



Numerical study on criteria for design and operation of water curtain system in underground oil storage cavern using site descriptive fracture networks

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Underground unlined caverns have been constructed in fractured rocks to stockpile oil and petroleum products, where they are hydraulically contained by natural groundwater pressure. However, for the case that natural groundwater pressure is not maintained at the required level, water curtain boreholes, through which water is injected, are often constructed above the cavern as engineering barrier to secure water pressure enough to overwhelm the operational pressure of the cavern. For secure containment of oil and petroleum products inside the cavern, it is essential to keep water pressure around the cavern higher than operational pressure of the cavern using either natural groundwater pressure or engineering barrier. In the Republic of Korea, a number of underground stockpile bases are being operated by Korea National Oil Corporation (KNOC) and private companies, most of which have water curtain system. The criterion that KNOC adopts for water curtain system design and operation such as the vertical distance from the cavern and operational injection rate is based on the Åberg hypothesis that the vertical hydraulic gradient should be larger than one. The criterion has been used for maintaining oil storage cavern without its thorough review. In this study, systematic numerical works have been done for reviewing the Åberg criterion. As groundwater predominantly takes places through fractures in underground caverns, discrete fracture modeling approach is essential for this study. Fracture data, obtained from boreholes drilled at the stage of site investigation at the Yeosu stockpile base in Korea, were statistically analyzed in terms of orientation and intensity, which were used to generate the site descriptive three dimensional fracture networks. Then, groundwater flow modeling has been carried out for the fracture networks. Constant head boundaries were applied along the circumference of the cavern and water curtain boreholes. Main flow channel and hydraulic connectivity between water curtain boreholes and the caverns have been identified, along which hydraulic heads are monitored to find out whether the required hydraulic pressure is maintained around the cavern. The flow modeling has been repeatedly carried out at different constant head boundary conditions to create the criterion for the optimal operation of water curtain system.