Transmissive fracture analysis from constant injection and geophysical logging in a fractured aquifer, S. Korea

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Abstract: A field technique for assessing the transmissive fractures in an aquifer was applied to a fractured rock formation in Youngchun waterway tunnel area, Korea. The fracture sets of N16°E, 46°N, N23-35°E, 65°S, N65-72°E, 60°N, N61-64°W, 60-66°N, N80-85°W, 85°SW, and N70-72°W, 13-17°S were identified as a distinct transmissive fractures through the results of each tests.

Key words: transmissive fracture, aquifer, fractured rock, Youngchun waterway tunnel

Introduction

The location of anomalous geological conditions in a rock mass is of considerable importance in the construction and design of most civil engineering structures, and is essential factor controlling groundwater flow in crystalline rocks. Considering groundwater, it is rarely possible to assume that a rock mass is homogeneous and isotropic, since there are usually natural fracture patterns which commonly have preferred orientations and frequently faulting is also present. The study area is located in the section of a waterway tunnel, which connects Imha dam with Youngchun dam at Kyungbuk province, Korea (Fig. 1). This waterway tunnel construction project aims at delivery of a water of the Imha dam and Kilan stream to Youngchun dam in order to provide for sufficient water to the southeast area, Kyungbuk province. The decline of groundwater level and a loss of groundwater resources were caused by groundwater inflow in to the tunnel. The purpose of this study is to evaluate a transmissive fractures related to the leakage of groundwater by tunneling. For this, attempts such as geological mapping, injection injection, acoustic borehole televiewer (BHTV), and geophysical logging were performed.

Hydrogeology and fractures

The study area is composed mainly of sedimentary rocks of the Hayang Group, with volcanic rocks of the Yuchon Group and the Bulguksa intrusive rocks. The Hayang Group consists primarily of shales and sandstones, characterized by interstratification of typical reddish shales of oxidant sediments. The Yucheon Group consists of various acidic volcanics including rhyolitic tuff, welded tuff, and rhyolite. The Bulguksa intrusives are adamellite and quartz monzonite which show an equigranular texture throughout the whole area but

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locally porphyritic texture at the margins of the intrusives. Sedimentary rocks and igneous rocks in the study area contain a number of joints with several directions of WNW, NW and NS, and seldomly EW. In the areas of volcanic rocks, the joints with the orientation of N40-50°E, 85°SE/85°NE and N70°E, 80°SE are predominant.

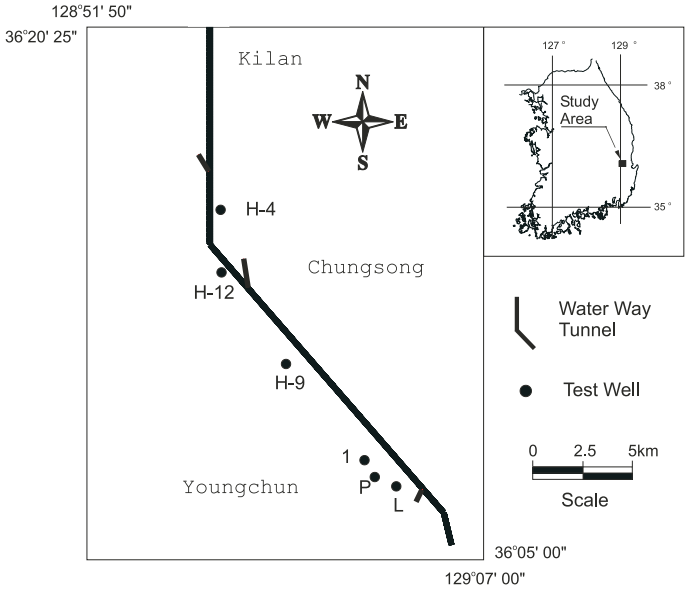

Figure 1. Location of the study area and test wells

Geophysical log analysis

Conventional geophysical log

Some geophysical logs from three wells of Wells 1, P, L were performed in order to identify conductive fractures related to groundwater flow in the vicinity of tunnel. For these three wells, we performed all logs including BHTV and injection test simultaneously. Fracture zone is identified in Well 1 at the depth of 350 m (above mean sea level), 321 m, in Well L at 236.74 m, 233.95 m, 221.11 m, and 219.44 m, and in Well P at 240.81 m to 240.65 m, 239.07 m to 238.68 m, 225.47 m to 218.77 m, 216.17 m, 209.48 m, and 204.04 m. In numerous cases, evidence of fluid movement is amplified in the temperature gradient log. Shifts in these fluid properties with depth, such as is clearly observed in Well 1 at 350 m, in Well P at 235 m, 232 m, 226 m, and in Well L at 221 m, 208 m, indicate an exchange of fluid between the well and the surrounding aquifer and, consequently, the proximity of transmissive zones.

The acoustic borehole televiewer

A much more effective identification of fractures intersecting the well bore is given by downhole imaging devices, such as BHTV or remote video camera. The borehole televiewer produces a magnetical photographic image of the intensity of acoustic reflection off of the borehole wall (Zemanek et al., 1970). The predominant fracture set in Well H-4 strikes N40-70°W and dips 45°NE, N75°W, 25°SW, and the mean fracture spacing is 1.1 m and 0.35 m, respectively. The second major fracture subset strikes N40-70°E and dips 55-85°SE and the mean spacing is 1.19 m. The fracture set in Well H-9 have orientations of N5-25°W trend and 15°NE dip, and the mean spacing in this well indicating the fractures in H-9 were formed by the production of regional stress. The network of fractures in Well H-12 was statistically classified three principal subsets. This well have a strike of N70-72°W and dip of 13-17°S, N70-85°E, 45°SE, N23-35°E, 65°S. The preferred fracture orientations for the Well 1, L, and P are N80-85°W, 85°SW, and N70°E, 80°SE.

Distribution of hydraulic conductivity

The hydraulic conductivity in the Well H-4, H-9, H-12, 1, L, and P ranged from 3.363E-10m/sec to 1.364E-06 m/sec, 2.138E-06 m/sec to 2.731E-06m/ sec, 5.126E-08 m/sec to 2.040E-07 m/sec, 1.563E-09 m/sec to 4.768E-07 m/sec, 1.537E-06 m/sec to 1.737 E-06 m/sec, and 1.181E-08 m/sec to 9.945E-07 m/sec, respectively. In six wells of Well H-4, H-9, H-12, 1, L, and P, a total of 324 permeable fractures showing high value in hydraulic conductivity were reliably identified, accounting for about 15.3 percent of the total fracture population. In three wells of Well H-4, H-9, and H-12, because fluid property logs were not performed, we could not corroborate that a specific fracture is transmissive fracture related to the groundwater leakage resulted from tunnel excavation. In case of three wells of Well 1, L, P which performed all logs, a total of 116 permeable fractures indicating high value in hydraulic conductivity and a great amount of water injection were identified, accounting for about 25 percent of the total fracture population for the three wells.

Summary and conclusions

This field study demonstrated the scientific and practical value of applying injection test and geophysical logging to a groundwater investigation in a fractured rock aquifer. Most of the permeable fractures were distinguished from the general fracture population by means of comparison between the result of injection test and geophysical logs, especially temperature log. Transmissive fracture orientations were identified from the data of BHTV for the section showing anomalies in the rate of water injection and water movement is recognized in temperature log. The most transmissive fractures identified at sedimentary rock site are bedding plane partings or bedding joint observed near the surface. High angle fractures

have a slightly narrower range of hydraulic conductivity values with no clear depth correlation. From this study, the fracture sets of a strike of N16°E, and dip of 46°N, N23-35°E, 65°S, N65-72°E, 60°N, N61-64°W, 60-66°N, N80-85°W, 85°SW, and N70-72°W, 13-17°S were identified as a distinct transmissive fractures related to the leakage of groundwater by tunneling.

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