The remote wireless monitoring system for raft foundation of super high-rise building based on IoT

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Abstract. In order to solve the lack of wireless transmission signal for structural health monitoring during the construction of raft foundation of super high-rise building, a remote wireless monitoring system was built for raft foundation of super high-rise building based on NB-IoT. It was composed of sensors, data acquisition and wireless transmission equipment, and monitoring cloud platform. The collected monitoring data could be remotely uploaded to the cloud platform through NB-IoT, thus the automatic acquisition, wireless transmission and remote monitoring of raft foundation monitoring for super high-rise building were realized and applied in engineering. The results showed that the remote monitoring system could play an active role in improving the safety management level during the construction of super-high-rise building.

Keywords: remote wireless monitoring; NB-IoT; super high-rise building; cloud platform.

1 Introduction

In recent years, high-rise and super-high-rise buildings have been developed rapidly, and raft foundation is an important part of it. The mechanical behavior of raft is very important to the safety and normal use of the high-rise and super-high-rise structure, which could reflect the uneven settlement and abnormal force of the foundation. The in-situ test studies of sparse piled raft foundations was carried out for Nanjing University MBA buildings in Li et al [1]. The foundation reaction of Raft Foundation was measured and studied by Zhang et al [2]. The deformation coordination equation was established of frame structure, raft foundation and foundation by Wang [3]. The safety of Shanghai Tower piled raft foundation was analyzed and evaluated by Yuan Juyun et al [4]. The in-situ testing analysis was carried on the multi-tower building with big area raft foundation in Gong et al [5]. The calculation of pile-top reaction force of piled raft foundation in super high-rise building was studied by [6].

There was a lack of long-term stress data on the mechanical performance of raft foundation, and traditional manual monitoring methods were no longer sufficient to

G. Zhao et al. (eds.), *Proceedings of the 2023 5th International Conference on Civil Architecture and Urban Engineering (ICCAUE 2023)*, Atlantis Highlights in Engineering 25,
https://doi.org/10.2991/978-94-6463-372-6_31

meet the demand. Therefore, establishing an intelligent monitoring system for structural health status assessment and safety warning has become a hot topic in structural health monitoring research [7-11]. However, the monitoring system was rare for raft foundation of super high-rise building with weak signal environment. The transmission method was wired or wireless in current intelligent monitoring data collection system. The wired transmission technology has advantages such as strong anti-interference ability and fast transmission speed, but it requires a large number of cables to be installed, which is relatively cumbersome, and the installation and maintenance of monitoring equipment are difficult. The wireless transmission technology mainly includes NB-IoT, 4G, 5G, Wi Fi, ZigBee, LoRa, etc [12-16]. A large amount of wiring work could be eliminated in wireless transmission technology with strong adaptability, so it is the main development trend in the field of engineering automation monitoring technology. Among them, WiFi, ZigBee, and LoRa were mainly used for internal networking and data transmission of on-site monitoring equipment, while NB-IoT, 4G, and 5G were mainly used for remote data transmission with cloud server. NB-IoT technology has superior coverage, ultra-low power consumption, and ultra-low cost compared to 4G and 5G, especially with wide signal transmission coverage, making it particularly suitable for scenarios with weak signals such as basements. Therefore, the remote wireless monitoring system was built for raft foundation of super high-rise building based on IoT using NB-IoT in this study.

2 The intelligent monitoring system based on NB-IoT technology

NB-IoT is widely used in Internet of things because of its wide coverage, wide connection and low power consumption. The operating voltage range of NB-IoT is only 3.0 ~ 3.6 V. The system adopts three-layer architecture of Internet of things, which is composed of sensor node, data acquisition and wireless transmission node, remote monitoring cloud platform in Figure 1. Among them, the sensor data acquisition nodes are located in the raft foundation, and the data acquisition and wireless transmission nodes get the raft foundation force monitoring data, which were sent to the remote monitoring cloud platform by NB-IoT. The cloud platform parses, stores, analyzes and displays the received monitoring data.

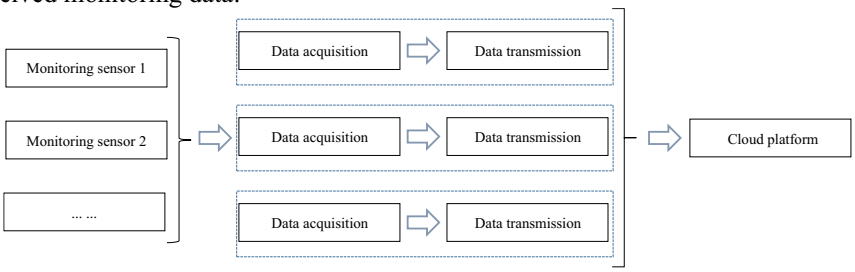

Fig. 1. The intelligent monitoring system

2.1 Intelligent monitoring equipment

During the construction of raft foundation of super high-rise building, the key parameters of structural health monitoring include stress, water level, earth pressure, settlement and so on. The sensor data acquisition and transmission node was a device for acquiring various monitoring parameters, which was shown in Figure 2. Its functions include monitoring data acquisition, processing, remote wireless transmission, etc.

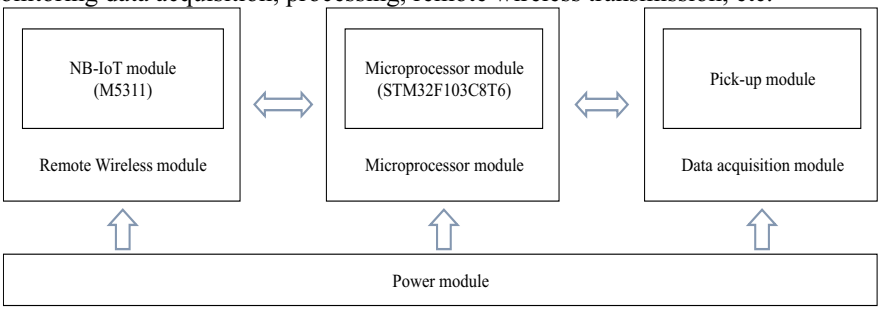

Fig. 2. Schematic of sensor data acquisition

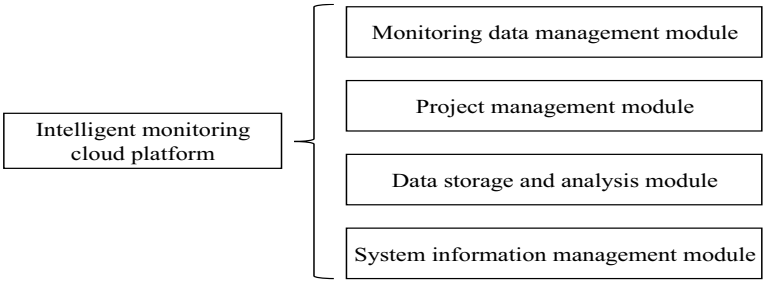

Fig. 3. Cloud Platform functional architecture

2.2 Health monitoring cloud platform for super high-rise buildings

In order to manage and analyze the monitoring data of super-high-rise building conveniently and accurately, and to warn the hidden danger of safety in time, a health monitoring cloud platform of super-high-rise building was developed by using Java language. The J2EE + SQL Server mode of B/S structure was used in cloud platform, and users could use Web Server to interact with cloud database anytime and anywhere, which effectively reduces the cost and workload of system maintenance and upgrade, it also reduces the overall cost to users. The cloud platform includes four functional modules: real-time management of monitoring data, project management, data storage and analysis, and system information management, as shown in Figure 3.

3 Case study

3.1 Project profile

The project is located in the Nanshan District, Shenzhen. The building height is 380 meters, and the basement floor depth is -35.2 meters with 5 stories as shown in Figure 4. In order to understand the mechanical performance of super high-rise building during construction and operation stage, to monitor the internal force of raft, to compare with the design value, and to grasp the change of internal force of super high-rise building during the whole construction process.

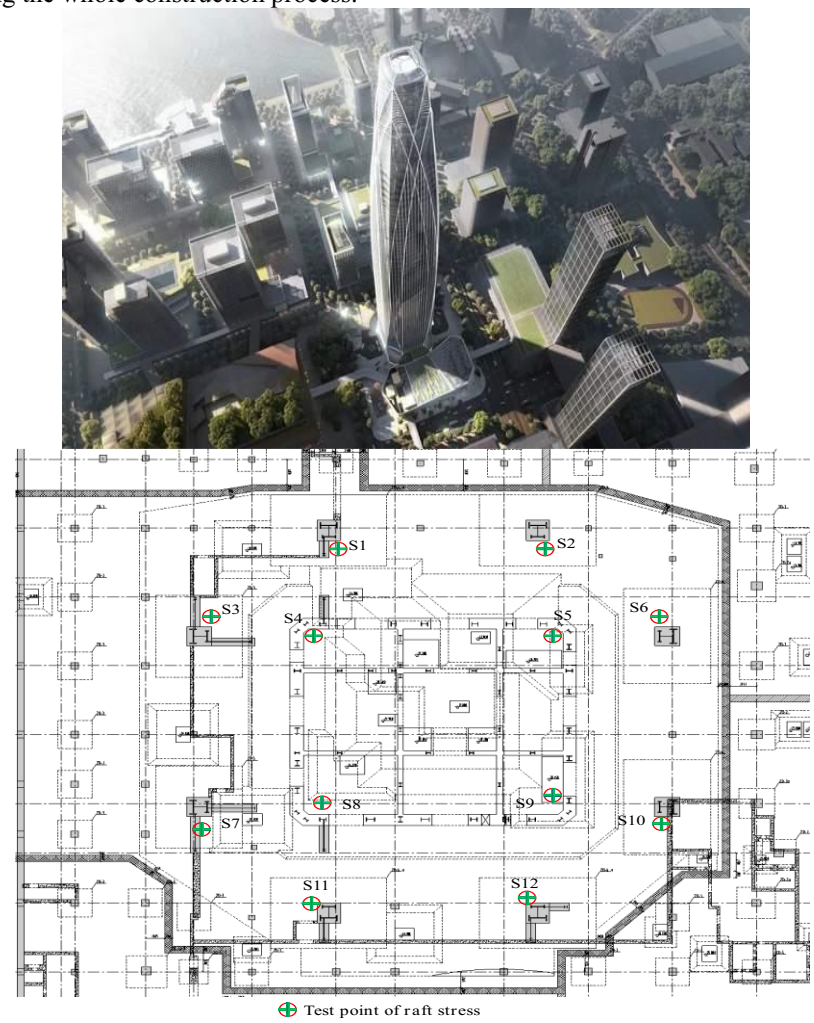

Fig. 4. Project profile and testing points

3.2 On-site implementation

Each testing point embeds two sensors on the plate surface and bottom at the x and y directions of the reinforcing steel bar, namely, each measuring point embeds 8 reinforcing steel meter sensors was shown in Figure 5.

Fig. 5. The sensors of raft

3.3 Monitoring results and discussion

The monitoring acquisition frequency was 1 hour per time in the system. The monitoring curve of the S1 sensor was shown in Figure 6. It shows that the monitoring cloud platform could monitor and control the monitoring data by J2EE + SQL Server mode based on B/S structure. The monitoring system based on NB-IoT was effective for raft foundation of super high-rise building with weak signal environment. Moreover, the data change could be monitored in a timely manner. It would play an important role in improving the safety management during the construction of raft Foundation of super high-rise building.

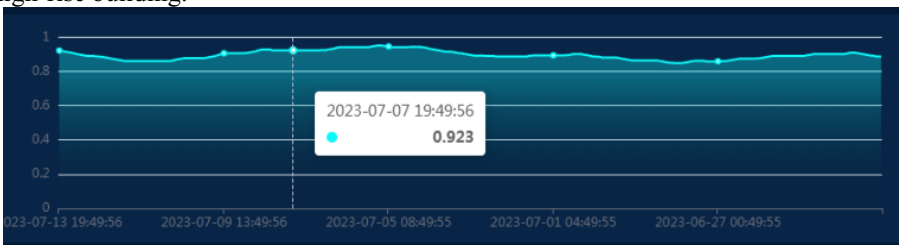

Fig. 6. The monitoring curve of S1

4 Conclusion

In order to solve the problem of the lack of wireless signal transmission for structural health monitoring during the construction of raft foundation of super-high-rise building, a remote wireless monitoring system for raft foundation of super-high-rise building based on NB-IoT is built and applied in engineering. The conclusions are as follows:

(1) The remote monitoring system based on NB-IoT for raft foundation of super-high-rise building was set up, and the real-time data acquisition, transmission and processing were realized.

(2) The engineering practice has proved that the system was easy to install and has high applicability, and could be rapidly deployed in raft foundation monitoring.

(3) The monitoring cloud platform based on B/S structure J2EE + SQL Server mode could monitor and control the monitoring data and equipment anytime and anywhere, it would play an important role in improving the safety management during the construction of raft foundation of super high-rise building.

Acknowledgments

The research described in this paper was financially supported by the Science and Technology Program of Guangdong Province(Granted No 2021A0505080009), Science and technology planning project of Guangzhou Municipal Construction Group Co., Ltd(Granted No [2021]-KJ017, [2022]-KJ030, [2022]-KJ003, [2022]-KJ011), Guangzhou Science and Technology Project (Granted No 2024B03J1389), Guangzhou Baiyun District Innovation and Entrepreneurship Leading Team Project(2021-0305), Science and Technology Program of the Ministry of Housing and Urban-Rural Development (Granted No 2020-K-130, 2021-K-075), Guangdong Provincial Department of Housing and Urban Rural Development Science and Technology Innovation Project(Granted No 2021-K1-300220), Shenzhen Department of Housing and Urban Rural Development Science and Technology Innovation Project(Granted No 2023-34). The financial support is gratefully acknowledged.

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