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# Numerical evaluation of the groundwater drainage system for underground storage caverns

Eui Seob Park and Byung Gon Chae
Korea Institute of Geoscience and Mineral Resources, Daejeon, Korea (espark@kigam.re.kr)

A novel concept storing cryogenic liquefied natural gas in a hard rock lined cavern has been developed and tested for several years as an alternative. In this concept, groundwater in rock mass around cavern has to be fully drained until the early stage of construction and operation to avoid possible adverse effect of groundwater near cavern. And then rock mass should be re-saturated to form an ice ring, which is the zone around cavern including ice instead of water in several joints within the frozen rock mass. The drainage system is composed of the drainage tunnel excavated beneath the cavern and drain holes drilled on rock surface of the drainage tunnel. In order to de-saturate sufficiently rock mass around the cavern, the position and horizontal spacing of drain holes should be designed efficiently. In this paper, a series of numerical study results related to the drainage system of the full-scale cavern are presented. The rock type in the study area consists mainly of banded gneiss and mica schist. Gneiss is in slightly weathered state and contains a little joint and fractures. Schist contains several well-developed schistosities that mainly stand vertically, so that vertical joints are better developed than the horizontals in the area. Lugeon tests revealed that upper aquifer and bedrock are divided in the depth of 40-50m under the surface. Groundwater level was observed in twenty monitoring wells and interpolated in the whole area. Numerical study using Visual Modflow and Seep/W has been performed to evaluate the efficiency of drainage system for underground liquefied natural gas storage cavern in two hypothetically designed layouts and determine the design parameters. In Modflow analysis, groundwater flow change in an unconfined aquifer was simulated during excavation of cavern and operation of drainage system. In Seep/W analysis, amount of seepage and drainage was also estimated in a representative vertical section of each cavern. From the results, groundwater level drawdown and drainage rate during the operation of drainage system were calculated and the efficiency of drain holes in case of specified spacing of drain hole was well evaluated. The relationship between drawdown and drainage time will make it possible to determine the proper spacing of the drain hole. However, careful considerations are needed in case of 2D hydro-geologic model for selection of model section and assignment of boundary condition. The calculated drainage rate, which is also an important design parameter for the storage cavern, will make it possible to estimate the required capacity to pump out the drained water. The efficiency of the drainage system can be evaluated with numerical models when the proper conditions are used.