Study on Performance Evaluation and Forward Geological Prediction of TBM Construction Tunnels

長崎大学大学院工学研究科
李 寧博

With the vigorous development of World's economic construction, the demand for infrastructure construction, especially transportation facilities, is increasing daily, bearing the brunt of railway, road, and other land transport. The perfection and development of highway networks need to construct a large number of long-buried mountain tunnels. What is the magnitude and distribution of the water load acting on the lining? What are the effects of high water pressure on the stability and structural stress of tunnel surrounding rock? What is the mechanism of structural stress? In the past, groundwater research mainly focused on groundwater flow rate in engineering structures, the prevention and control of drainage of structures, and the treatment of groundwater in concrete projects. However, the research on the water pressure borne by structures is less. Therefore, the previous research on high water pressure tunnel engineering is not enough. It has become a new topic in the current tunnel engineering. At present, the treatment results of this kind of engineering are either not very high water pressure, taking too conservative countermeasures, resulting in much waste; Or lining in the considerable water pressure, taking too risky or blind countermeasures, there are security risks, causing security problems. In particular, there is no reasonable way to determine how much groundwater pressure the lining is subjected to. Therefore, it is more and more essential to study the seepage field near the tunnel and determine the external water load on the lining grouting ring based on the characteristics and laws of underground flow. There is no doubt that the tunnel surrounding rock, grouting circle, lining the determination of water pressure distribution for structure design and construction provide essential theoretical basis, help to enrich and develop the tunnel mechanics theory, solve the high water cut rich water tunnel engineering design, in order to solve the high water pressure rich area of tunnel engineering technical problems and structural design of determining the accuracy of the load, It provides technical support and theoretical basis for the formulation of relevant norms and standards.

Under the action of high ground stress and high water pressure, karst cracks, karst pipelines, and other wide cracks and hidden water channels can induce sudden flood and tunnel collapse rapidly. The rock fracture mechanism caused by high water pressure in the excavation process is not accurate, and the advanced detection efficiency of tunnel excavation is low. High resolution and advance detection is an urgent need for the tunnel to pass through water-rich strata safely. Therefore, it is urgent to study the mechanism of rock fracture caused by high water pressure and establish a suitable advanced detection method for tunnel crossing water-rich strata safely. Based on the actual granite samples, this paper conducted hydraulic fracturing, laboratory tests, and numerical simulation to study the granite hydraulic fracturing method, micro-crack evolution characteristics, and the influence of temperature and confining pressure on fracturing pressure. Different cross-hole resistivity observation devices in tunnel environments were compared and analyzed from sensitivity analysis. Select an effective observation device suitable for cross-hole resistivity detection of tunnels; Based on the analysis of rock parameters affecting TBM utilization, a genetic algorithm based on the BPNN-TBM efficiency prediction model was proposed. Based on the maximum surface settlement (Smax) and tunnel design parameters (tunnel depth H and tunnel diameter R), a feasible method for estimating the two parameters of ground settlement prediction is proposed. This method can be used to predict ground movement curves of circular and non-circular tunnels. The results show that rock temperature is the main factor controlling the hydraulic fracturing behavior of granite. The sample is in a state of tensile failure, with short branching fractures appearing on the outer edge of the sample or around the wellbore -- the number of microfractures increases during hydraulic fracturing. According to the growth rate of microfracture, the fracturing process can be divided into three stages. According to the change of microfracture growth rate, the hydraulic fracturing process can be divided into three stages: initial stage (the first stage), sound stage (the second stage), and rapid fracturing stage (the third stage). By studying the influence of the preset crack Angle on the hydraulic crack propagation behavior, it is found that stress concentration occurs at the crack tip under the influence of the stress field. Due to the symmetrical distribution of load, the crack propagation path is center-symmetric concerning the midpoint of the preset crack. LightGBM is used to predict the specific section PR of Hanjiang-Weihe water transfer engineering geology with the high wear rate and in-situ stress.

The prediction shows that the prediction model is suitable for practical engineering. Through the importance analysis of parameters, the importance of each input parameter identified by LightGBM can be UCS, CT, RPM, MCP from high to low, which is different from the correlation order of UCS, MCP, RPM, CT. The prediction results of the BPMN-GA model combined with the traditional model show that the stability and accuracy of prediction results optimized by the genetic algorithm are improved. Compared with the traditional BPNN prediction model, the accuracy of the BPNN-GAA model on the test set is improved by 8.95%, and the mean square error is reduced by about 60%. This proves that the BPNN-GA model is independent of specific data sets and has good portability and generalization. It can be seen that the tunnel-induced ground movement predicted by the simplified formula of random medium theory is in good agreement with SM theory and field measurement results for circular and non-circular sections of single tunnel and double tunnel. The simplified calculation formula can reduce the computational workload and provide a more reasonable prediction of surface movement caused by tunnel excavation. Furthermore, it can provide a more reasonable prediction of ground movement caused by tunnel excavation.