Design and Application of Automatic Monitoring System based on Total Station in Construction of Shield-bored Underneath Metro

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Abstract. When metro shield passes through existing operating lines, it is necessary to carry out automatic monitoring of existing lines. Taking Changsha Metro Line 4 shield tunnelling through existing Metro Line 2 as an example, this paper carries out automatic deformation monitoring of existing Metro and judges the influence of shield tunnelling on existing Metro. According to the actual situation of the field, a whole set of automatic monitoring system is designed, and the detailed implementation plan is worked out. Finally, the deformation data are analysed, and the characteristics of the whole system are summarized.

1. Introduction
At present, with the development of economy and the acceleration of urbanization process, more and more cities are vigorously building subway, and urban traffic forms a three-dimensional layout. In the process of subway construction, shield tunnelling often occurs under existing subway lines. How to reduce the disturbance of construction on the ground and ensure the safety of existing subway lines is one of the urgent problems to be solved in subway construction. Among them, automatic monitoring plays an important role in the process of subway construction. The actual effect of construction methods and the impact of construction on the surrounding environment can be real-time understood by acquiring monitoring data, so that effective measures can be taken in time to control tunnel deformation and protect the safe operation of existing lines.

This paper designs and develops an automatic monitoring system based on total station. The whole system can automatically collect the deformation data of field structure, upload the data to server database in real time. At the same time, using mobile interconnection technology, relevant personnel can view the data in real time through computers, tablets and mobile phones, and generate data reports. At the same time, the application of the whole system in Changsha Metro Line 4 shield tunnel crossing the existing operating line is introduced.

2. The Design of Automated Monitoring System

2.1. The design of hardware system
The whole monitoring system consists of field data acquisition unit and remote monitoring unit [1,2]. The two are connected by a data communication module using 4G communication technology. The Composition block diagram of the automatic monitoring system is shown in Fig. 1 below.

The measurement robot adopts the TS50 high-precision total station manufactured by Leica company. Its Angle measurement accuracy is 0.5" and range measurement accuracy is
0.6mm+1ppm[3], which can meet the requirements of high-precision measurement. A prism is installed on the vault, waist and ballast of tunnel as the monitoring point, and the other four prisms are installed outside the affected area of the shield as the reference point. The coordinates of intelligent total station are calculated by aiming at several known datum points using the method of free station three-dimensional overall adjustment method [4]. Then the coordinates of monitoring points are obtained by polar coordinate measurement method [5]. In this way, the whole monitoring network can be formed. Field installation is shown in Fig. 2. Two total stations are installed in the upper and lower tunnels respectively.

2.2. The design of software system
The whole software is developed under the integrated development environment of Visual Studio 2015, using vb.net as the development language and SQL Sever2008 as the database. The software supports multi-project, multi-user, extension authority management and other operations. It also has the functions of system configuration, data display, report generation, early warning and alarm. The software interface is shown in Figure 3.
3. Engineering Application

3.1. General situation of engineering

In the section between Yingwanzh en and Hunan Normal University of Changsha Metro Line 4, the shield machine will run through the existing Metro Line 2 shortly after its start. During the construction of the project, the deformation of the tunnel in the affected area is monitored, and the influence of shield tunnelling on the tunnel is analysed, so that effective measures can be taken in time to control the deformation of the existing line and protect the safe operation of Line 2.

3.2. Measuring point arrangement and field installation

According to the plane position maps of newly built and existing metro tunnels, the monitoring range of the tunnels on Line 2 and downward is 90 meters. There are 17 monitoring sections in one section of 5 meters. Five measuring points are arranged in each section at the position of ballast bed, arch waist and vault. The datum point is located in the stable position outside the area affected by construction [6]. Each tunnel has 85 measuring points and 4 datum points. The layout of measuring points is shown in Figure 4.

Field installation can be divided into the following steps: 1) Fixation of total station bracket. The total station bracket is installed at the pre-planned position with expansion screw. 2) Installation of monitoring prism. Likewise, the L-prism is fixed at the pre-planned position with expansion screw.
Attention should be paid to keeping the prism and total station in line with each other, and the problem of small field of view should be considered at the same time. 3) System debugging. The learning and storage of the initial position of each measuring point.

3.3. Data verification and analysis
In order to verify the accuracy and stability of the system, after the system is installed, the initial values of the measuring points are measured manually by total station. After a period of construction, through comparing the data of automation and manual measurement at the same time, it can be seen that the two groups of measurement data are consistent, the data deviation is less than 0.5mm, and the data of the right line are compared. As shown in Figure 5 below.

![Figure 5. Contrast Diagram of Accumulated Settlement Data between Automatic Monitoring and Manual Observation of Downlink Line 2.](image)

4. Conclusion
This paper introduces the application of the automatic monitoring technology based on intelligent total station in the project of shield boring underneath metro. Through the field test and application, the system realizes all-weather monitoring of three-dimensional deformation of each measuring point, which reduces labour cost, eliminates human error and improves construction information. As an open monitoring platform, it can share real-time data and facilitate information management through SMS and mobile client information pushing. According to the data of automatic monitoring feedback, the construction parameters are adjusted in real time to ensure the safety of construction.

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