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Estimation of Coal Bed Length using Tunnel Electrical resistivity Prospecting System (TEPS) in Sim-Gok tunnel, South Korea

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ABSTRACT

Existence of unexpected ground during tunneling causes many problems such as displacement on surface, groundwater inflow, and tunnel collapse at tunnel crown and face. Coal region during tunnel excavation has high enough uni-axial compression strength during construction of tunnel, however, simultaneously decreases and loses its strength after excavation. Therefore, tunnel support pattern is changed with length of coal region. Length of coal region in Sim-Gok tunnel which is railway tunnel located in Danyang, South Korea is estimated using Tunnel Electrical resistivity Prospecting System (TEPS). TEPS is selected to estimate the length of coal region because its short measurement time (about 30 minutes) compared to Tunnel Seismic Profiling (TSP) and probe drilling method. Experimental tests to estimate the coal region are performed with seven sensors installed on tunnel face. Predicted length of coal region using TEPS is around 20m ahead of tunnel face and excavation data shows the coal region ends in 23m ahead of tunnel face.

1. INTRODUCTION

Tunnel excavation in coal region has serious problem that strength of coal region drastically dropped after excavation. Therefore, many tunnels in coal region changes support patterns for safe excavation.

Hong et al. (2002) performed strain measurement and numerical simulation using FLAC 2D based on measured strain and face mapping results for analyzing the characteristics of coal region. In coal region, measured strain occurs about 20 times higher and simulated results is 10 times higher than that of non-coal region. Effects of invert and tunnel support in coal region are reduction of strain, settlement, and stress of shotcrete.

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Cho et al. (2015) performed forecasting methods such as probe drilling, tunnel seismic profiling (TSP), and face mapping in Boryeong tunnel which is first subsea tunnel in South Korea which contains coal region. They checked water pressure by coring tunnel face and determined to install water cutoff grouting.

Sim-Gok tunnel which is our target tunnel is located in Danyang, South Korea. This tunnel pass through coal region and they asked to forecasts the length of coal region using TEPS which is developed by Ryu (2010). This technology forecasts ahead of tunnel face using electromagnetic waves. This technology has been verified in over 20 tunnels.

2. TUNNEL ELECTRICAL RESISTIVITY PROSPECTING SYSTEM (TEPS)

The TEPS (Tunnel Electrical resistivity Prospecting System) investigates the size, location, and status of irregular geological conditions (faults, boulders, soil-rock interface, and weak zones) ahead tunnel face and existing structures (cable tunnels, sewage tunnels, and the foundation of structures). Furthermore, TEPS estimates the rock quality of tunnel face and anomalies using the relationship between RMR value and electrical resistivity measured by TEPS. The basic concept of TEPS is that the electrical voltage and current are applied to a sensor and is received at another sensor. This steps are performed in simultaneously with several sensors. Electrical resistance is obtained in a previous step. The irregular geological condition and presenting structures are predicted by back analysis developed theoretically. The basic concept and expected results of TEPS are given in Figure 1.

TEPS can be performed in 30 minutes including sensor installation and measurement. And back analysis takes about two hours. TEPS has merits compared to TSP and probe drilling in time and convenience on measurement.

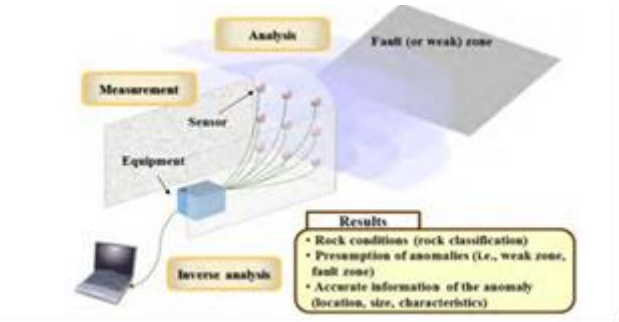

Fig. 1 Concept of TEPS

3. SIM-GOK TUNNEL

Sim-Gok tunnel is located in Danyang, South Korea. Danyang region is famous on limestone and there are many cement facilities. Sim-Gok tunnel is for railway tunnel with over 200 km/h trains. Figure 2 shows RMR mapping of Sim-Gok tunnel based on coring data. Sim-Gok tunnel lane is consists of most of limestone and partial fault zone and coal region. Total length of this tunnel is about 5 km long and its section is about 11 m in diameter.

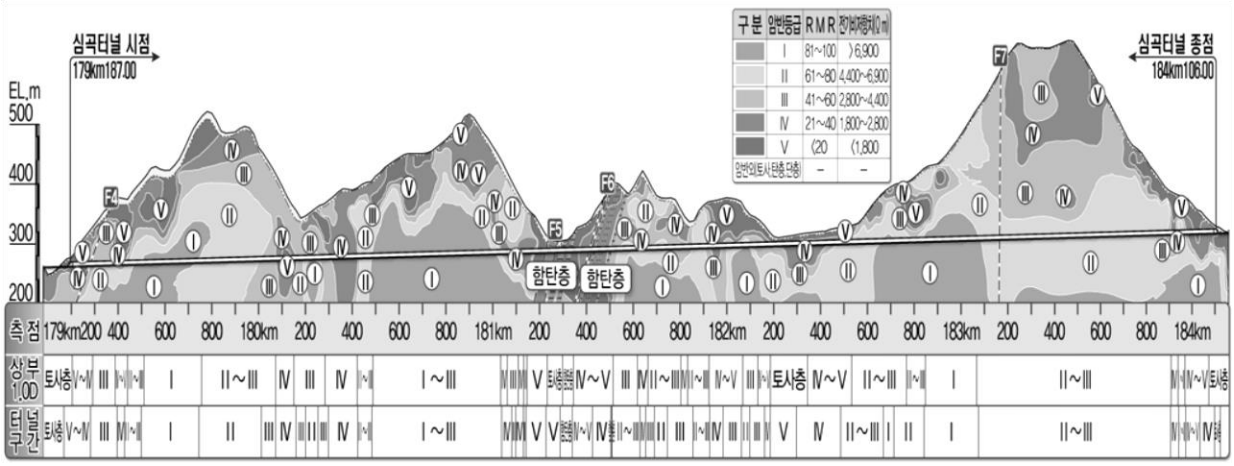

Figure 2. RMR estimation of Sim-Gok Tunnel from coring data

4. TEPS MEASUREMENT ON TUNNEL FACE

Tunnel face consists of coal (Figure 3) and construction company is eager to know length of coal region. We performed the TEPS on Sim-Gok tunnel with 7 sensors (Figure 4). #a (b,c) in Figure 5 means sensor number ‘a’ with location ‘x=b’ meter and ‘y=c’ meter.
Applied voltage was 0.5 V and contact area of sensors is 0.001 m^2.

Figure 3. Status of tunnel face

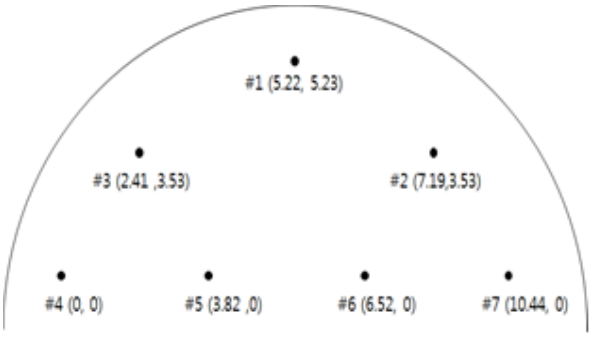

Figure 4. Location of sensor installation

5. TEST RESULTS

5.1 Tunnel ahead prediction results

The length of coal region is analyzed by using back analysis program which is developed by Ryu (2010). Result shows that coal region ends in about 20 m. This result is verified compared to probe drilling and real excavation results.
Figure 5 shows probe drilling results. Probe drilling result shows that coal region will ends in 23 m ahead of tunnel. This results are similar with TEPS measurement. And also real excavation result shows coal region ended in 23 m ahead of tunnel

Figure 5.Core from probe drilling

5.2 RMR results

Estimated RMR value from electrical resistance ranges from 30 to 42 which is grade III-IV (Figure 6). This RMR result is kind of verification of technology. RMR value from face mapping was 33 which is within our estimation.

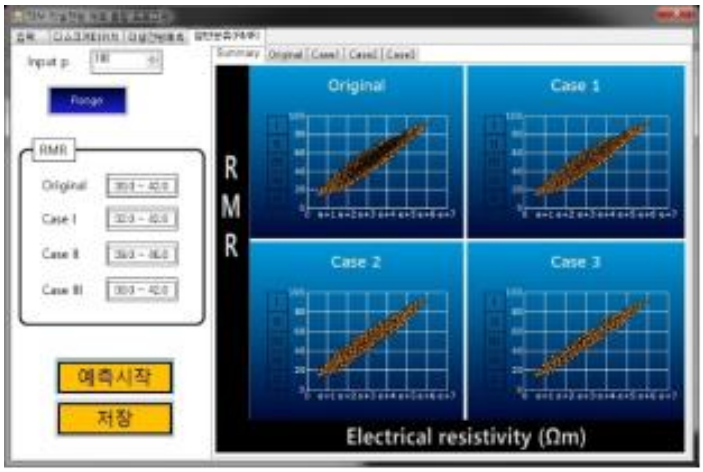

Figure 6. Rock mass rating (RMR) estimation using electrical resistance

6. Conclusion

Tunnel electrical resistivity prospecting System (TEPS) was performed in Sim-Gok tunnel to estimate length of coal region. 7 sensors are attached on tunnel face and electrical resistance between sensors are measured.
Back analysis result shows that coal region will end in about 20 m and this result is similar to probe drilling result. Real excavation result is also similar to this estimation.
RMR value from tunnel face using TEPS was 30-42 and RMR result from face mapping was 33.
TEPS result was well-matched from various result from different method. TEPS can be utilized not only NATM tunnel but also TBM tunnel because TEPS can estimates RMR value and status of anomalies on tunnel ahead.

ACKNOWLEDGEMENT

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REFERENCES

Cho, B.H., Heo, D.H., Seo, S.H., and Hong, E.J. 2015. Site survey of the Boryeong Tunnel, Nation's First excavated subsea tunnel. Yooshin Technical Bulletin **22**, 344-353.

Ryu, H.H. 2010. Development of tunnel electrical resistivity prospecting system and its application. Thesis (PhD in Geotechnical engineering), Korea Advanced institute of Science and Technology, South Korea.

Hong, W.P., Han, J.G., Kim, D.N. 2002. Characteristic of tunnel behaviour during NATM tunnel excavation for coal seam, Korean Society of Civil Engineers Conference, 3120-3123.