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A technical study of advanced geological prediction of tunnels under complex geological conditions

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Abstract: *Advanced geological prediction, as an indispensable step in tunnel construction, is an essential measure for reducing the occurrence of geological disasters in tunnel construction and disaster losses. To solve intractable technical issues relating to advanced geological prediction of tunnels under complex geological conditions, this research explores construction methods of advanced geological prediction of tunnels under complex geological conditions and relevant specific implementation process by taking tunnels in Maanshan as engineering objects. Furthermore, construction methods applicable to complex geological conditions were proposed to investigate key construction processes of advanced geological prediction. The research can provide reference for similar engineering practices and technology.*

Keywords: *geological conditions; tunnels; advanced geological prediction; technique*

1. Introduction

Advanced geological prediction (AGP) of tunnels utilizes techniques including borehole drilling and modern geophysical prospecting to explore geological conditions ahead of the excavation face of tunnel rock masses on the basis of analyzing existing geological data. It acts as a type of means used to determine geological information including the structure, properties and status of rock masses, groundwater and gas occurrences as well as geostress. In doing so, positions and occurrence of adverse geological bodies ahead of a working face, integrity of surrounding rock structure as well as possibility of water-bearing conditions can be predicted. This can further provide a basis for accurately selecting excavation faces, support design parameters and optimized construction schemes. Furthermore, AGP can timely offer information of predicting possibly occurring hazard events including water inrush, mud outburst and gas outburst of tunnels. Thus, suggestions for technical measures can be provided for ensuring construction safety.

Tunnel construction may encounter a variety of complex geological conditions, which may influence normal construction of AGP. Hence, how to determine construction methods and specific construction flow of tunnel AGP under complicated geological conditions is essential to safe and efficient construction of tunnels. Currently, the construction methods and key process of tunnel AGP under complex geological conditions remain unclear and key technological research is sparse, thus it is necessary to carry out relevant research based on actual construction engineering[1-2].

2. Engineering situation

The tunnel project in Maanshan is located at about 1500 m on the east of Beizhentou village in Wangfen Town, Qingzhou, Weifang, Shandong Province, China. The starting and ending pile numbers of the axis of the left line for the tunnel are ZB1K99+097 and ZB1K101+088, with a total length of 1991.0 m; while the starting and ending pile numbers of the axis of the right line for the tunnel tunnels are K99+115 and K101+110, with a total length of 1995.0 m. The tunnel is a long six-lane two-way split type tunnel. The surrounding rocks of tunnel site are Cambrian Limestone and shale interbedding layer, the overburden layer is fairly thick and there are cracks developed. The rocks demonstrate relatively severe breakage and weathering; while rock failure is mainly shown as arch loosening, which leads to a possibility of rock collapse and water leakage occurring in large-sized cracks of relatively soft rock in rainy season. There are multiple complexing geological conditions during the construction process of this tunnel project.

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3. Technical study of advanced geological prediction of tunnels

3.1. Applicable ranges of each method for the tunnel advanced geological prediction

During the advanced geological prediction of tunnels in Maanshan, a method that integrates long- and short-distance prediction was proposed. Among which, long-distance prediction is fulfilled using TRT7000 geological prediction system, while short-distance prediction is completed using geological radar. In the case that he excavation length of tunnels is below 50 m, a geological radar is used for short-distance prediction; in the case of the excavation length above 50 m, TRT7000 is used for long-distance prediction; when approaching adverse geological bodies, short-distance prediction methods such as geological radar are used to carry out detailed probing; when TRT7000 and geological radar are unable to make accurate assessment of the geological conditions ahead of a working face, advanced drilling should be made to ascertain the adverse geological tectonic conditions. Summarizing properties and scales of adverse geological bodies predicted[3-5].

3.2. TRT prediction method

3.2.1. Prediction methods and device

The prediction employed a TRT7000 geological prediction device, with a single forecast of 100-150 m, the tunnel measuring 30 m on its upper, lower, left and right sides. The overlap length of two forecasts should be no less than 10 m.

3.2.2. Sensor arrangement method

TRT 7000 sensor arrangement adopts a three-dimensional arrangement method. Four sensors are longitudinally arranged respectively on two sides of the tunnel in every 5 m spacing. Afterwards, two sensors are longitudinally arranged in every 10 m at the arch of the tunnel so as to acquire real three-dimensional diagram.

3.2.3. Installation of sensors

During the application of TRT7000, sensors should be fixed at corresponding positions of the tunnel, as illustrated in Points 2-11 in Fig. 2. The mounting holes with a diameter of 8 mm and a depth of 6 cm were installed at corresponding positions. Expansive quick-drying cement was coated on the fixed blocks, which were coated on the sidewall and the roof surface of the tunnel. Sensors were installed on the fixed blocks using screws to ensure the tight coupling of sensors and rock mass. The specific installation method is shown in Fig. 1.

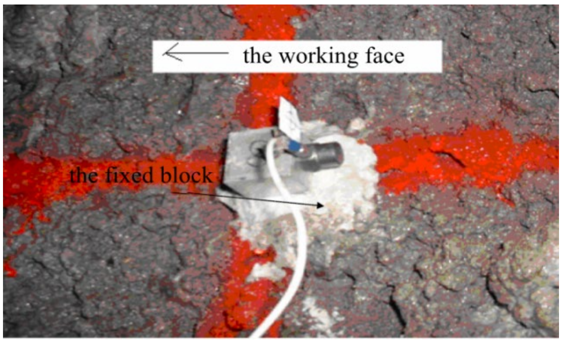

Figure 1: TRT7000 sensor arrangement method

3.2.4. Earthquake hypocenter excitation

The earthquake hypocenter excitation method of TRT7000 is hammering. When operating TRT7000, flip-flops are well connected at the ends of the 8-pound heavy hammer flip-flop. The earthquake hypocenter is generated successively at Points S1-S8 in Fig. 2. Sensor groups with wireless modules are used to receive seismic wave vibration signals propagating in surrounding rocks. The sensors save the signals in the computer using a wireless sensor base station to further acquire seismic signals. The wired connection between “heavy hammer” and the computer is realized by means of the base station. In doing so, earthquake hypocenter excitation and receival of seismic signals can be free from delay. The sensors and the computer are connected via wireless connection, which facilitates the sensor installation inside the tunnel.

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3.3. Geological radar probing

3.3.1. Forecast method and device

Geological radar is equipped with 100 MHz antenna for probing. The spacing of single forecast at the III-level surrounding rock section should not exceed 30 m; the spacing of single forecast at the IV and V-level surrounding rock sections should not exceed 20 m. The overlap length of the two forecasts should be no less than 5 m.

3.3.2. Forecast process

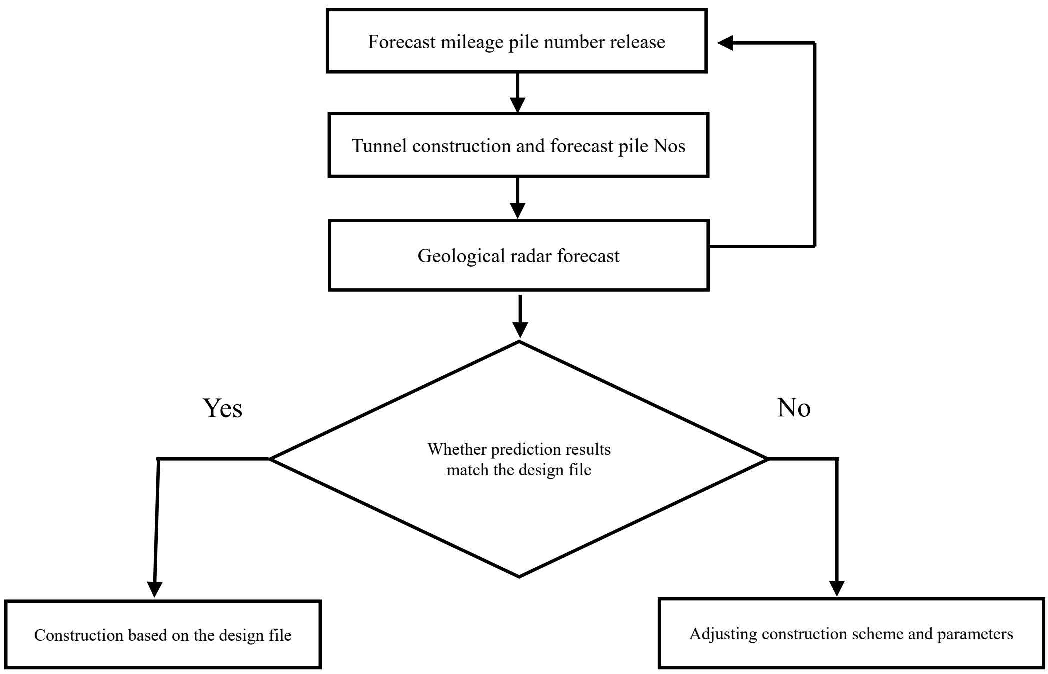

Figure 2: Advanced prediction process of geological radar

3.3.3. Technical highlights

Technical highlights include: the observations of rocks surrounding the working face of the tunnel, geological radar survey line arrangement and geological radar data acquisition and reporting.

(1) Observations of rocks surrounding the working face of the tunnel

This project uses digital photography as a means to achieve image recording of rock surface characteristics. According to engineering geology of rocks surrounding the working face of the tunnel and hydrogeological characteristics, the forecast results were verified to further allow the revision suggestions of forecast parameters[6-7].

(2) Geological radar survey line arrangement

This tunnel project in the construction process mainly includes the double-side heading method, the cumulative rainfall departure (CRD) method, the center diaphragm (CD) method, and bench method. Geological radar survey arrangement of each construction method is respectively,

1) The double-side heading method: one observation set and two survey lines are arranged respectively on the working faces of ① and ③ subsections, as shown in Fig. 3.

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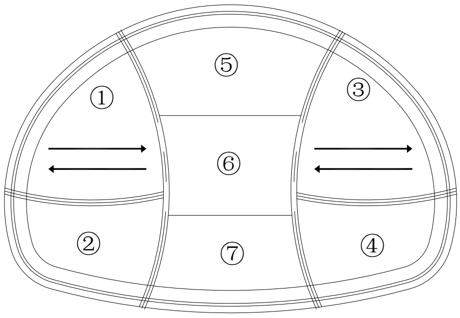

Figure 3: Geological radar survey line layout of the double-side heading method

2) CRD and CD methods: one observation set and two survey lines are arranged respectively on the working faces of ① and ③ subsections, as illustrated in Figs. 4-5.

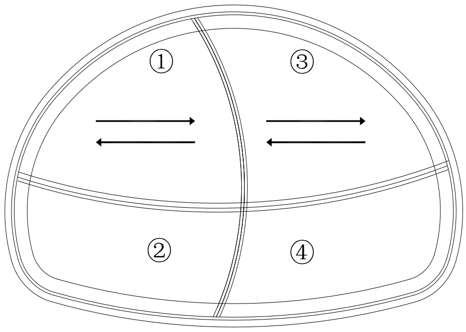

Figure 4: Geological radar survey line layout of the CRD method

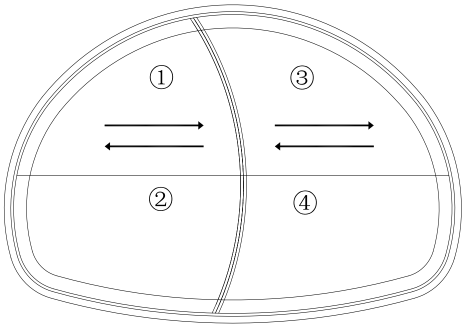

Figure 5: Geological radar survey line layout of the CD method

3) The bench method: one observation set and two survey lines are arranged respectively on the working faces, with specific arrangement as shown in Fig. 6.

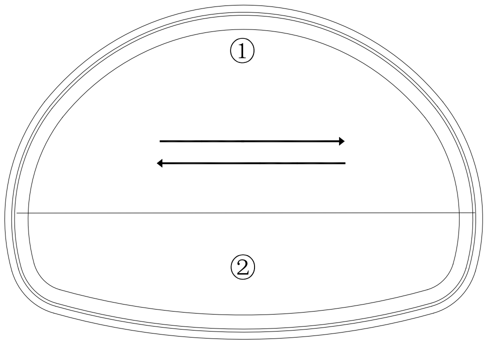

Figure 6: Geological radar survey line layout of the bench method

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(3) Forecast information reporting

Data acquisition of testing units is completed within 1 to 2 working days and then feedback to construction affiliations by way of AGP to further ensure guiding role of forecast data in tunnel construction.

3.4. Advanced probing method

A geophysical prospecting method probed adverse geological bodies, which needs to be discerned and verified using an advanced probing method. During the specific construction, the combination of TRT and advanced probing method is usually adopted for prediction. The specific forecast method is described as:

(1) The combination of TRT and advanced geological probing (one hole)

In the section of complex engineering geology and hydrogeological conditions, only using the TRT advanced geological prediction system is unable to satisfy tunnel construction demands. At this time, advanced geological borehole drilling should be supplemented to check and validate forecast results of TRT, with 30-50 m long probing holes.Φ76 mm drilling rig is used for coring.

(2) Combination of TRT and advanced geological probing hole (three-holes) arrangement

Judging from karst and geological tectonic intensive development as well as preliminary assessment, the combination of TRT and advanced geological probing hole (three-holes) arrangement was used in tubular sections containing hidden large water-bearing bodies or middle- and large-sized karst tubular sections. The probing length is 30-50 m around; probing holes 1 and 3 employ Φ 38 mm drilling rig to perform coring; probing hole 2 uses the Φ 76 mm drilling rig to conduct coring[8].

4. Conclusion

(1) For tunnels subjected to geological conditions, excavating the arch and sidewall warrants close attention to the changes in rocks surrounding the tunnel working faces, abiding by construction rules “short footage, weak blasting, strong support, early closure and frequent measurement”. In addition, measures such as strengthening advanced support, timely closure of surrounding rocks as well as waterproofing and drainage should be adopted to prevent occurrence of hazard events.

(2) Due to the difference in application characteristics of each tunnel AGP, methods including long-distance, short-distance or the combination of long and short distances should be selected according to actual engineering application situations when conducting tunnel AGP under complex geological condition.

(3) When performing tunnel AGP, the forecast probing distance of each testing method and the overlap length of two forecasts should be checked to improve accuracy of testing data.

(4) When carrying out tunnel AGP, the working face should be ensured to be flat as much as possible and noises and vibrations generated during tunnel construction are reduced to guarantee a favorable working environment. This can further ensure the accuracy of radar signal sending or receiving of AGP as well as TRT probing data.

(5) AGP of tunnels should be accompanied by timely follow-up detection according to practical engineering situations so as to avoid the influence of untimely follow-up on tunnel engineering processing and construction safety.

(6) AGP staff should well coordinate with parties including supervisors, construction and proprietors to ensure orderly measurement of tunnels under complex geological conditions.

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