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Evaluation of Tunnel Seismic Prediction (TSP) Test Results based on Geological Observations and Analysis of the Parameters of the EPB Hard Rock Machine

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Abstract

Bazideraz's water transfer tunnel is located in the Zagros structural zone. To excavation this tunnel, an EPB Hard Rock type TBM machine was used. The axis of the tunnel is located on an Anticline. In this anticline, there are various geological structures such as folding, fault, karst, and so on. The underlying studies of the design and implementation of exploratory specimens in the core of this anticline have been confined. In this research, for study of geological conditions during drilling, seismic prediction of tunnel (TSP) test was carried out at two positions of 3+287 and 5+577. In this geophysical method, seismic waves are used to illustrate geological structures. The distribution of shear waves in a three-dimensional tunnel model provides evidence of lithological changes (alternation of marl and shale and limestone layers) and the existence of several crushed zones along the drilling path. Bazideraz Tunnel is the first project in the world to use the TSP method to drill a EPB machine. In this study, the analysis of the operational parameters of the EPB machine and Observe rock mass during drilling was used to measure the accuracy of the TSP results. The fluctuations of the penetration rate, thrust and torque in the drilling path are in accordance with the low velocity and high velocity regions of the three-dimensional shear waves. Results of controlling the drilling materials indicate that the shear waves distribution models have a relative adaptation to the geological conditions in the drilling path.

***Key words**: TSP, Shear Waves, EPB Machine, Penetration Rate, Thrust, Torque, Crushed Zones*

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Extended Abstract:

1. Introduction

Bazideraz's water transfer tunnel is located in the Zagros structural zone. To excavation this tunnel, an EPB Hard Rock type TBM machine was used. The axis of the tunnel is located on an Anticline. In this anticline, there are various geological structures such as folding, fault, karst, and so on. The underlying studies of the design and implementation of exploratory specimens in the core of this anticline have been confined.

2. Methodology

In this research, for study of geological conditions during drilling, seismic prediction of tunnel (TSP) test was carried out at two positions of 3+287 and 5+577. In this geophysical method, seismic waves are used to illustrate geological structures. The Tunnel Seismic Prediction method developed by Amberg Technologies AG detects chang-es in rock mass such as irregular bodies, discontinuities, fault and fracture zones ahead of the tunnel face. Employed as a predictive method during excavation process for both drill & blast and TBM headings, no access to the face is required to perform measurements, which are tak-en in tunneling production breaks. Acoustic signals are produced by a series of 24 shots of usually 50 to 500 grams of detonation cord aligned along one tunnel wall side and having an additional shot line along the opposite tunnel wall side in cases of more complex geology. Four sensor probes, consisting of highly sensitive tri-axial receivers, are contained in protection tubes whose tips are firmly cemented into boreholes in both side-walls. The 3-component receivers pick up the seismic signals which were being reflected from any kind of discontinuity in the rock mass ahead. Highly sophisticated processing & evaluation software has been devised for ease of operation. The capability of the system to record the full wave field of compressional and shear waves in conjunction with the intelligent analysis software enables a determination of rock mechanical properties such as Poisson ratio and Young’s Modulus within the prediction area. The final 2D- and 3D-summary results produced by the system software present as well detected events and boundary planes crossing the tunnel axis coordinates ahead of the face. The TSP 303 system integrates 3D data acquisition and processing software containing rou-tines for optimal seismic imaging with respect to tunneling requirements. It exploits the infor-mation in the seismic wave field by separate compression (P) and shear (S) wave analysis and the 3D-Velocity based Migration & Reflector Extraction technology (3D-VMR). The 3D-VMR technology provides an adequate and detailed 3D image of the ground leading to a more relia-ble interpretation compared to conventional 2D approaches. Bazideraz Tunnel is the first project in the world to use the TSP method to drill a EPB machine. In this study, the analysis of the operational parameters of the EPB machine and observe rock mass during drilling was used to measure the accuracy of the TSP results.

3. Discussion

The distribution of shear waves in a three-dimensional tunnel model provides evidence of lithological changes (alternation of marl and shale and limestone layers) and the existence of several crushed zones along the drilling path. Low velocity regions of shear wave, indicating the presence

of rock mass with weak geomechanical parameters and high velocity regions, also indicate that rock masses with higher geomechanical parameters. According to the results obtained from the TSP data, the variation in shear wave propagation velocity at a position of 3+287 km ranges from about 1260 to 1740 m/s. These values, with the experimental values of shear wave velocity in the rock masses of this The range (marl, calcareous marl and calcareous shale In the Gurpi Formation) is the same. The oscillation of the operational parameters of the digger machine is also dependent on rock mass resistance (UCS), quality index (RQD) and other characteristics engineering of the rocks. Therefore, the study of the status of the digging machine parameters and the comparison of their trends with the results of the TSP test can be a way to measure the validity of the results of the TSP predictions. For example, rock mass conditions at 3379 km (Calcareous Marl: Rectangular with low RQD), a certificate for the existence of a relation between the parameters of the machine (Increase Penetration rate: 37 mm/rev, Decrease Thrust: 830 ton, Increase Torque: 230 ton.m) with shear wave velocity (approx. 1380 m/s) in this area. Also, rock mass conditions at 3387 km (Calcareous shale with RQD>80), a certificate for the existence of a relation between the parameters of the machine (Decrease Penetration rate: 18 mm/rev, Increase Thrust: 1035 ton, Decrease Torque: 130 ton.m) with shear wave velocity (approx. 1700 m/s) in this area.

The second phase of the TSP test was carried out at position of 5+577 km (in the range of two Pabdeh Formations and Telezang). The lithology of Pabdeh Formation in this area is Chilean lime and the lithology of the Telezang Formation consists of limestone mass. As shown in Fig. 1, the shear wave velocity in several zones has fallen sharply from 3100 to 2200 m/s.

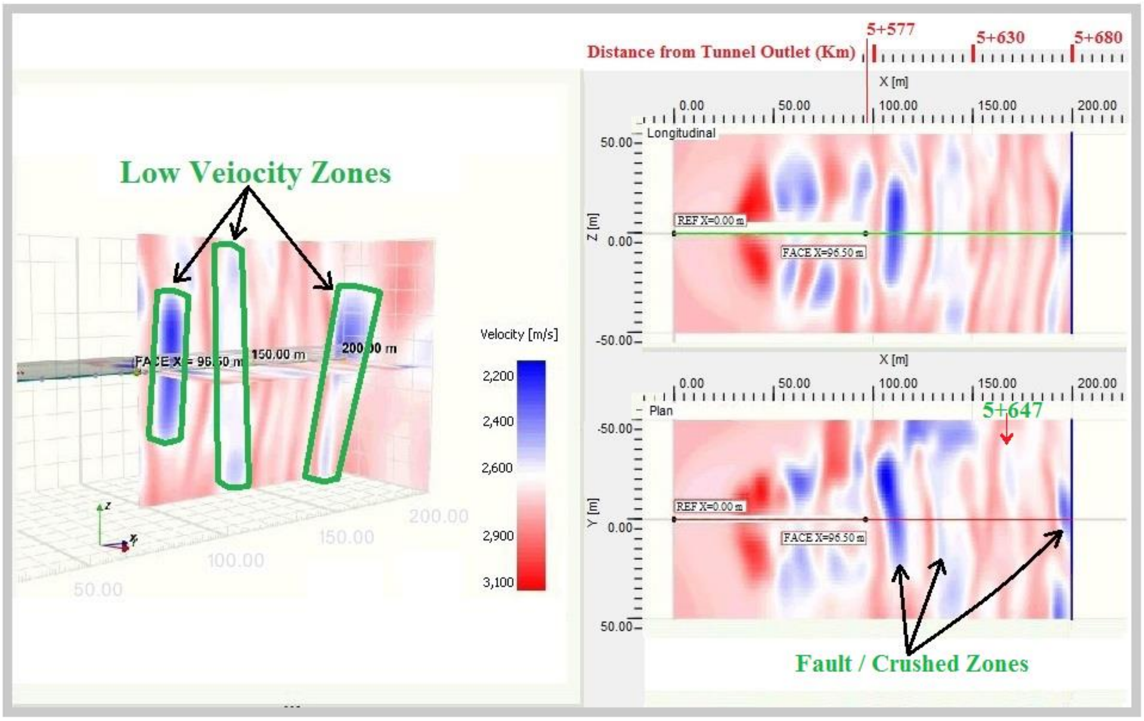

Figure 1. Three-dimensional model of S-wave velocity distribution in km 5 + 577.

Investigating the geological conditions during drilling showed that Low velocity regions of the shear wave are correspond to the location of fault zones in the drilling path. Investigating the conditions during drilling showed that the lithology composition (in terms of low impurity and high potential for water storage), and crushing of rocks has led to the development of underground water flows. In this range, low-velocity zones in the shear wave model (at speeds of about 2200-2400 m/s) are in line with the location of fault zones in the drilling path (in the km of 5598, 5620, 5647, and 5671).Analysis of the operational parameters of the digger machine indicates that there is a relative adaptation between the shear wave velocity distribution model and the variations in the parameters of the machine. Under normal conditions in crushed rocks, the penetration rate of the machine should increase. But at this area, the penetration rate is declining. In the crushed zones, the chamber compartment quickly filled with large stone pieces and large volumes of water. Therefore, machine operators had to control the penetration rate so that the discharge process (water and rock materials inside the chamber) would create fewer problems for executive operation. Meanwhile, the chamber valve closure and drilling into EPB mode (applying EPB pressure in the chamber compartment) also increased the thrust force of the device. The second factor in increasing thrust force is that the movement of crushed stone mass and their friction with the shield of the device, has also affected increased the thrust force. At km 5598, 5620, 5647 and 5671 (With shear wave speed about 2200-2400 m/s) , due to the influx of water and the fall of the stone blocks into the chamber, the penetration rate reached the lowest limit (respectively: 3, 4, 4, and 3 mm/rev), and the thrust force (respectively: 1650, 1350, 1650 and 1400 tons) Increased. In the km 5645 to 5650, the rock mass was crushed, but this region shows a speed of about 2600 m/s in the shear wave model, therefore, unlike other crushed zones in the shear wave model, it is clearly not visible. This is due to the low width of the crushed region (5 m) and also because of the Reduce the potential for separation of the TSP method (due to increasing distance).

4. Conclusion

The fluctuations of the penetration rate, thrust and torque in the drilling path are in accordance with the low velocity and high velocity regions of the three-dimensional shear waves. Results of controlling the drilling materials indicate that the shear waves distribution models have a relative adaptation to the geological conditions in the drilling path.