The Design and Application of Information Management System Based on IOT for Precast Concrete Segments

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Abstract. Metro shield tunnels have been widely used in Metro construction. The pre-cast concrete segments of shield tunnels are important prefabricated components in the construction of metro shield tunnels. The quality of segments is directly affected the quality of shield tunnels. In the construction process, a large number of precast concrete segments should be installed and some segments should be formed into rings, so manufacture management, carriage management and constructing of precast segments also directly affect the efficiency and quality of construction. Therefore, it is very important to establish an information management system for precast concrete segment through Internet of Things technology. The system would provide manufacture management (including concealed acceptance, quality inspection, and production-inventory), carriage management (including pre-delivery management, transportation tracking) and construction management (including quality inspection, warehousing management, installation management).

1. Introduction

With the development of economy, the problem of urban space congestion and traffic congestion is becoming more and more serious. It has become a common choice for large and medium-sized cities in China to vigorously develop the transportation modes such as subway. It is expected that by 2020, the mileage of metro lines in China will reach 6600 km. At present, the metro construction is still in the stage of high-speed development [1]. Shield tunnel is generally used in metro construction in most cities of China. When the shield machine has driven a certain distance, the precast segments are assembled at the same time. Precast tunnel segments were not manufactured at the construction field usually, but were manufactured with strict standards and production processes in factory for prefabrication, and then be trunked to the construction field for assembly [2]. With the progress of technology, precast tunnel segments are used more and more in metro construction. The construction quality and efficiency of tunnel segments will directly affect the overall quality and efficiency of tunnel construction. There are some problems in the production, carriage, installation and maintenance of precast tunnel segments, which are mainly manifested in the following aspects: Firstly, the construction of metro tunnels is large and the construction line is long. Precast segments are usually provided by multiple suppliers or factories for prefabrication. However, there is no unified and effective means of quality control and management in the production process. Secondly, during the construction of metro tunnel, a large number of precast tunnel segments are needed. The cubage of precast segment is large, so a large amount of fields are needed in both production and construction sites. Due to the unreasonable stacking of segments, some segments may be damaged. The managerial level of segment stacking directly affects the quality and efficiency of construction. In order to improve the efficiency of production and construction, it is particularly important to establish an
effective management mechanism of segment stacking. Thirdly, there are many processes in the construction of Metro tunnel. In the process of production, carriage, construction and maintenance, information management is usually accomplished by multiple systems. It is lack of a unified information management system, which leads to asymmetric information of all participants in the project and difficulty to trace all information of segments.

Therefore, it is very important to establish an information management system for precast shield segments with Internet of Things and Mobile Technology. It can complete the information collection and management of the production, carriage and construction process of tunnel segments. It can also be associated with BIM model to improve the quality and efficiency of metro tunnel construction. At the same time, it can provide basic data for metro operation and maintenance stage.

2. Design of the system

2.1. Identification of precast concrete segments

RFID system is composed of three parts: RFID reader, RFID tag and application software, as shown in Fig.1. RF reader sends out radio signals to form a magnetic field, to receive information that was stored in the chip of RFID tag. Information was transmitted by the energy obtained from induced current, which was generated in the magnetic field. RFID reader decodes the information, and then sends it to CPU for data processing. RFID system can collect and process information quickly and accurately, furthermore RFID tag could be easily fixed on the material, so it has inherent superiority in material management [3].

![RFID Principle](image)

RFID systems would work on low frequency, high frequency, ultrahigh frequency or microwave. When the RFID system worked on low frequency which is on 134.2 KHz, the distance of reading and writing is less than 1m and it is unsafe; The RFID system works on high frequency which is on 13.56MHz could follow protocol about ISO14443 and ISO15693. RFID reader can work between 0m and 1m when follow ISO14443, and it is low cost. The biggest advantage of ISO15693 is its recognition efficiency. The high-power RFID reader followed ISO15693 has efficient recognition and may work in more than 1.5 meters; The UHF RFID reader can reach about 10m in ideal state.

Each RFID tag has a unique tag id, which could be associated with the precast segment as the unique identity id. The tag id is used as an index to record the information of the prefabricated segment from production to end of construction. In order to identify precast concrete segments with RFID tag, it is necessary to embed the RFID tag into the precast segment in the production stage. Because the signal of the RFID tag embedded in the segments will become weaker and the identification range will be closer, so performance testing was carried out on different frequencies. The RFID tags worked on different frequencies were embedded on steel reinforcing cage. After pouring and steaming curing, we try to read and write RFID tag with different RFID reader, and then the results showed that: Low-frequency RFID reader cannot read the tag information at all; high-frequency RFID reader need to be closest to the surface of the segment to get the tag information, and it is very unstable; UHF RFID reader can read the tag information, and the recognition distance can reach 1-2 meters, which meets the actual needs of the management system.
Therefore, we choose UHF RFID for identification of precast shield segments. The RFID tags are sealed with ABS, which could work normally under high temperature and high humidity. The packaging form of tags is shown in Fig. 2.

2.2. Architecture of system
The information management system of precast concrete segments includes data acquisition terminals and remote server, see Fig. 3. The data acquisition terminal is composed of a microcontroller, a UHF RFID module, a two-dimensional code laser scanning module, a GPS module, a touch screen, a Bluetooth module and a communication module. The UHF RFID module followed ISO18000-6B and ISO18000-6C was used to identify the RFID tags embedded in the precast concretes. Information of precast concretes was managed by the unique RFID tag. The two-dimensional code laser scanning module was used to identify the information of haulage vehicles by a two-dimensional code was assigned to each haulage vehicle that will leave the factory. The GPS module was used to track the position of haulage vehicles. Communication module was 4G communication module used to communicate with remote server. The system was compatible with other RFID device by Bluetooth module. The remote server provides the service of data processing, data storage, data report and account management.
2.3. Design of software
The software of information management system for precast concretes consists of control software of data acquisition based on Android and server software base on Asp.net, see Fig. 4. Control software would run on RFID reader or mobile phone. Data acquisition terminals communicate with server by HTTP, communication data has standardized on JSON as a data format. Data report and management are shown on dynamic page based on B/S structure. In order to avoid performance problems due to high concurrent data access, a date cache was set between server and database, which would reduce duplication of data physical loading and improve the accessing efficiency.

3. Workflow of management
Information management system for precast concrete segments provides production management, carriage management and construction management. Workflow of information management system for precast concretes is shown in Fig. 5, including concealed acceptance, quality inspection, production-inventory, pre-delivery management, transportation tracking, checking and accepting, ware-housing management and installation management. Each process as a controlling point could be operated only when previous process has completed and accepted. Information about precast concretes will be stored in database permanently. Administrators could get tag ID by RFID reader and then get information of precast concrete from database anytime. At the same time, it can provide basic data for metro operation and maintenance stage.

3.1. Production management
The production of shield segment is a very important process in shield construction. The production quality of shield segments will directly affect the quality and efficiency of shield construction. Factories for prefabricating shield segment in China are relatively mature in terms of production scale.
and production technology, but the production information has not been shared with the construction part. The management system for precast segments collects and controls information from the following aspects: (1) The concealed acceptance includes steel cage inspection and die inspection which includes inspection of the dies for the substrate, standard, adjacent and sealing blocks of each ring segments. (2) The quality inspection includes dimension inspection, surface inspection, leakage inspection and splicing seam inspection. The surface inspection ensures that there are no cracks, holes, linen, honeycombs and slag on precast segment; Leakage inspection is carried out under the condition of water placement. Increasing pressure is applied to the segment to detect the leakage of the segment; Inspection of splicing seam is used to test and assemble the production segments in a ring, and to inspect the inner and outer clearance points of longitudinal seam and annular seam. (3) The stacking information of qualified segments would be recorded in production-inventory management.

The RFID tag is fixed in the steel reinforcing cage. After the steel reinforcing cage is tied up, the RFID tag is tied to the inner surface of the steel reinforcing cage before concreting. The RFID tag id is associated with the unique id of pre-fabricated shield segment in concealed acceptance. Administrators can obtain the unique id of precast shield segment with RFID reader, and then get or upload other related information, as shown in Fig. 6.

3.2. Carriage management

Usually factories for prefabricating shield segment are far away from the construction field, and transportation takes several days [4]. In actual construction, managers often ask questions such as what time can the precast shield segments arrive at the construction filed and where they are. Because this information will affect the construction plan and progress. The carriage management will record the information of vehicles, real-time location of vehicles and segments in vehicles.

A two-dimensional code is assigned to each vehicle that will leave the factory. The information of vehicle such as number plate, name and phone number of the driver, loading place and discharging place, can be quickly provided by identifying two-dimensional code. When information of vehicle has been recorded, the precast concretes that were loaded in this vehicle can be checked out automatically by RFID reader and be associated with the vehicle, as shown in Fig. 7.
Figure 7. Carriage management.

The vehicles that have been leave the factory and not yet arrived the discharging place can be traced by GPS, position information is uploaded up to remote server and marked on the map. Administrators could get the position information of transporting vehicles and the information of precast concretes in the vehicle.

3.3. Construction management

When the vehicle arrives at the construction field, the project managers can confirm the vehicle information by scanning the barcode, and can obtain the information of precast segments on vehicles. Then the manager carries out quality checking and accepting, including whether the specifications and models are identical, appearance inspection (whether there are damages, honeycombs, holes, leaks, cracks, etc.), bolt hole inspection, hoisting hole inspection, water stop belt and force cushion inspection, etc. If unqualified segments are found in the process of quality inspection, information such as problem description and pictures will be recorded. After the quality inspection is accepted, the segments can enter the construction field normally. The system will assign the number of idle field to the segment according to the current situation of all fields. If some precast concretes in this vehicle were not checked off, information of these concretes would be shown to the manager until they have been checked off.

According to the number of field, the manager can stack the segments into the different areas with gantry cranes or forklifts. In this stage, segments that can form a ring will be associated with a sequence ring number which will be used by shield machine. When the segments need to be installed, the administrator can get the location of stacking fields according to the sequence ring number and transfer the segments to the shield machine by gantry crane.

After the installation of tunnel segments, managers would input information of installation, such as including annular joints, longitudinal joints, corner, grouting situation, fragmentation, leakage, secondary grouting and so on, and the information will be uploaded to remote server.

4. Conclusion

Information management system for precast concrete segments has been applied in Metro Line in Changsha city of China. The practice shows that the system which is based on RFID technology and mobile technology, could manage information of prefabricated segments about manufacture, carriage and construction. Information about precast concrete segments will be monitored all the time, and can be shared to all related units. The work efficiency and the managerial level will be improved enormously in tunnel construction.

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