Modeling Spatial Distribution of 2D Anisotropic Hydraulic Conductivity Tensor of Fractured Groundwater Flow Media using Neural Network

Case Study Grasberg Open Pit of PTFI and Surrounding

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Abstract- Highly fractured rocks in Grasberg open pit and surrounding of PT Freeport Indonesia (PTFI) result in fractured groundwater flow media. It is due to the complex geological structure and lithological condition. Accordingly, it leads to anisotropic distribution of hydraulic conductivity. The paper will be devoted to the modeling of two dimensional (2D) spatial distribution of hydraulic conductivity using neural network. Surface fracture mapping database will be used to estimate 2D equivalent anisotropic hydraulic conductivity tensor based on the Oda et al (1996) approach. Modeled anisotropic hydraulic conductivity is then checked at some points where the slug tests for isotropic conductivity are observed. Co-relation, validation and training between modeled and observed hydraulic conductivity is then carried out using transformation of vector anisotropic hydraulic conductivity into the scalar isotropic hydraulic conductivity. Following training step, neural network will then generate two dimensional model of anisotropic hydraulic conductivity distribution. It is beneficial for modeling of shallow anisotropic flow of groundwater distribution.

Index Terms- hydraulic conductivity tensor, modeling two dimensional distribution, neural network (NN), Oda method

I. INTRODUCTION

PT Freeport Indonesia which is located in Mimika, West Papua Province, Indonesia is one of the largest mining company in Indonesia. One of the problem that happen in Grasberg is the present of groundwater that will affect slope stability and mud rush.

Hydraulic conductivity in fractured rock media is important to predict the flow direction of water. Every fracture has its own characteristic which are aperture, length, depth, orientation, (RQD), frequency and density of fracture. The characteristic above may result in anisotropic, vectorial as well as tensorial hydraulic conductivity.

II. METHOD

The absolute hydraulic conductivity will be calculated according to Oda et al (1996) in which flow media is modeled as a pair of parallel lines. This geometric description have characteristics as follow :

- Each line has a length l .
- Fracture aperture (e) is defined as a distance (opening) between the parallel lines and taken to be constant.
- The position of parallel lines is characterized by the coordinate of their end points in the planar media.

- The parallel lines have orientation in planar media corresponding to the normal vector of each line.

Hydraulic conductivity tensoric absolute can be expressed in numerical as follow

$$K_{ij} = \frac{1}{12XY} \sum_{k=1}^{k=m} l_k e_k^3 \cos(\theta_k) \sin(\theta_k) \quad (3)$$

Whereas :

m : sumation Index

K : tensoric absolute permeability

N : Number of fracture

l, e : length and aperture of fracture

X, Y : Normal in X and Y axes

θ : Orientation

To create surface model, neural network will be used to predict tensoric hydraulic conductivity. Neural network enables information processing is performed at different layers, dividing network nodes into three categories, input nodes, output nodes and hidden nodes. Input nodes do not perform calculations, while output and hidden nodes are computational nodes. The output node values are the final numerical outputs of the network.

III. DATA AND CALCULATION

3.1 Data Preparation

This paper uses secondary data that is obtained by Geotech and Geology Division PTFI, 2014 using scanline in Grasberg Open Pit mine site surface. Structure data consists of 51,040 points with aperture, length of fracture, coordinate, elevation and orientation as its properties. Also, this paper uses 13 drill holes in which hydraulic conductivity value is observed using slug test.

3.2 Anisotropic Hydraulic Conductivity Calculation

Correlation between K_{scalar} and K_{slugtest} also K_{xy} and K_{slugtest} is created in scatter plot to figure the connection between 2 data. Correlation in scatter plot shows that coefficient of correlation in this two data are 0.742 and 0.773 respectively which means the calculation using Oda method is accurately enough. Also, the correlation between K_{xy} and K_{slugtest} shows that the flow of ground water follows the path of major structure which is North East. Above is the scatter plot that shows coefficient of correlation.

Fig.1. Correlation between K_{sclar} and $K_{slugtest}$

Fig.2. Correlation between K_{sclar} and $K_{slugtest}$

3.3 Neural Network Process

Neural network structure is constructed from input data which consist of aperture, length of fracture, orientation, coordinate, and elevation. To optimize the result of neural network, number of results are selected. This selection process based on the cross-validation and mean squared error. Above is the result of layer optimisation

TABLE I
SUMMARY OF LAYER OPTIMISATION

Hydraulic Conductivity	MSE Value	Optimum Layer
kxx	1.73E-15	12
kyy	4.87E-15	11
kxy	1.76E-14	9

By using this optimisation in neural network, distribution of anisotropic hydraulic conductivity can be generated using aperture, length of fracture, orientation and Rock Quality Designation (RQD) as input data. Figure above shows hydraulic conductivity in K_{xx} , K_{yy} , and K_{xy} .

Fig 3. Distribution of hydraulic conductivity K_{xx}

Fig.4 Distribution of hydraulic conductivity K_{yy}

Fig.5. Distribution of hydraulic conductivity K_{xy}

IV. ANALYSIS AND DISCUSSION

4.1 Correlation of RQD and geological condition with Data

The blue color shows low RQD value, while the red color shows high RQD value. There is correlation between RQD and hydraulic conductivity value. From the figure shown above, area with low RQD value is concentrated in West, East and North East area. By this condition we can conclude that there is a correlation between RQD and hydraulic conductivity. The least RQD value will result in high hydraulic conductivity value.

Fig.6. RQD and geological Map

For the next part, From the geological map shown above we can conclude the reason why hydraulic conductivity value high in 'East, West, and North East Grasberg area. First, The East and North east area of Grasberg have high hydraulic conductivity due to Kali Formation and continuity from Grasberg Fault to North east from South west. Secondly, in West area the cross section of Grasberg Fault and Idenberg 1 fault create fractured area that result to high hydraulic conductivity value.

V. ACKNOWLEDGMENT

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VI. REFERENCES

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