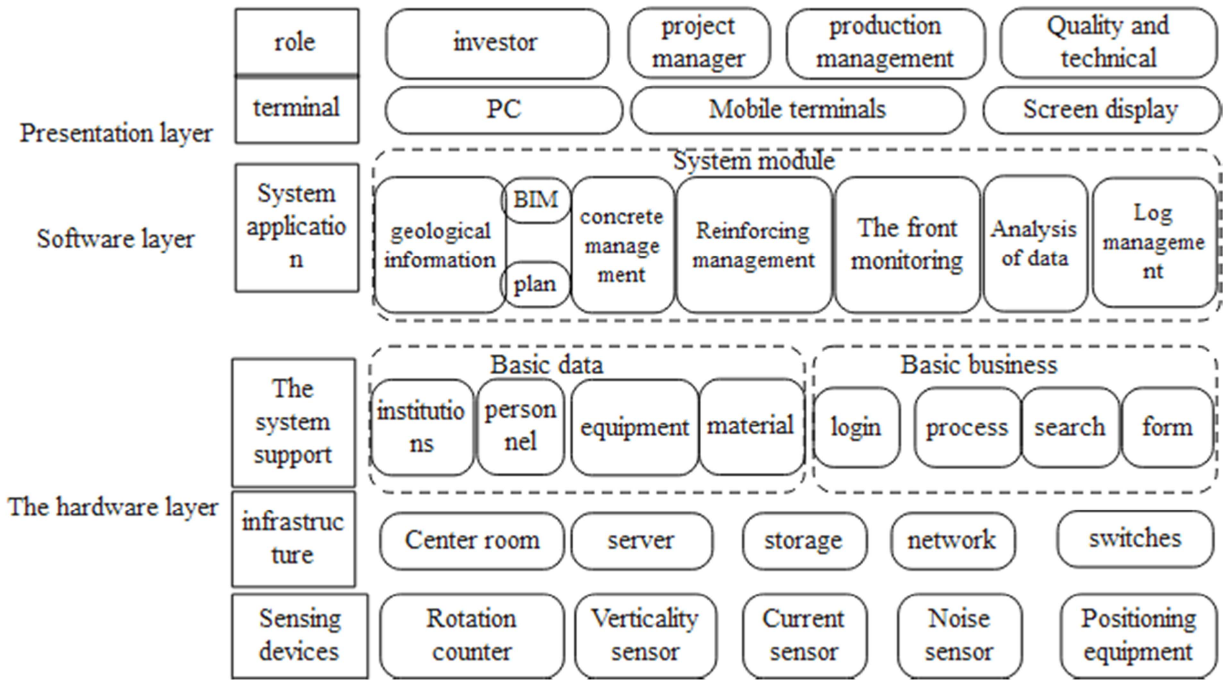

Figure 1. *Construction management system architecture diagram of rotary drilling pile.*

3. Technical Solutions

3.1. Monitoring Technology of Pile Foundation Construction Parameters

In the construction process of rotary excavator, the following parameters should be controlled: position of drill, depth and speed of rotary excavator drilling, verticality, rock-socketed judgment. At present, the rotary excavators on the market were divided into two categories: 1) the old version of the machine and tools, the main parameters were displayed by the traditional instrument panel, only the drilling depth and verticality parameters, and cannot be directly obtained data from the machine; 2) New version of the machine, the main parameters using digital display and remote data reading conditions, manufacturers need to provide data interface. According to the current situation of market application, monitoring of construction parameters adopts the mode of adding sensors externally.

(1) Positioning

Using BeiDou Navigation Satellite System (BDS), high-precision positioning technology provides more convenient construction management and control [14], and forms a mutual checking and verification mode with traditional survey alignment positioning.

(2) Depth and rate of drilling

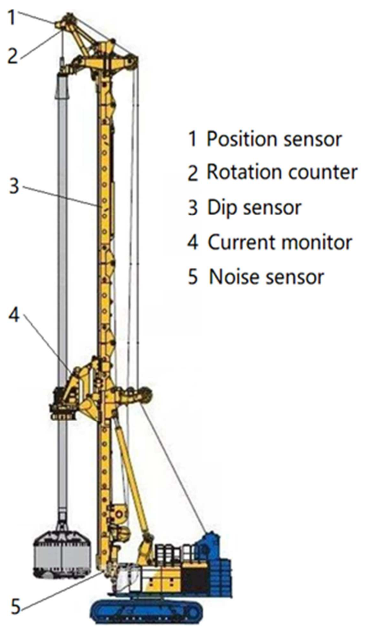

Figure 2. *Schematic diagram of monitoring sensor layout of rotary excavator.*

The drilling depth of rotary excavator was a key parameter for construction control, which could be determined by drill bit and drill pipe. The length of drill pipe was positively correlated with the elongation of steel cable at the top, as shown in Figure 2. According to the structural characteristics of the machine, the drilling depth of the drill could be calculated by measuring the expansion of the steel cable and adding the length of the drill pipe outside the drill bit. Based on the principle of strong adaptability and small measuring error, two measuring schemes had been put forward to measure the elongation of steel cable: 1) the measuring method of rotation of top pulley, a rotation counter was installed at the central axis of fixed pulley of top steel cable, and the elongation of steel cable could be calculated by calculating the rotation of pulley; 2) hoist revolution measurement method, in the hoist shaft end of the installation of a rotary counter, through the hoist revolution could be calculated steel cable elongation. Compared with the two schemes, the top sliding revolution measurement method was more accurate to calculate the length of steel cable, so the first scheme was adopted.

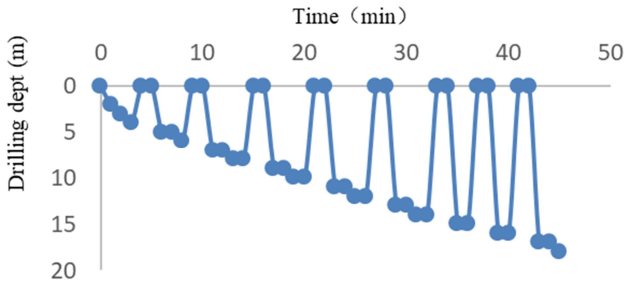

Figure 3. *Time history curve of bit position of rotary excavator.*

The drilling process of rotary excavator was quite different from that of traditional drilling machines. The drilling process of rotary excavator was a repeated process [15]: drilling down - soil extraction - lifting - soil pouring - footage. Therefore, the time history curve of the rotary excavator's drill bit running in the hole presents a wavy shape (as shown in Figure 3), and the drilling rate could be calculated by the time history curve.

(3) Verticality control

Verticality control was an important parameter of pile foundation quality. When encountering the miscellaneous fill stratum, the drill was easy to deviate and cause a large verticality error. If it was not adjusted in time in the construction process, the hole location deviation would be continuously amplified with the hole depth, which would seriously lead to the inclined pile, reinforcement cage cannot be placed and other problems, seriously affecting the quality and safety of the project.

On the drill stem placement verticality sensor, could obtain the real-time verticality of drill, verticality control system set in the threshold value could be real-time warning, made drilling verticality of visualization and convenient management.

(4) Current monitoring

The current sensor could be arranged on the main cable of drilling machine to monitor the current change value in the process of drilling, so as to establish the current relationship between the stratum and pile foundation, and provide data support for the later formation judgment.

(5) Noise monitoring

In the process of drilling into the rock, there would be noise which was different from the soil layer, and it was also one of the conditions for determining whether to enter the rock manually. A noise sensor on the drill could establish the relationship between noise and soil layer, and provide diversified data support for formation and rock-socketed judgment.

3.2. 3D Geological Visualization and Multivariate Data Comprehensive Diagnosis Technology

This system converted borehole information from geological survey report into 3D geological information, which could obtain the formation information of any pile foundation point and provide a clear relationship between formation and hole depth for field construction personnel.

The investigation report was affected by the spacing of boreholes and cannot fully reflect the actual stratum situation, so a lot of manual interpretation work was needed in the construction process of rock-socketed pile. When the drill got into the rock, there were usually some characteristics which clearly differed in the soil stage: 1) the drill rate decreased significantly; 2) noise increased; 3) the current increased significantly. The boundary of the criterion for judging the depth of artificial rock entry was fuzzy, and there were often different criteria from different people, which caused great controversy. Therefore, the judgment and measurement of pile foundation rock entry had not found a good solution.

Pile foundation management system simultaneously monitors the rate of drilling, verticality, sound and noise, current to obtain multiple data, combined with three-dimensional geological information to judge the combined formation into rock. Due to the different performance of each drill, the monitoring control indexes were different, which should be determined by engineers in the pile test stage combined with the system data. After the monitoring indexes was determined, the system recorded the whole process of drilling and judges the state of drilling rock. The construction process management flow of rotary drilling pile was shown in Figure 4.

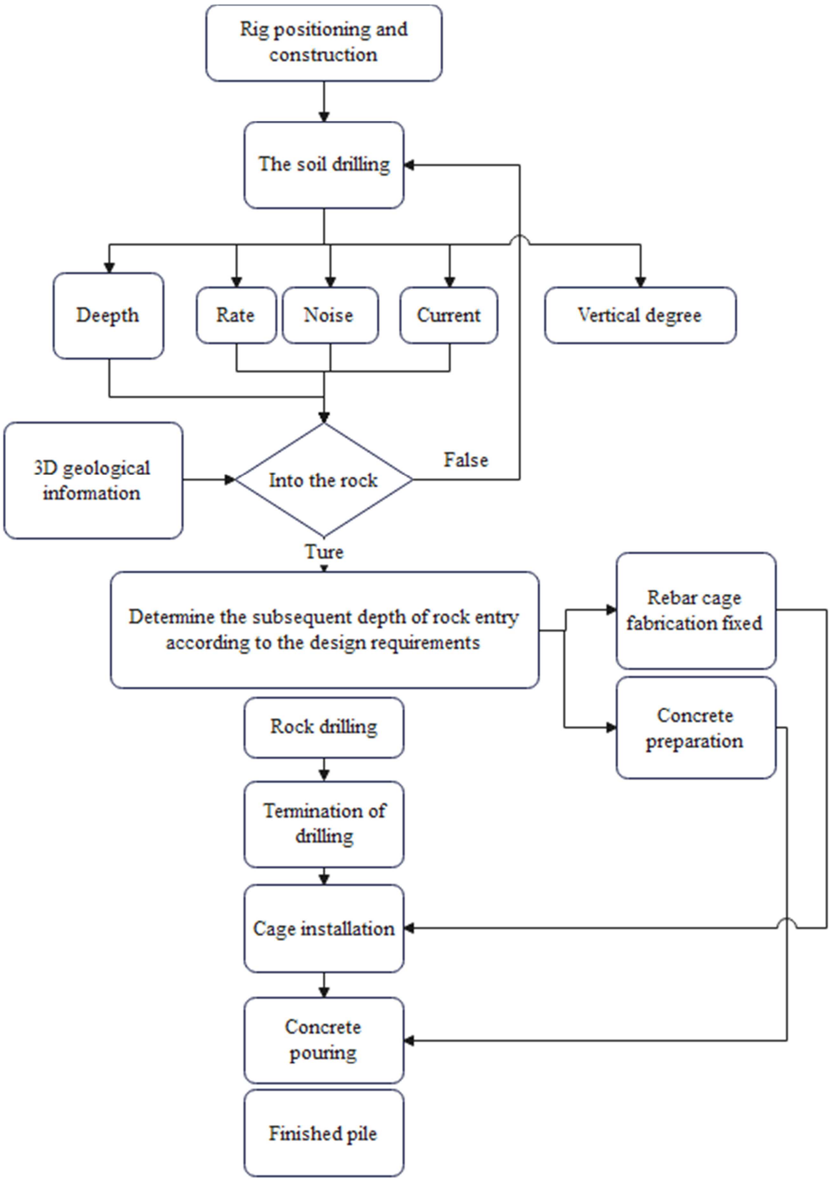

Figure 4. *Rotary drilling pile construction process management process.*

4. Information Management Technology Based on BIM

The application of BIM (Building Information Modeling) technology to integrate all the relevant information in the construction process was the requirement of the whole life cycle management. BIM information management process was as follows: 1) established a BIM model of pile foundation, pile foundation classification number; 2) researched and development production planning module, could click on BIM model pile foundation and construction plan, according to the date after handing out the task ahead of time to construction management personnel, remind drill, concrete, steel reinforcement cage made of preparatory work; 3) monitored construction status of rotary drilling piles, and stored relevant data in BIM model.

The transparent management of project progress and quality by the application system realized the comprehensive management of plan, raw material and finished product, as shown in Figure 5.

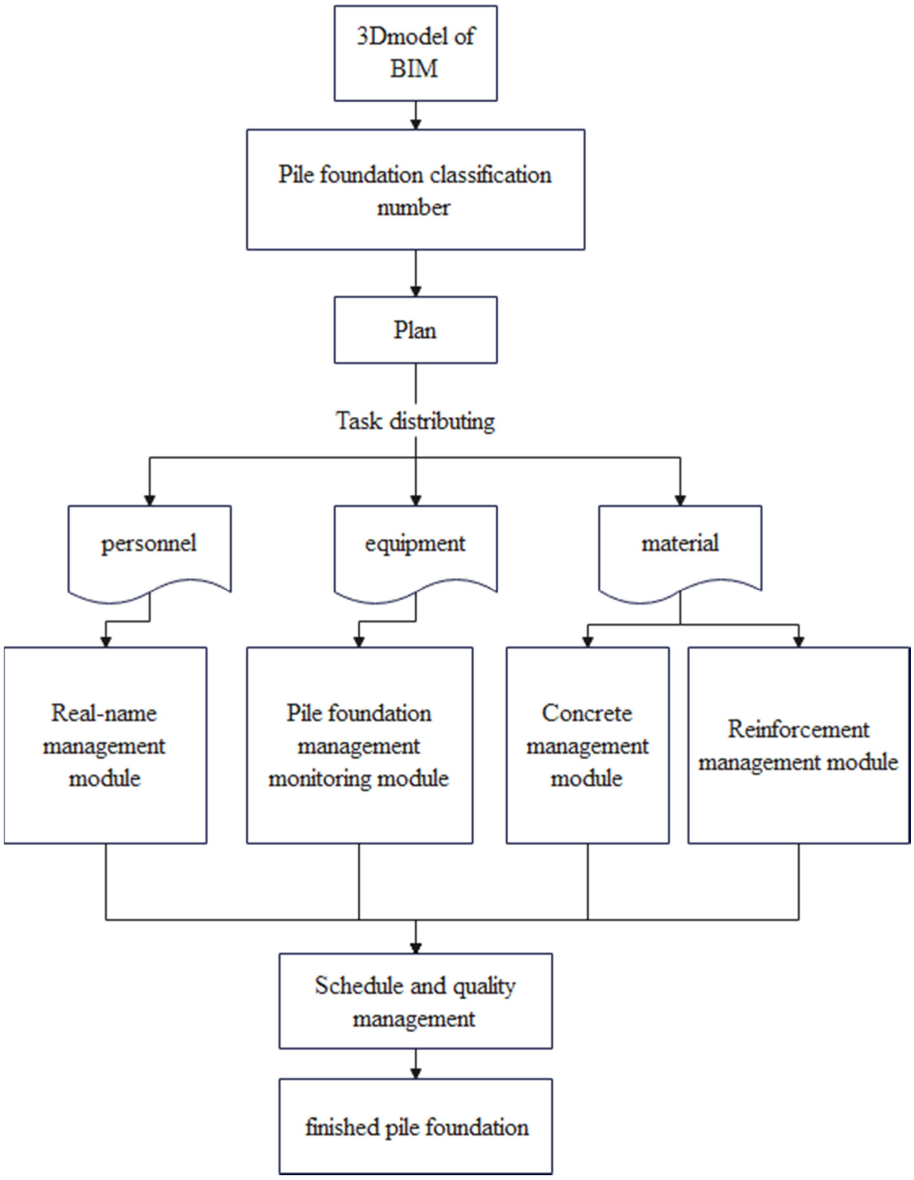

Figure 5. *Information management process based on BIM technology.*

5. Conclusion

With the development of intelligent iot technology and the demand of engineering informatization, it was a necessary way to upgrade traditional construction machines and tools using technology of iot transformation and information. This paper proposes a set of rotary drilling pile management system based on 3D geology and BIM. The system design scheme mainly had the following innovations:

1) Intelligent equipment was adopted as the sensing end of the system to monitor the rate, verticality, noise and

current of drilling, which had provided accurate data timely for the system, and realize intelligent management.

2) Multi-data was used to comprehensively judge the state of pile foundation into rock, which had solved the disadvantage of large error of long-term manual judgment.
3) Based on BIM-data management process had realized the whole chain management of human, machine and things, effectively reducing the difficulty of quality management on hidden work.
4) Next, the author will focus on the joint commissioning and test of equipment, project engineering experiments to verify the effectiveness of the system.

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