Evaluation of groundwater in fractures adjacent to tunnel using information of waveforms of Ground Penetrating Radar

*Kazuhiko Masumoto[1]

1. Kajima Corporation

For construction of underground structures in a rock, it is important to characterize the ground water flow in the fracture. Fractures developing around the tunnel during the excavation, which is called as EDZ (Excavation Damaged Zone), result in issues related not only to the mechanical stability of the rock cavern, but also to the groundwater flow paths. Specifically, in terms of the safety assessment of geological disposal of radioactive waste, the groundwater management of rock caverns for oil/LPG storage using hydraulic containment system, or planning of countermeasures for water seepage of tunnels, it is important to have a thorough understanding of the groundwater conditions around the tunnel.
As the GPR (Ground Penetrating Radar) method is unique technique to survey the groundwater condition, indirectly, and with no disturbance of original ground water condition, so the GPR is possible to grasp the water condition in the fractures around the tunnel, however, the output is just the profile image of the fractures so far. In this study, the change of reflected waveforms (amplitude or frequency) of GPR is focused in order to estimate the water content and concentration of liquid in the fractures, and the target of this study is to show the possibility of application of the information of GPR waveforms to evaluate the groundwater in the fractures.
Firstly, based on the results of theoretical discussion of electromagnetic wave and numerical simulation using FDTD method, it was concluded that the change of water content, saturated or non-saturated condition and the existence of high conductivity reflector have influence on the waveforms, that is, the change of amplitude and dominant frequency of reflected wave. So, the change of amplitude and frequency would be a possible indicator to evaluate the water condition in the fractures.
Next, in order to validate the possibility of application of GPR in the actual site, three types of experimental study were conducted; (1) preliminary test using the artificial fractures, which consisted of the wooden cement-boards between a concrete block (Masumoto and Kurihara, 2014), (2) verification test on the surface of the concrete placed on the granitic rock with fractures to evaluate groundwater permeation in the rock of lining backfaces (Masumoto and Kurihara, 2015), (3) verification test along the side wall of 500m access tunnel of Mizunami Underground Research Laboratory of JAEA to estimate the fractures around the tunnel as flow paths (Masumoto and Takeuchi, 2016).
From these results of monitoring of the reflected waveforms from the target fractures using GPR, it could be concluded that the difference of water condition in the fractures caused the change of intense of amplitude and spectrum due to the results of spectrum analysis of reflected waveforms. The results indicated that the water condition in the fractures and the flow paths or transport channels along the fractures could be evaluated using the information of reflected waveforms of GPR.
In the future, this non-destructive method using GPR could be applied to monitor the submerge process of unsaturated zones around rock caverns, to measure the break-through process in tracer tests 2-dimensionally, and to monitor the permeation of grouting materials in grouting work.

References:

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