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Application of Induced Polarization Method to Detect Water-bearing Structure in Tunnel Rock Masses

Shi Yehui
Tunnel and Underground Engineering Research Center of Jiangsu Province (TERC)
Nanjing, China
shoece@qq.com

Lu Hao
Tunnel and Underground Engineering Research Center of Jiangsu Province (TERC)
Nanjing, China
465576221@qq.com

Deng Shuxin*
School of Mechanical Engineering
Nanjing University of Science and Technology
Nanjing, China
***corresponding auteur: dsx@njust.edu.cn**

***Abstract*—Advanced detection of water-bearing structure is a key technical problem in the prevention and control of sudden water gushing disaster during tunnel construction. Induced polarization method based on the correlation between the attenuation characteristics of the excitation parameters and the formation water content, can be very intuitive to reflect the water distribution in cracked rock masses. In addition, with good anti-interference ability, easy operation, etc., induced polarization method can be well applied to advanced detection of water-bearing structure in tunnel rock masses, and has important applications.**

Keywords—induced polarization method; tunnel engineering; advanced detection; Electrical prospecting

I. INTRODUCTION

With the rapid development of civil infrastructure constructions, more and more tunnels are being built in the fields of hydraulic engineering, traffic engineering, mining engineering, defense engineering. During the excavation of these tunnels, water inrush disasters often occur, causing damage to construction equipment and even casualties [1–4]. Advanced detection of water-bearing structures in tunnels is a key technical problem for preventing and controlling water inrush disasters [5], and can be very meaningful for tunnel construction.

Induced polarization method is an electrical exploration method that makes a geological exploration by measuring the induced polarization effect of rock strata[6]. Due to the correlation between the attenuation characteristics of the excitation electrode and the water content, the excitation polarization method can be used to detect water-bearing structures in tunnel construction in advance. Li et al.[7] developed a set of special induced polarization instruments for the advance detection of tunnel water-bearing structures, and utilized the 3D imaging technology for the advance detection of tunnel water-bearing structures based on the three-dimensional resistivity inversion method. Song et al.[8] found that the combination of density resistivity method and the induced polarization method is effective in groundwater surveys in arid areas and has good application effects. Liang et al.[9] analyzed the water finding cases with geophysical prospecting and believed that the induced polarization method is less affected by the topography, and the reflection of the depth of the karst fissure water level and the relative water-rich zone is relatively intuitive.

At present, the induced polarization method has been widely used in geological prospecting, and there are few cases of geological prediction in tunnel construction. In the present paper, the detection principle of induced polarization method is introduced, and based on engineering cases the application of induced polarization method in the detection of tunnel water-bearing structures is discussed.

II. DETECTION PRINCIPLE OF INDUCED POLARIZATION METHOD

The induced polarization method is an important branch of electrical exploration. When conducting resistivity surveys, it can be observed that when a stable current is supplied to the ground, the potential difference between the electrodes does not reach the saturation value instantaneously, but changes with time and reaches a stable saturation value after a period of time. After disconnecting the power supply current, the potential difference does not decay to zero instantaneously, but drops quickly at the first instant, and then slowly decreases over time and tends to zero.

This type of physical and chemical phenomenon that occurs in the geological medium due to the excitation of the external current causing the charge separation inside the medium, and the additional electric field caused by the electrochemical action, is called the induced polarization effect. The induced polarization method is an electrical method for geological exploration by observing and studying the induced polarization effect of the measured object based on the difference of the induced polarization effect between different geological media.

Figure 1 shows a schematic diagram of the induced polarization phenomenon in the time domain. By analyzing and inverting parameters such as the polarizability, resistivity, and half-life difference in the induced polarization method, the resistivity and polarizability structure of the rock mass in front of the face can be obtained, which can provide advance geological prediction Important reference.

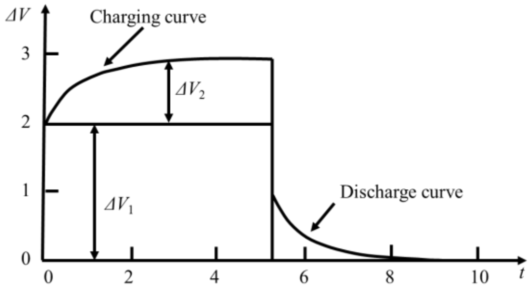


Fig. 1. *Schematic diagram of the induced polarization phenomenon in the time domain*

III. Measuring line arrangement of induced polarization method

Take the detection of water-bearing structures in the working face and surrounding area of a highway tunnel engineering as an example, the advanced prediction instrument is shown in Figure 2. Parameters such as apparent resistivity and half-life time difference are investigated. The measurement electrode arrangement of the excitation polarization is shown in Figure 3. Two rows of measuring electrodes are arranged on the working face of the tunnel, with a distance of 1.5m between the top and bottom and a distance of 0.8m between the left and right. There are 8 in each row, totaling 16 electrodes. The power supply electrode arrangement is: power supply electrode rings are arranged on the side wall, 4 electrodes per ring (A1, A2, A3, A4), a total of 5 rings, a total of 20 electrodes. The distance between the electrode ring and the working face is 0m, 4m, 8m, 12m and 16m.

Fig. 2. *The advanced prediction instrument*

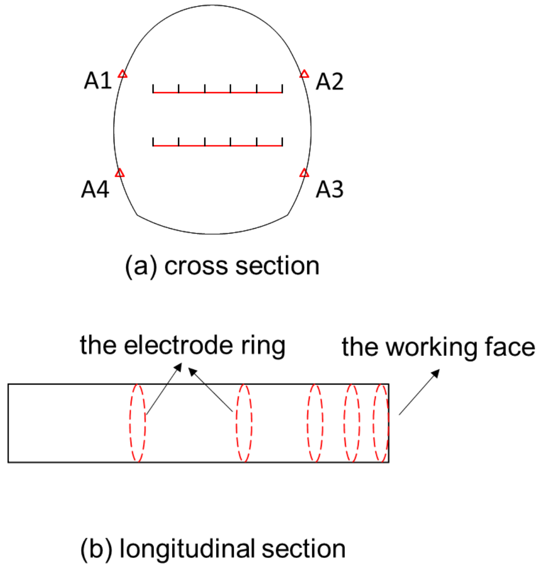


Fig. 3. *The measurement electrode arrangement of the excitation polarization*

IV. Detection Results Analysis of Induced Polarization Method

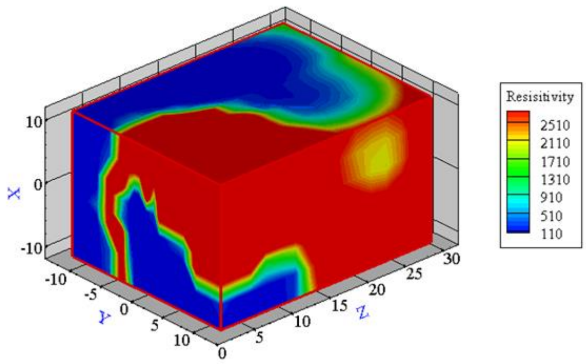
The detection result of the difference in the half-life of the excitation polarization of a certain detection is shown in Figure 4, the three-dimensional imaging is shown in Figure 5, and extraction results in low-resistance regions are shown in Figure 6 and Figure 7. In these figures, the X direction indicates the vertical direction of the tunnel working face, the Y direction indicates the width direction of the tunnel working face, the Z direction indicates the excavation direction, and the coordinate origin is the center position of the tunnel working face. The scope of the inversion area is $-10\text{m} \le X \le 10\text{m}$, $-10\text{m} \le Y \le 10\text{m}$. The contour range of the tunnel working face is $-4\text{m} \le X \le 4\text{m}$, $-4\text{m} \le Y \le 4\text{m}$. Figures 5~7 show that:

(1) In the section close to the tunnel working face $0 \le Z \le 13\text{m}$, the low resistivity area is distributed in the lower part of the tunnel face. The resistivity is about 50Ωm. The difference between the two current half-decays appears positive. It is inferred that it may be a water channel or broken water-rich area.

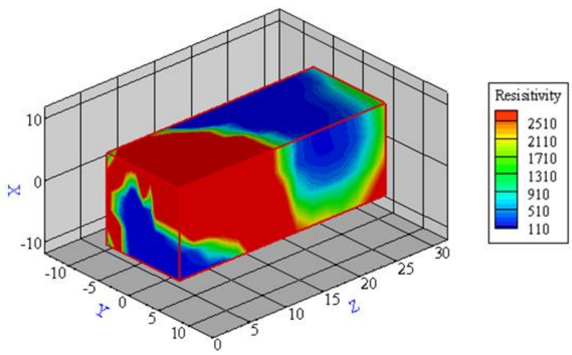
(2) In the section of $13 \le Z \le 21\text{m}$, the low resistivity area is mainly distributed in the left and middle areas of the tunnel working face, and the resistivity is about 80Ωm. These areas are likely to be water channels or broken water-rich areas.

(3) In the section of $21 \le Z \le 30\text{m}$, the low resistivity area is distributed over the entire area of the tunnel face, and the resistivity is about 70Ωm, which may be inferred as a water channel or broken water-rich area.

Fig. 4. *Detection result of the difference in the half-life of the excitation polarization of a certain detection*

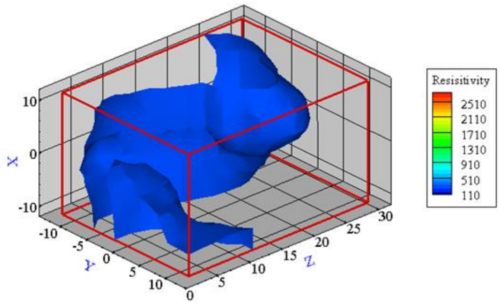


(a) working face and surrounding area

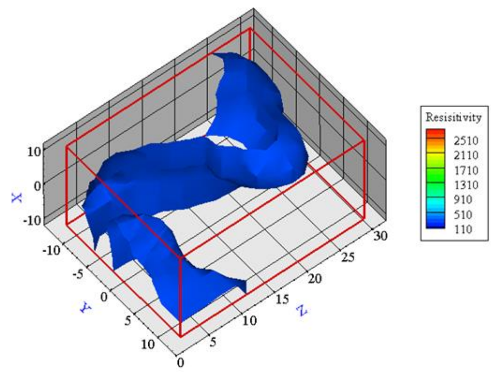


(b) contour area of the working face

Fig. 5. *Three-dimensional resistivity contours of induced polarization method*

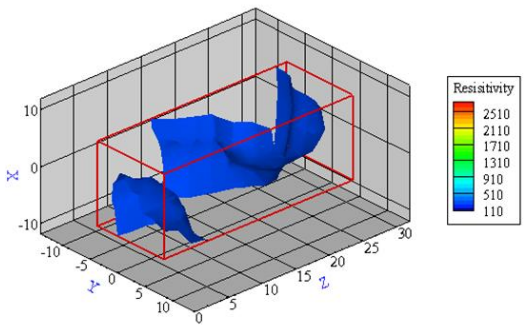


(a) lateral view

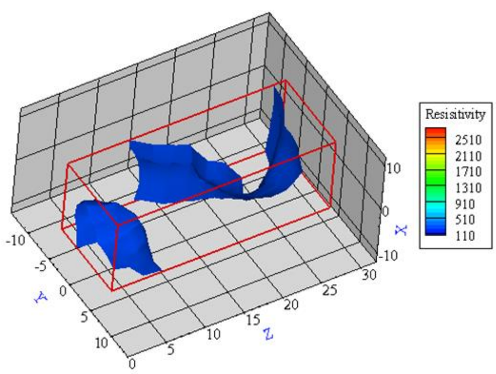


(b) top view

Fig. 6. *Distribution of low-resistance anomaly areas on the working face and surrounding areas*



(a) lateral view



(b) top view

Fig. 7. *Distribution of low-resistance abnormal areas in the contour areas of the working face*

V. CONCLUSION

The present paper briefly describes the principle of induced polarization method, and discusses the application of induced polarization method in the detection of tunnel water-bearing structures based on engineering cases. Considering the relationship between the induced polarization parameters and the water content, the induced polarization method not only directly reflects the distribution of karst fissure water, but also has the advantages of good anti-interference ability and easy operation. It can be well applied to solve the advanced detection problems of intermediate water-bearing structures and has important application prospects.

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