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Investigation of geological conditions beyond the excavation face using a MSP boring data monitoring system

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ABSTRACT

Pre-investigation of geological conditions beyond the excavation face is crucial for assessment of safety and design in underground construction. This study developed a boring data monitoring system equipped for a multi-setting smart-investigation of the ground and pre-large hole boring (MSP) machine that typically drills a horizontal distance of 50 m to reduce blast-induced vibration. The monitoring system was applied to the tunnel construction site, which drills 40 m with the MSP method to investigate the geological conditions ahead of the excavation face. In addition, the analysis results of the boring data were compared with the observed images taken inside the holes, using a borehole alignment tracking and ground exploration system. The analysis of the boring data indicated rapid changes in pressure and boring speed with changes in geological conditions. Furthermore, the ground conditions ahead of the excavation face can be classified into three stages based on the boring pressure and speed variations. Therefore, these boring data can be the basis for predicting the geological conditions beyond the excavation face without additional effort and processes, and can help in ensuring the safety and efficiency of tunnel construction projects.

1. Introduction

The construction of underground tunnel structures has been rapidly increasing to solve traffic congestion in urban areas.[1] Rocks are natural materials with heterogeneous properties and pose uncertainties when subjected to excavation, owing to varied geological properties depending on the location.[2–4] Geological hazards encountered during tunnel construction can be caused by natural factors, including ground conditions and the presence of unexpected weak zones, but also by human factors such as construction conditions and support designs,[5,6] with the potential for massive losses and injuries. Therefore, it is essential to understand the engineering characteristics of the target excavation site for safe and economical underground construction.[4]

Site investigations are carried out through vertical borehole drilling to estimate the in-situ underground conditions over a wide area. However, there are limits to evaluate underground structures in detail. To solve this problem, various types of geological survey techniques, such as pilot horizontal boring and tunnel seismic prediction surveys, have been adopted to estimate the subsurface conditions ahead of the tunnel face during excavation.[7–10] However, the application of these techniques during tunnel construction requires additional steps and costs.[11]

Measurement while drilling (MWD) techniques have been developed for evaluating in-situ rock mass characterization for predicting the geological conditions ahead of the tunnel face.[12] Several studies have been conducted to investigate the geological conditions ahead of the tunnel face by pressure monitoring using a hydraulic drilling machine.[13–21] Furthermore, many researchers have carried out studies using artificial intelligence technologies, such as machine learning, to analyze the relationships among drilling datasets, and predict geological conditions,[22–24] concluding that MWD techniques are an objective and reliable method for assessing geological conditions ahead of the tunnel excavation face.

Large-diameter empty holes over 250 mm in diameter have been applied at the excavation face in the New Austrian Tunneling Method (NATM) tunnel to reduce blast-induced vibrations and are generally drilled to a distance of 50 m at a time in Korea.[25] It is reported to be efficient in reducing blast-induced vibration through the formation of additional free faces[26]; however, it is time consuming because of the underdeveloped boring machines. In addition, boring operations rely on the operator's experience and not on any monitoring devices, resulting in large differences in boring quality depending on the operator's proficiency. Furthermore, it is difficult to control the boring machine in

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