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Determining Hydraulic Conductivity Tensor of Anisotropic Rock Mass in Cavern of Roudbar Dam, Lorestan, Iran

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Abstract: The importance and necessity of using underground spaces in the present era is not overlooked. Caverns are used as an important bunch of underground spaces for the storage of radioactive waste, hydrocarbons, and hydroelectric power plant projects. Construction of caverns has particular complexity and water seepage into the caverns is one of the most important problems. The purpose of the present study was to investigate the 3D modeling of the fracture network of a cavern for the pumped storage power plant of Rudbar Lorestan dam by using DFN method and 3DEC software and then determining the tensor of hydraulic conductivity by using the model. To achieve the goal, statistical analyses were performed on the in situ data extracted from the area. Power law distribution was determined as a suitable statistical distribution proportional to the data. Then, the DFN model was created and validated using the Watson-Williams test. In the following, a block model of DFN made from the fractures was constructed to determine the Representative Elementary Volume for different dimensions from 1 to 12 m. It was found that a 7-meter model was appropriate. Furthermore, the tensor of hydraulic conductivity was determined by using a hydraulic head on a generated REV.

Keywords: Hydraulic conductivity tensor, Anisotropic, Fractured rock mass, Cavern, DFN.

INTRODUCTION

In many projects, the hydrogeological models are unreliable. There are many reasons for this, some of which are: 1) Hydrogeological environments are anisotropic and heterogeneous, while this assumption is not applied due to the complexity and lack of adequate data. 2) Due to high drilling costs, limited numbers of boreholes are used in most studies concerning the estimation of hydraulic conductivity.

Hydraulic conductivity is an important parameter in the analysis of water flow in fractures [1]. Rock mass is considered isotropic on the permeability of the environment in different studies [2].

Caverns have been used for the storage of crude oil and other petroleum products. Yu et al. [2] used 4 drilled boreholes data in China for 3D modeling of the environments using 3DEC package. Zhou et al [3] determined the hydraulic conductivity using back analysis calculation and measurement of leakage to a cavern.

The aim of this study was to determine the tensor of hydraulic conductivity coefficients and investigate the rock fractures anisotropy using these coefficients in the study area. For this purpose, the concept of separated fracture network applying 3DEC software was used to calculate the amount of water leakage from rock mass. Also, in developing and verifying the separate fracture network model, various statistical distributions and the Watson-Williams test was used. Using the predicted leakage amount, the flow rate can be obtained. Finally, the velocity values achieved from the tensor of hydraulic conductivity was determined using the relationships between the components.

METHOD

The fracture network method was used to determine the hydraulic conductivity. For this purpose, the DFN block model was initially constructed using the characteristics of the surveyed fractures. The model was used to determine the size of the REV (Representative elementary volume). Then, using the pressure heads in the three directions of x, y and z, the constructed values of the tensor of hydraulic conductivity were obtained. Watson-Williams test and in-situ data were used to validate the model, .

RESULT

Hydraulic conductivity tensor calculated for the fractured rock mass of hydroelectric cavern of the Roudbar Dam was obtained as follows:

$$K = \begin{bmatrix} 18 & 5.4 & 7 \\ 6.3 & 12.3 & 6.35 \\ 8 & 7 & 9.5 \end{bmatrix} \quad (1)$$

In addition, the values of this tensor in m/s are given as follows:

$$K = \begin{bmatrix} 2.34E-6 & 7.02E-7 & 9.01E-7 \\ 8.19E-7 & 1.60E-6 & 8.26E-7 \\ 1.04E-6 & 9.01E-7 & 1.24E-6 \end{bmatrix} \quad (2)$$

Based on the results, the distribution of hydraulic conductivity coefficients in different directions of the study area is between 4.5 and 18 lugeons. In other words, the value of the hydraulic conductivity coefficients of yz plane in the x direction is more than three times the hydraulic conductivity of the yz plane in the y direction. If the hydraulic conductivity considered to be perpendicular to the coordinate planes, then the hydraulic conductivity perpendicular to the yz plane will be approximately twice the hydraulic conductivity perpendicular to the xy plane (Kxx = 2Kzz).

The tensor components of hydraulic conductivity coefficients in the main coordinate system are calculated as follows:

$$K = \begin{bmatrix} 27.2 & 0 & 0 \\ 0 & 9.0 & 0 \\ 0 & 0 & 3.6 \end{bmatrix} \quad (3)$$

The main components of the hydraulic conductivity coefficients tensor show that the maximum hydraulic conductivity coefficient at one point is 27.2 / 3.6 = 7.5 times the minimum hydraulic conductivity coefficient at the same point. This high ratio indicates the high error rate of leakage analysis in this region with the assumption of isotropic rock mass.

CONCLUSIONS

Hydraulic conductivity is one of the most important factors in determining the amount of leakage to underground spaces, which is influenced by the physical properties of fractured rock mass such as opening, roughness, joint length, and number of joints. The difference between values of hydraulic conductivity in isotropic and anisotropic conditions is considerable and cannot be ignored. The maximum value of the hydraulic conductivity coefficient is 7.5 times the minimum value in the situation when these values in the tensor are main values. It is important since in the case of isotropic assumption for fractured rock mass, the hydraulic conductivity can be assumed up to 7 times more than the actual value.

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