ESTIMATION OF PERMEABILITY VALUE BASED ON ROCK QUALITY DESIGNATION

by Barlian Dwinagara

ESTIMATION OF PERMEABILITY VALUE BASED ON ROCK QUALITY DESIGNATION

Pawitra Wijaya[1,a)], Barlian Dwinagara[1,b)], Oktarian W. Lusantono[1,c)], Shofa Rijalul Haq[2,d)], Bagus Wiyono[1)].

[1]*Mining Engineering Department, Universitas Pembangunan Nasional Yogyakarta, Indonesia*
[2]*PT Studio Mineral Batubara, Indonesia*
[a)] *pawitra.rara@gmail.com*
[b)] *barliandn@upnyk.ac.id*
[c)]*oktarian.lusantono@upnyk.ac.id*
[d)]*shofa@mcsindonesia.co.id*

Abstract. The presence of groundwater flow in an underground mine is influenced by the aquifer fractures interconnected to rocks. Permeability testing method is commonly used to estimate the amount of groundwater. However, permeability tests, both in the laboratory and in-situ, are limited and expensive. Meanwhile, rock quality designation (RQD) which is a standard parameter for determining rock mass classification, can be measured rapidly. Therefore, the this study aims to obtain a mathematical permeability value approach with RQD. The RQD values were compared to the previously established mathematical permeability of Snow theory. Lithological samples (40 samples from 6 drill holes) were collected from PT Cibaliung Sumberdaya's underground mining concession, located in Pandeglang Regency, Banten Province, Indonesia. The results showed that the coefficient of determination (R2) for the overall lithology from the comparison between permeability and RQD was 0.42. Meanwhile, the R2 for Porphyritic Andesite (ANDS), Andesitic Flow (PAND), Vein Breccia (VNBR), Vein Crustiform - Colloform (VEIN), Vein Quartz Stocwork (FTVN), and Andesitic Breccia (BRAN) were 0.7046, 0.56, 0.845, 0.651, 0.7403, and 0.726, respectively. In conclusion, the permeability of mathematical calculations with RQD could not be used as a standard method because RQD does not include aperture discontinuity information, where the aperture is the main factor affecting rock mass permeability. Nevertheless, RQD measurement may provide preliminary permeability description.

Keywords: Underground Mine, Permeability, Fracture, Rock Quality Designation

INTRODUCTION

Highly fractured rocks at underground mine lead to fractured groundwater flow media. The presence of groundwater flow in an underground mine is influenced by the aquifer fractures interconnected to rocks. Permeability testing method is commonly used to estimate the amount of groundwater. However, permeability tests, both in the laboratory and in-situ, are limited and expensive. Meanwhile, rock quality designation (RQD) which is a standard parameter for determining rock mass classification, can be measured rapidly.

Based on the results of drilling activities in the underground mining concession of PT Cibaliung Sumberdaya, which is located in Pandeglang Regency, Banten Province, Indonesia, a lot of information can be explained for characterization of hydrogeological conditions. Therefore, using secondary permeability calculations (Snow, 1968), lithology samples (40 samples from 6 boreholes) were used to obtain approximate permeability values from comparisons with RQD.
The purpose of this study was to obtain a mathematical permeability value approach with RQD.

STUDY SITE

The data for this study were collected at the Cibaliung Mine. The concession lies in the center of the Neogene-aged Sunda-Banda magmatic arc. The host rock that carries the gold-silver ore is the Late Miocene Honje Volcanic rock that is penetrated by subvolcanic andesite-diorite in the form of a plug or dike and sometimes cut by diatreme breccia. Incompatible hitchhiking on these origin rocks in the form of dacitic tuff, young sediment, and basalt lava flows dating back to the Quaternary Miocene.
The oldest pre-mineralized (host) rocks are thick layers of basaltic to andesitic volcanic (ANDS), volcanic breccias (BRAN), polymict breccias (PLBX) and heterolithic milled matrix breccia or called monomict breccias (MNBX).
Tuff is generally several meters thick in the mine area, but can also be up to 30 m. A thin layer of unconsolidated colluvium / alluvium consisting of pre-mineral rock and vein material quartz is generally at the base of the tuff.
Rainfall at the research location is quite high, in the range of 2774 - 6003 mm / year.

HYDROGEOLOGICAL DATA COLLECTION

This research was conducted in 2017 in underground mining research data is limited to the cross sections of N4390, N4450, N4510 as shown in **FIGURE-1**. The lithology sample (40 samples from 6 boreholes in **TABLE-2**) was used to obtain the approximate permeability value from the comparison with RQD. Data from 6 drill holes has been analyzed in detail, so that it can be used to determine the relationship between hydrogeological, geological and geotechnical conditions.

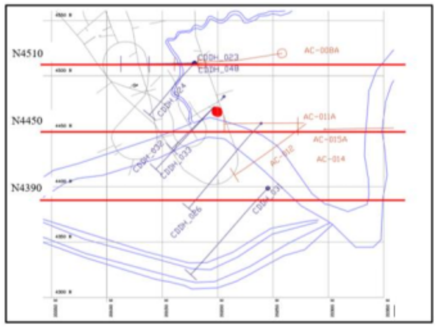

FIGURE 1. Cross section of the research area at PT.CSD Cibitung block.

The magnitude of the permeability value is influenced by several factors including lithological conditions, where the primary permeability is known that lithology with solid characteristics such as volcanic rock will have a very low primary permeability value because these rocks will tend to have almost no gaps between grains. Meanwhile, lithology such as sandstones will have a large primary permeability value because sandstones tend to have intense gaps between grains (Indrawan et al., 2014).

Experiments conducted by Darcy (1856) described ground flow and the notion of permeability, known as Darcy's law:

$$Q = -KA\frac{dh}{dl} \qquad \text{...(1)}$$

where Q is the amount of water flowing through a unit area A with a hydraulic gradient of dh / dl. The proportionality factor K is called the hydraulic conductivity which is expressed in units of length per time.

Discontinuous field conditions in the expanded rock mass, such as too large an opening, will cause groundwater flow to become turbulent in the rock mass so that Darcy's law can no longer be applied. To determine the permeability value, the equivalent permeability theory is used, as formulated in equations 2, 3 and 4.

Duncan and Christoper (2000) in their book writing the flow of water through fractures in rock has been studied in detail by Huitt (1956), Snow (1968), Louis (1969), Sharp (1970), Maini (1971) and others. Davis (1969) has also investigated the flow of water in fractures with the design of underground nuclear waste storage facilities, this work has provided a lot of additional information on fluid flow in fracture rock or fracture media. The hydraulic conductivity coefficient in the fracture plane or secondary permeability is given:

$$K \approx \frac{gd^3}{12\mu s} \qquad \text{..(2)}$$

Where,

g = acceleration due to gravity (9.81 m / s^2)

d = fracture (m)

s = fracture space (m)

μ = coefficient of kinematic viscosity at 20^0C

FIGURE-2. shows the equivalent of hydraulic conductivity in the fracture plane.

Iklima (2013), Indrawan (2014) applied Snow's (1968) research for delineation and analysis of groundwater potential in the underground mine of PT. Aneka Tambang, Pongkor, West Java. Secondary permeability (Ks) is the ability of rocks to flow rock through fracture media in rock or soil. Secondary permeability in fractures depends on the size of the fracture space and the opening (aperture). Secondary permeability is obtained from the equation (Snow, 1968). :

$$K_s = \frac{\gamma(2d)^3}{6\mu s} \qquad \text{……………………………………….(3)}$$

Where,
γ = Density of rock (N / m^3)
μ = fluid viscosity (Pa.s) or (N s / m^2) at suhu 20^0C
d = fracture (m)
s = fracture space (m)

Typical values for K for soil and rock (Priest, 1993) are listed in **TABLE-1**.

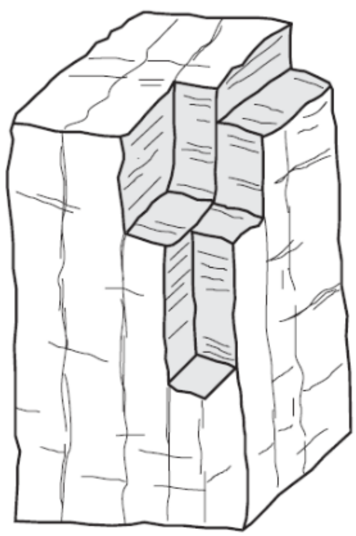

FIGURE 2. Rock mass with persistent vertical joints and relatively high vertical hydraulic conductivity (Modification from Atkinson (2000)).

TABLE 1. Typical permeability coefficients for soil and rock

K(ms^{-1})	Information
$>10^{-3}$	High, example : rough sand, gravel
10^{-3} to 10^{-5}	Medium, example : coarse sandstones, find sand, and laces
10^{-5} to 10^{-7}	Low, example : medium sandstones, limestone, muddy clay
10^{-7} to 10^{-9}	Very low, example : fine sandstones, limestone, clay
$<10^{-9}$	Impermeable, example : mostly igneous, rock material, and metamorphic

Secondary permeability data in this study were obtained from mathematical calculations using the Snow equation (1968). As in **TABLE-2**.

TABLE 2. Research Results between RQD and Secondary Permeability

Drillhole	Litologi	Cluster Elevation	Spation (m)	Aperture (m)	RQD	logK(s)
			m	m	%	
AC_008A	BRAN	P170	9.38	9.38	97	2.5
AC_008A	PAND	P120	15.05	16.55	98	1.9
AC_008A	PAND	P080	11.81	12.86	99	2.1
AC_008A	PAND	P060	48.16	49.66	100	1.0
AC_008A	BRAN	P010	13.65	15.15	97	2.0
AC_008A	VEIN	M010	1.40	1.40	93	4.2
AC_008A	BRAN	M010	4.26	3.70	96	3.4
AC_008A	FTVN	M030	1.45	1.45	100	4.1
AC_008A	VNBR	M050	0.50	1.93	97	3.3
AC_008A	VNBR	M050	1.28	1.28	82	4.2
AC_008A	VEIN	M050	1.15	1.15	88	4.3
AC_011A	BRAN	M010	10.05	11.55	99	2.3
AC_011A	ANDS	M020	0.53	0.53	94	5.0
AC_011A	VNBR	M020	0.90	0.90	58	4.6
AC_011A	FTVN	M020	2.00	2.00	95	3.8
AC_011A	VEIN	M030	1.05	1.05	90	4.4
AC_011A	ANDS	M050	6.85	7.42	98	2.7
AC_012	ANDS	P160	9.85	9.70	99	2.5
AC_012	ANDS	P030	12.60	12.70	100	2.3
AC_012	VEIN	M030	1.70	1.70	100	4.0
AC_012	VNBR	M100	2.85	2.85	100	3.6
AC_014	BRAN	P160	1.20	5.40	100	2.3
AC_014	ANDS	P130	7.66	7.67	100	2.7
AC_014	PAND	P110	28.51	30.11	100	1.4
AC_014	BRAN	P070	36.14	35.81	99	1.3
AC_015A	ANDS	P110	1.45	1.45	98	4.2
AC_015A	PAND	P100	1.80	3.30	83	3.1
AC_015A	BRAN	M020	3.50	0.50	93	5.9
AC_015A	PAND	M030	52.10	45.27	99	1.2
AC_015A	ANDS	M090	3.30	3.30	99	3.4
AC_015A	ANDS	M120	2.50	2.50	97	3.7
AC_015A	VNBR	M130	1.05	2.25	93	3.4
AC_015A	PAND	M130	5.45	5.45	88	2.9
AC_015A	VNBR	M130	2.40	2.65	92	3.6
AC_015A	FTVN	M140	0.65	0.65	81	4.8
AC_015A	PAND	M150	15.45	11.75	100	2.4
CDDH_032	ANDS	P150	13.50	13.55	100	2.2
CDDH_032	VEIN	P100	4.00	4.00	100	3.3
CDDH_032	VNBR	P100	3.05	3.05	100	3.5
CDDH_032	PAND	P070	34.60	34.60	100	1.3

RESULT AND DISCUSSION

Researchers have linked the rock mass permeability measured from the pecker test to the rock mass quality index such as rock quality determination (RQD) by El-Naqa (2001), Jiang et al. (2009) and rock mass classification (RMR) by El-Naqa (2001).

$$\text{logK} = 2.300 - 0{,}0157\text{RQD},\ r^2 = 0{,}64 \quad \text{..........................(4)}$$

Where,
Log K = permeability coefficient (cm / day)
RQD = Rock Quality Designation
r^2 = coefficient of determination
The permeability coefficient shows a progressive decrease with increasing RQD.
Research at another site consisting of monzonite granite, monzonite quartz, and syenite quartz in the East Shandong Province, China showed a similar relationship with Equation (6) between the K field rock mass permeability coefficient and RQD but the determination coefficient is different.

$$\text{logK} = 1.689 - 0{,}0236\text{RQD},\ r^2 = 0{,}78 \quad \text{..........................(5)}$$

Where,
Log K = permeability coefficient (cm / day)
RQD = Rock Quality Designation
r^2 = coefficient of determination

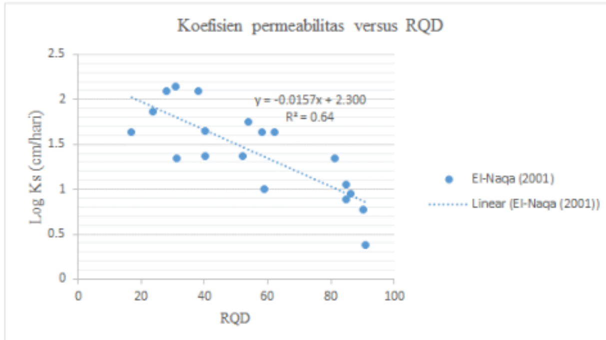

FIGURE 3. Measured permeability coefficient versus RQD for sandstone rock masses in central Jordan, El-Naqa (2001).

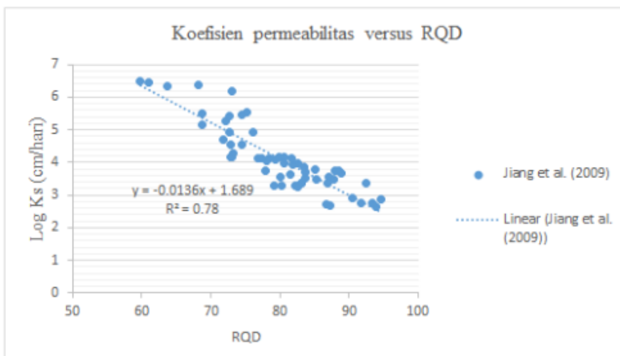

FIGURE 4. Secondary permeability coefficient versus RQD, Jiang et al. (2009)

In this study, RQD is associated with permeability from mathematical calculations with Snow's (1968) equation. As in **FIGURE-5**. shows that the coefficient of determination in overall lithology (CSD, 2017) is small, namely 0.42, this does not indicate a relationship between the two, in contrast to the research of El-Naqa (2001) and Jiung et al. (2009) [5].

FIGURE-6. shows that the coefficient of determination in each lithology (CSD, 2017) is above 0.6. This is different from the RQD relationship in the whole lithology because the RQD for rock mass does not exist and the use of RQD cannot be separated from detailed geological observations. And the RQD does not include information on aparture discontinuity, because aparture is the main factor affecting rock permeability.

Where the equations obtained in each lithology are found in:

1. Equation 6 for ANDS lithology, where the coefficient of determination generated from this graph is 0.7046, this indicates a strong relationship between secondary permeability and RQD. RQD in ANDS lithology is excellent and permeability value according to Priest (1993) in the medium to high range

$$\log K = 46.898 - 0{,}4447\text{RQD},\ r^2 = 0{,}7046 \quad \text{.......................(6)}$$

2. Equation 7 for PAND lithology, where the coefficient of determination generated from this graph is 0.656. RQD on PAND lithology ranges from good to excellent and permeability values according to Priest (1993) in the medium to high range.

$$\log K = 11.499 - 0{,}0993\text{RQD},\ r^2 = 0{,}656 \quad \text{.........................(7)}$$

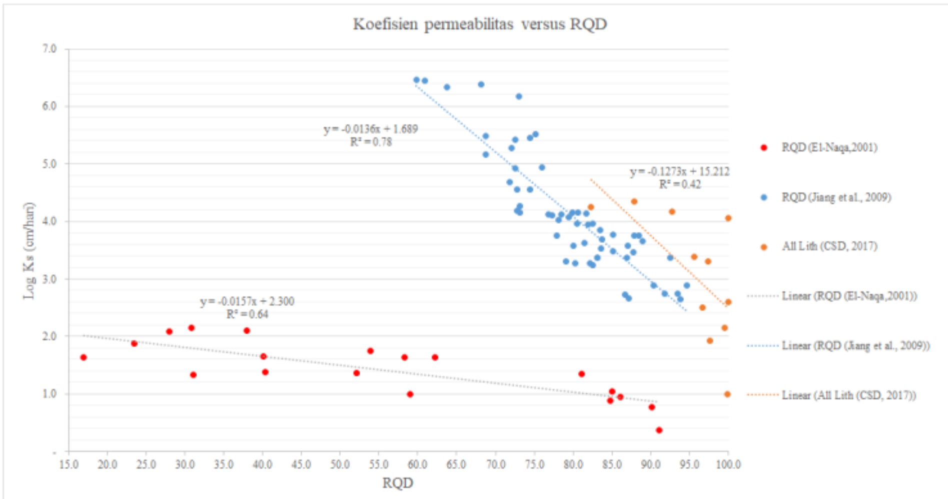

FIGURE 5. Secondary permeability coefficient versus RQD overall lithology.

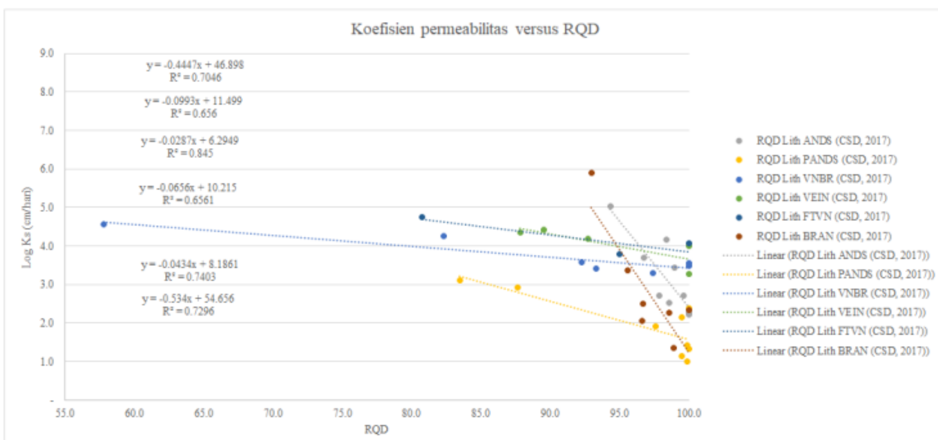

FIGURE 6. Secondary permeability coefficient versus RQD of each lithology

3. Equation 8 for VNBR lithology, where the coefficient of determination generated from this graph is 0.845, this indicates a strong relationship between secondary permeability and RQD. RQD in VNBR lithology ranges from very poor to excellent and the permeability value according to Priest (1993) is medium.

$$\log K = 6.2949 - 0{,}0287\text{RQD},\ r^2 = 0{,}845 \quad \text{.........................(8)}$$

4. Equation 9 for VEIN lithology, where the coefficient of determination generated from this graph is 0.6561. RQD on VEIN lithology ranges from good to excellent and the permeability value according to Priest (1993) is medium.
$$\log K = 10.215 - 0{,}0656\text{RQD},\ r^2 = 0{,}6561 \quad \text{.......................(9)}$$
5. Equation 10 for FTVN lithology, where the coefficient of determination generated from this graph is 0.7403. RQD on FTVN lithology ranges from good to excellent and the permeability value according to Priest (1993) is medium.
$$\log K = 81861 - 0{,}0434\text{RQD},\ r^2 = 0{,}7403 \quad \text{........................(10)}$$
6. Equation 11 for BRAN lithology, where the coefficient of determination generated from this graph is 0.726. RQD in BRAN lithology is excellent and the permeability value according to Priest (1993) ranges from low to high.
$$\log K = 54.656 - 0{,}534\text{RQD},\ r^2 = 0{,}726 \quad \text{............................(11)}$$

This shows that the secondary permeability calculated by the Snow equation (1968) does not have a strong relationship to the RQD in the overall lithology, this is indicated by the coefficient of determination of both regression analysis is 0.42. Because the RQD for rock mass does not exist and the use of RQD cannot be separated from detailed geological observations. And the RQD does not include information on aparture discontinuity, because aparture is the main factor affecting rock permeability. This is evidenced by the relationship between the two in each lithology where the analysis results of the coefficient of determination are greater than 0.6. Namely 0.7046 for ANDS, 0.656 for PAND, 0.845 for VNBR, 0.6561 for VEIN, 0.7403 for FTVN and 0.726 for BRAN.

CONCLUSIONS

Secondary permeability calculated by the Snow equation (1968) does not have a strong relationship to RQD in the overall lithology, this is indicated by the coefficient of determination of both regression analysis is 0.42. Because the RQD for rock mass does not exist and the use of RQD cannot be separated from detailed geological observations. And in the RQD does not include information on aparture discontinuity, because aparture is the main factor affecting rock permeability. This is evidenced by the relationship between the two in each lithology where the analysis results of the coefficient of determination are greater than 0.6. Namely 0.7046 for ANDS, 0.656 for PAND, 0.845 for VNBR, 0.6561 for VEIN, 0.7403 for FTVN and 0.726 for BRAN.
Mathematical permeability calculations with RQD cannot be used as a standard method because RQD does not include aperture discontinuity information, where aperture is the main factor affecting rock mass permeability. However, the measurement of RQD can provide an overview of the initial permeability

ACKNOWLEDGMENTS

The author also thanks PT. Cibaliung Resources for permits, research and data provision.

REFERENCES

[1] A. El-Naqa, "Application of RMR and Q geomechanical classification systems along the proposed Mujib Tunnel route, central Jordan," Bulletin of Engineering Geology and the Environment, vol. 60, pp. 257-269, 2001.

[2] B. Z.T, Engineering rock mass classifications: a complete manual for engineers and geologist in mining, civil, and petroleum engineering, New York: John Wiley & Sons, 1989

[3] Iklima N. N. w. P. H. H. w W. D. A. w. P. Y., "Analisis Potensi Aliran Airtanah berdasarkan Deliniasi Nilai Permeabilitas Sekunder, Pada Tambang Bawah Permukaan, Ciurug Central L.500, Unit Bisnis Pertambangan Emas, PT. Aneka Tambang, Tbk., Pongkor, Kabupaten Bogor, Jawa Barat", Geological Engineering E-Jornal, Universitas Diponegoro Vol-5, No-2, 2013.

[3] L.-S. Xiao-WeiJiang, "Estimation of rock mass deformation modulus using variations in transmissivity and RQD with depth," International Journal of Rock Mechanics & Mining Sciences, vol. 46, pp. 1370-1377, 2009

[4] P. H. H. w. P. Y. Indrawan D., "Deliniasi sebaran nilai permeabilitas sekunder untuk memperkirakan potensi aliran airtanah pada tambang bawah tanah kubang cicau PT. Aneka Tambang tbk, Lokasi Ramp Down, Pongkor Kabupaten Bogor, Jawa Barat," Geological Engineering E-Journal Universitas Diponegoro, vol. 6, no. 1, 2014.

[5] S. D. Priest, Discontinuity Analysis for Rock Engineering, Berlin: Springer Science & Business Media, 1993.

[6] T. Snow, Rock Mass Strenght, Luleå, Swedia: Departement of Civil Engineering Division of Rock Mechanics, 1968

ESTIMATION OF PERMEABILITY VALUE BASED ON ROCK QUALITY DESIGNATION

ORIGINALITY REPORT

0%	%	%	0%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

Exclude quotes	On	Exclude matches	< 2%
Exclude bibliography	On		