Research on the Application of Ground Penetrating Radar in Advanced Geological Prediction of Deep Buried Tunnels

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Abstract. With the development of the social economy and the emergence of a large number of tunneling projects, the importance of over-advance geological forecasting in the safe construction of tunnels has become increasingly obvious, and it has also attracted a lot of attention from the academic community. In this paper, the measured radar data are analyzed to verify the feasibility of ground-penetrating radar in the overtopping geological prediction of deep-buried tunnels and the validity of data characteristics. By analyzing the overtopping geological data of ground-penetrating radar and verifying the results by excavation, the following conclusions can be obtained: in the process of overtopping geological forecasting, ground-penetrating radar has the characteristics of simplicity, convenience, and high accuracy, and the method can make anomalies in advance for the abnormalities in front of the tunnel's palm face, and it can provide accurate and reliable geological information to ensure that the tunnel project can be constructed safely.

Keywords: Ground Penetrating Radar; advanced geological prediction; reflected waveforms.

1. Introduction

A tunnel is a form of human utilization of underground space, which refers to the existing building or earth and stone structures dug out of the passage buried in the ground within the engineering buildings. According to the classification of use, tunnels can be divided into transportation tunnels, hydraulic tunnels, municipal tunnels, mining tunnels, and human defense tunnels.

In China's central and western mountainous areas, poor topographic conditions and complex geological structures, fault zones, folds, joints and fissures and other tectonic development, groundwater is abundant, the engineering geological conditions of the tunnel surrounding rock are poor, increasing the difficulty and danger of tunnel construction.

At present, there are a variety of geophysical methods applied to the tunnel super-advanced geological forecast. According to the forecasting principle, they are divided into seismic wave detection method [1], electromagnetic wave detection method [2, 3], electric method detection method [4], and infrared water measurement method [5]. Different forecasting methods have different advantages, for example, the TSP method has a good effect on identifying the fault broken belt, but it is not very sensitive to the area containing groundwater such as caverns, so the accuracy of water exploration is not very high[6]; Ground Penetrating Radar utilizes the electromagnetic wave to reflect and transmit in different media to get the information of the rock layer, which is better for detecting the broken rock body, and the electromagnetic wave has the property of continuity of the homogeneous rock body with the same axis, so it is not easy to distinguish the soft and soft rock body. The electromagnetic wave has the property of continuity of a homogeneous rock body with the same phase axis, so it is not easy to distinguish the softness and hardness of the rock body [7]; the transient electromagnetic method obtains the apparent resistivity of the medium in the detection area by detecting the self-induced secondary field of the rock body, which is better for the sensitivity to groundwater, and not good for the effect of the fault fracture zones [8].

Each forecasting method has its applicable conditions and limitations. The seismic method can detect the change in mechanical properties of the surrounding rock, and forecast the change of

lithology, tectonic development, structural characteristics, mechanical strength, and other mechanical elements of the surrounding rock in front of the excavation through the detection results, and it is sensitive to the reflection of faults, weak zones, and crushed bodies, but it is not sensitive to the saturated nature of the surrounding rock, and it cannot forecast saturated bodies and water-rich sections, and it is easy to miss the report and lead to the occurrence of mud surge, water surge and other diseases. Sudden mud, water gushing, and other disease accidents occur, resulting in significant economic losses.

In this paper, the measured ground-penetrating radar data of representative caves are selected to be analyzed to further verify the feasibility of the over-the-horizon geological prediction method of the ground-penetrating radar data and the validity of the data characteristics.

2. Ground Penetrating Radar in Advanced Geological Prediction

Ground Penetrating Radar (GPR) is a kind of geophysical exploration method using UHF narrow pulse electromagnetic wave to detect the distribution of medium, and its working principle is that the transmitting antenna transmits tens of megahertz or even thousands of megahertz electromagnetic wave signals to the front of the tunnel palm surface, and in the process of propagation of the electromagnetic wave to the front of the palm surface, the electromagnetic wave will be reflected when encountering the target body of the difference of electromagnetic parameters (mainly resistivity and dielectric constant), and the reflected wave will be recorded by the receiving antenna. Receive the reflected wave, and record the arrival time of the reflected wave, based on processing and analyzing the geo-radar data, the geological structure in front of the palm surface can be deduced according to the parameters of radar waveform, electromagnetic field strength, amplitude and two-way travel time, as shown in Fig.1.

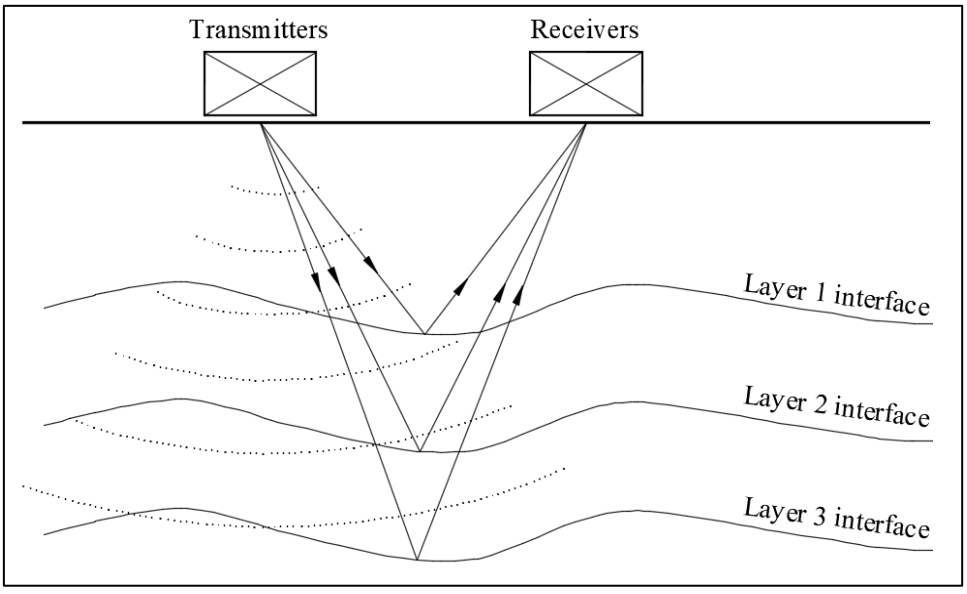


Fig. 1 The working diagram of Ground penetrating radar.

3. Analysis of measured data from Ground Penetrating Radar

The measured data were collected from the spillway of a tunnel in Hunan province, and the length of this probe is 30 metres. The surrounding rock of the tunnel is mainly slightly weathered striped grey rock with dark grey colour and the yield of the surrounding rock is 330°∠5°. The rock body is relatively intact, with a crisp hammering sound, rebound, and harder to break. The rock body is a harder rock, mainly with thick layer structure. There are 3 groups of joints in the surrounding rock, mainly calcite veins and mud filling. There is water seepage in the palm face. The tunnel palm face is shown in Fig.2.



Fig. 2 The face situation of the tunnel.

Ground Penetrating Radar (GPR) adopts a 100MHz shielded antenna, the number of sampling points of each scanning channel is 1024, the scanning time of each scanning channel is 600 nanoseconds, and the sampling mode is point measurement mode.

Due to the constraints of the construction conditions, we have arranged 1 measuring line along the palm face of the tunnel, and the antenna is held by two people when detecting the antenna close to the palm face to move from the detection starting point to the detection endpoint, and the layout of the measuring line is shown in Fig.3.

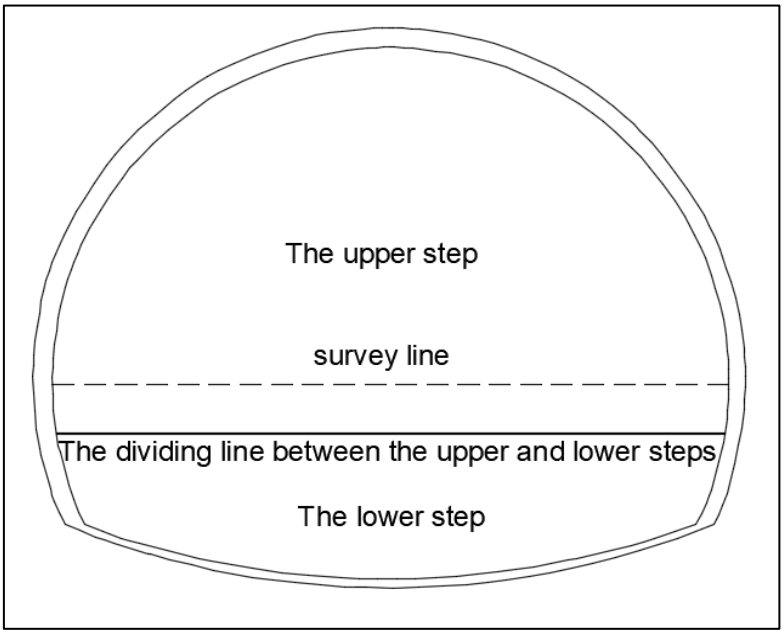


Fig. 3 The survey line layout diagram of Ground penetrating radar.

Figure 4 shows the stacked geological radar waveforms collected in the horizontal direction (from left to right), and Figure 5 shows the stacked geological radar waveforms processed by Hilbert transform. From Figures 4 and 5, it can be seen that the reflected waves are continuous with the same phase axis between 130 ns and 170 ns, and between 300 ns and 330 ns, and the amplitude of the reflected waves is enhanced, so it is presumed that these two anomalies are water-bearing karst fissures. As can be seen from Fig. 5, in the middle part of the reflected wave between 300ns and 330ns, there is a slight disconnection of the same-phase axis of the reflected wave, and it is presumed that the karst fissure at this place has been developed into a cave with a certain scale.

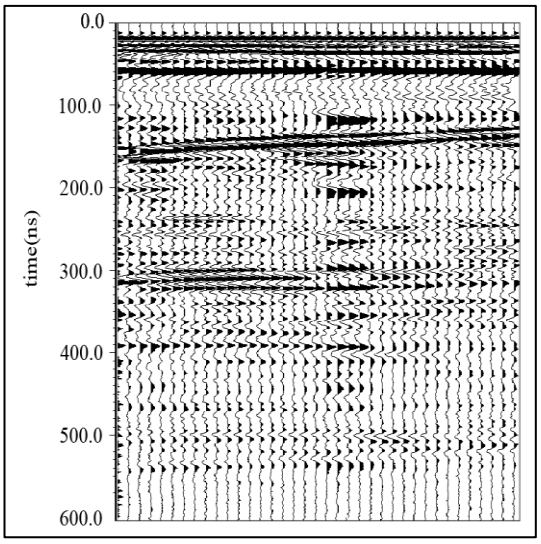


Fig. 4 Stacking of reflected waveforms from Ground Penetrating Radar.

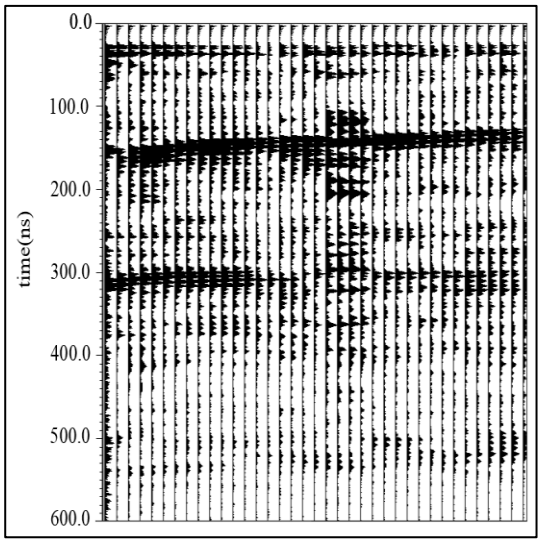


Fig. 5 Stacking of reflected waveforms processed by Hilbert Transform.

Figure 6 shows the groundwater exposed by over-drilling, which is in the form of strands, and Figure 7 shows the caverns after being exposed during excavation, which is developed along the dissolution fissures in the form of slabs. Figure 6 exposes the reflected wave anomalies between 130ns and 170ns and between 300ns and 330ns as water-bearing solution fissures, and Figure 7 exposes the reflected wave anomalies between 300ns and 330ns and in the middle as water-bearing solution caves.



Fig. 6 Water flow from over drilling.

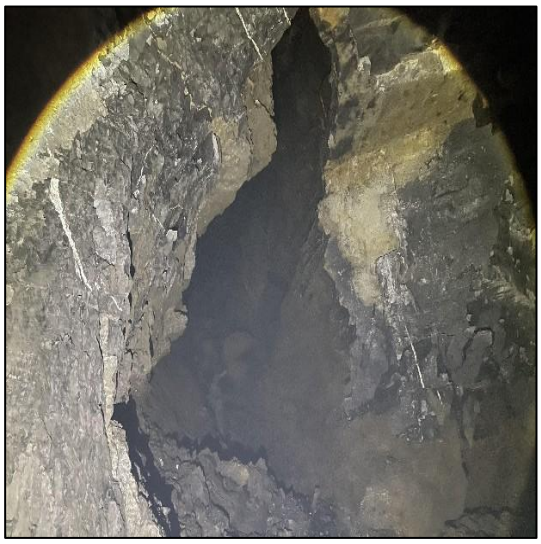


Fig. 7 Cave exposed after excavation.

4. Summary

By analyzing the data and verifying the results of the over-advanced geological forecasting example of ground-penetrating radar, the following conclusions can be obtained

(1) In the process of advanced geological forecasting, ground-penetrating radar has the features of simplicity, convenience, and high accuracy, and the geological conditions obtained through the exposure of advanced horizontal drilling and the verification of actual boring are basically the same. It can make early warning for the prediction of the tunnel palm face in advance, and can accurately provide reliable geological information to ensure the safe construction of the tunnel project.

(2) In the waveform stacking map of ground-penetrating radar reflection, the water-bearing fissure shows the characteristics of continuity of same-phase axis and amplitude enhancement, while the caves around the "water-bearing fissure" are characterized by discontinuity of same-phase axis and amplitude enhancement.

(3) The Hilbert transform can highlight the same-phase axis characteristics of the geological radar reflection waves, and in the interpretation of the data, the anomalies of the reflection waves should be interpreted in combination with the geological characteristics.

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