

ANALYSIS OF ROCK MASS CLASSIFICATION ON MINE SLOPES USING THE ROCK MASS RATING (RMR) METHOD

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Abstract

Indonesia possesses substantial mineral and coal resources due to its geological conditions. However, these resources must be used sustainably, as they are non-renewable. In addition, mining activities are required to ensure occupational safety, particularly in open-pit mining operations where activities are highly influenced by the presence of mine slopes (pit slopes). Slope stability is therefore a critical aspect, given the numerous slope failure incidents reported globally resulting from inadequate planning that fails to account for geotechnical conditions comprehensively. "This research aims to analyze open-pit mine slope conditions in Tanjung Enim, South Sumatra, using the Rock Mass Rating (RMR) classification method to determine the rock mass class. The research employs both qualitative and quantitative approaches, with systematic data analysis based on the RMR method. The research stages include a literature review, field surveys, data acquisition, data processing, and data analysis. Primary data consist of scanline measurements, discontinuity conditions, and groundwater conditions, while secondary data include the rock's Uniaxial Compressive Strength (UCS) values. The analysis results indicate an average uniaxial compressive strength (UCS) of 1.54 MPa, a Rock Quality Designation (RQD) value of 97.91%, an average joint spacing of 0.45 m, and discontinuity surfaces that are rough with apertures of less than 1 mm and slightly weathered joint walls, as well as groundwater conditions classified as damp. Based on the weighting of all these parameters, a Rock Mass Rating (RMR) value of 66 was obtained, which falls into Class II, corresponding to a good rock mass category. These results indicate that the rock mass quality of the mine slope at the study site is in relatively good condition according to the RMR classification.

Keywords: Geotechnics, slope stability, mine slope, rock mass, Rock Mass Rating (RMR)

1. Introduction

Indonesia, based on its geological conditions, has abundant mineral and coal resources and reserves. The balance between the utilization of mineral and coal resources and their reserves must be maintained by mining industry stakeholders, as mineral commodities are non-renewable (Gobel & Rikumahu, 2016).

Not only that, companies operating in the mining sector must create a safe working environment for both workers and mining equipment (Aprilia et al., 2024). The working environment in open-pit mining is closely associated with mine slopes (pit slopes), which are the primary zones of activity, where slope stability is a critical factor that must be carefully considered (Irianto & Afasedanya, n.d.)

Slope failures in mining operations have been widely reported in global mining accident records

and case studies, indicating the high risk when slope design is not carefully carried out with proper consideration of geotechnical conditions. The complexity of slope stability is further increased by geological heterogeneity, variations in the mechanical properties of soil and rock, and the influence of groundwater on pore pressure (Abdillah et al., 2017).

The objective of this study is to analyze the mine slope using the Rock Mass Rating (RMR) classification method. The Rock Mass Rating (RMR) classification is applicable for determining rock mass classes on open-pit mine slopes in Tanjung Enim, South Sumatra. (Pangaribuan & Retongga, 2022).

2. Literature Review

2.1 Rock Mass Rating (RMR) Rock Mass Classification

The Rock Mass Rating (RMR) rock mass classification system is determined by summing several rating parameters to obtain a total RMR value.

Uniaxial Compressive Strength (UCS)

Rock strength describes the ability of a rock to withstand applied stress. In the RMR system, the strength of intact rock is expressed by the Point Load Index or the Uniaxial Compressive Strength (UCS). The UCS value represents the strength of intact rock obtained from uniaxial compressive strength testing. According to Deere and Miller (1996), as cited in Syam et al. (2018), the UCS value can also be estimated from the Joint Compressive Strength (JCS), which is determined through Schmidt Rebound Hammer plotting results.

Rock Quality Designation (RQD)

Rock Quality Designation (RQD) can be calculated using two methods, direct and indirect approaches. The direct calculation is based on observations of recovered drill core, in which core pieces shorter than 10 cm are excluded, and the percentage of core length meeting this criterion is then calculated relative to the total drilled length.

One parameter that reflects the quality of a rock mass before excavation is the Rock Quality Designation (RQD), introduced by Deere (1964) and cited in Syam et al. (2018). RQD data are obtained from exploration drilling activities in the form of cylindrical drill cores that represent the condition of the rock mass.

The direct RQD calculation is performed by determining the percentage of core length that has a minimum size of 10 cm. The number of core pieces is generally measured at 2-meter core

intervals. Furthermore, RQD can be determined

Joint Spacing

Joint spacing is defined as the distance between two adjacent discontinuity planes on a single scanline. This spacing is measured along each scanline, as shown in Figure 1.

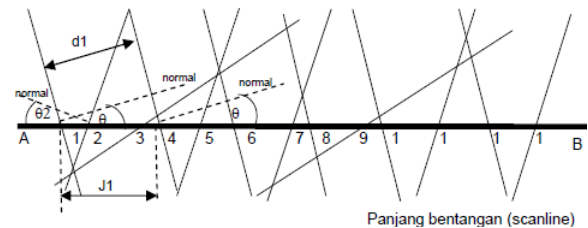


Figure 1. Measurement of joint distance on scanline

(Source: Wulandari, et al., 2016)

The RMR ranges of values are presented in Table 1.

Joint Condition

Several parameters, including persistence, surface roughness, the presence of infilling material, degree of weathering, and aperture width, determine joint conditions.

1. Roughness

According to the ISRM (2006), the surface roughness condition of joint planes is described as follows:

- Very rough, when the steps formed on the joint surface are nearly vertical
- Rough, when the roughness is clearly visible and feels abrasive to the touch.

Table 1. Rock Mass Rating Range of Values

Parameter		Ranges of Values							
1	Strength of intact rock material	Point-load strength index (MPa)	>10	4-10	2-4	1-2	For this low range, uniaxial compressive test is preferred		
		Uniaxial compressive strength (MPa)	>250	100-250	50-100	25-50	5-25	1-5	<1
		Rating	15	12	7	4	2	1	0
2	Drill core quality RQD (%)		90-100	75-90	50-75	25-50	<25		
		Rating	20	17	13	8	3		
3	Spacing of discontinuities		>2 m	0.6-2 m	200-600 mm	60-200 mm	<60 mm		
		Rating	20	15	10	8	5		
4	Condition of discontinuities		Very rough surfaces Not continuous No separation Unweathered wall rock	Slightly rough surfaces Separation < 1 mm Slightly weathered walls	Slightly rough surfaces Separation < 1 mm Highly weathered wall	Slickensided surfaces or Gouge < 5 mm thick or Separation 1-5 mm Continuous	Soft gouge > 5 mm thick or Separation > 5 mm Continuous		
		Rating	30	25	20	10	0		
5	Groundwater	Inflow per 10 m tunnel length (L/min)	None	<10	10-25	25-125	>125		
		Ratio $\frac{\text{Joint water pressure}}{\text{Major principal stress}}$	0	<0.1	0.1-0.2	0.2-0.5	>0.5		
	General conditions		Completely dry	Damp	Wet	Dripping	Flowing		
		Rating	15	10	7	4	0		

- c. Slightly rough, when the surface roughness of the joint plane can only be clearly recognized by touch.
- d. Smooth, when the fracture surface is smooth and feels smooth to the touch.
- e. Slickensided, when the fracture surface appears polished or gently undulating.

2. Separation/Aperture between Joint Surfaces

The separation or aperture between joint surfaces represents the width of the gap along a joint or fracture plane, which is commonly filled with other materials (infilling) or water. Field measurements of joint separation can be used to describe joint aperture conditions, ranging from tightly closed joints to widely open fractures.

3. Infilling Material

According to Bieniawski (1989), infilling material is the material that fills the space between joint surfaces and commonly consists of sand, calcite, clay, silt, breccia, quartz, and pyrite. This infilling material influences the shear strength of joint planes. The infilling has two influential aspects, namely:

- a. Thickness-dependent effect, where the infilling material inhibits interlocking due to the hardness of the joint surfaces.
- b. Intrinsic properties of the infilling material, including shear strength, permeability, and deformation behavior. The characteristics to be identified include the type, thickness, continuity, and interrelationships of the infilling material.

4. Degree of Weathering

According to Bieniawski (1989), the degree of

weathering on rock walls or discontinuity surfaces developed within the rock mass can be classified into several categories, namely:

- a. Unweathered (fresh), characterized by the absence of weathering indicators; the rock remains fresh with clearly visible crystals.
- b. Slightly weathered, characterized by staining or discoloration along discontinuity surfaces, which may be filled with a thin layer of alteration material. These changes may extend from the discontinuity surfaces into the rock mass to approximately 20% of the spacing between discontinuities.
- c. Moderately weathered, in which discoloration extends over more than 20% of the spacing between discontinuities. Discontinuity surfaces may be filled with mineral alteration products, and grain boundaries may begin to open.
- d. Highly weathered, characterized by the extension of weathering into the rock mass accompanied by the formation of friable rock zones. Although the original rock texture can still be recognized, grain separation has occurred.
- e. Completely weathered, a condition in which the rock has undergone thorough decomposition and is in a very friable state.

5. Joint Persistence

Persistence refers to the length of continuity of a discontinuity within the rock mass that can be measured directly. The determination of persistence is carried out through observation and measurement of the length of joint planes within the rock mass (Irwandy, 2006).

Groundwater Condition

Groundwater conditions indicate that water can reduce the shear strength between two discontinuity surfaces. The weighting of the groundwater parameter can be determined through several approaches, including direct field observations and assessment of the general groundwater conditions.

In applying the classification system, the rock mass is divided into several structural zones, bounded by faults. Each structural zone generally has similar rock types or discontinuity characteristics; therefore, each zone is classified and analyzed separately (Hoek, 2007)

The RMR classification table consists of five main parameters. Since each parameter has a different level of influence on the overall rock mass assessment, each is assigned a specific rating range based on its relative importance. Higher ratings indicate better rock mass conditions, as presented in Table 2 (Bieniawski, 1989).

Table 2. Rock Mass Rating (RMR) Analysis Results (Bieniawski, 1989)

Class	I	II	III	IV	V
Rock Mass Rating Range	81 – 100	61 - 80	41 - 60	21 - 40	<21
Desc.	Very Good	Good	Fair	Poor	Very Poor

3. Research Methodology

This study employs both qualitative and quantitative approaches, in which data are expressed numerically and analyzed systematically. The data analysis is conducted using the Rock Mass Rating (RMR) classification method (Hoek, 2007). The research stages include a literature review, field surveys, data collection, data processing, and data analysis. The data used in this study are primary data collected through direct field observations. The data collected directly include:

1. Scanline Measurement

Scanline measurements were conducted at a height approximately equal to eye level from the bench floor, using a 5-meter scanline drawn along the study slope. The data obtained from this measurement include joint spacing (m), joint strike and dip values, and the slope's strike and dip directions. In its implementation, the measurements utilized the following equipment:

- Geological compass
- Measuring tape
- Clipboard

2. Discontinuity Surface Conditions

The conditions of discontinuity surfaces were directly observed on the study slope to determine joint spacing (separation between joint surfaces), surface roughness, infilling material, degree of weathering, and joint persistence. These

measurements were conducted along the entire scanline on the slope.

3. Groundwater Conditions

Groundwater conditions were determined through direct field observations on the study slope, with reference to the general groundwater rating criteria in the Rock Mass Rating (RMR) classification.

In addition to primary data, secondary data were also used in the form of Uniaxial Compressive Strength (UCS) data. These data were subsequently processed by assigning ratings to each parameter:

Rock Mass Rating

The RMR rating classification according to Bieniawski (1989) consists of several parameters, namely rock strength testing (Point Load Strength Index [PLI] / Uniaxial Compressive Strength [UCS]), Rock Quality Designation (RQD), joint spacing, discontinuity surface conditions, and groundwater conditions, which are determined as follows:

1. Data were collected based on the Rock Mass Rating (RMR) classification parameters, where the intact rock strength values were obtained through laboratory testing using the Uniaxial Compressive Strength (UCS) test.

2. The Rock Quality Designation (RQD) value can be calculated from scanline measurement data using the following equation:

$$RQD = 100e^{-0.1\lambda} (0.1\lambda + 1) \quad (1)$$

where λ is the average number of joints per meter (Priest, 1989).

In addition, RQD can also be calculated from drill core data using the following equation:

$$RQD = \frac{\text{Jumlah bor panjang} \geq 10 \text{ cm}}{\text{Total Panjang Bor Inti}} \times 100\% \quad (2)$$

3. Data on discontinuity density and orientation, including strike, dip, and joint spacing, were collected directly in the field using the scanline method.

4. The discontinuity frequency was calculated using the following equation:

$$\text{Frekuensi } (\lambda) = \frac{\sum \text{Diskontinuitas}}{\text{Panjang Scanline}} \quad (3)$$

5. Joint spacing was calculated using the following equation:

$$\text{Joint Spacing} = \frac{\text{Panjang Scanline}}{\sum \text{Diskontinuitas}} \quad (4)$$

6. Groundwater conditions at the slope research location were directly observed in general accordance with Bieniawski (1989).

7. The Rock Mass Rating (RMR) value was determined based on standard rating tables and calculated using the following equation:

$$RMR = UCS + RQD + \text{Jarak Kekar} + \text{Kondisi Kekar} + \text{Kondisi umum air Tanah} \quad (5)$$

4. Results and Discussion

Uniaxial Compressive Strength (UCS)/Rock Compressive Strength

The Uniaxial Compressive Strength (UCS) parameter values constitute secondary data for each rock layer on the slope. The UCS data for each layer are presented in Table 3.

Table 3. UCS Data for each Rock Layer on the Slope

Rock Layer	UCS	
	Qu (Kpa)	E (Kpa)
Overburden	1031,52	1005,64
Seam A1	6199,99	4609,26
Interburden (IB) A1-A2	1038,37	536,98
Seam A2	9405,46	6990,7
Interburden (IB) A2-B1	1771,55	1411,79
Seam B1	3235,14	4205,72
Interburden (IB) B2-C	859,18	960,67
Seam C	2593,85	4873,99
Under C	1545,85	1737,68

Laboratory testing was conducted on all rock layers, including overburden (OB) A1, seam A1, interburden (IB) A1–A2, seam A2, interburden (IB) A2–B1, seam B1, interburden (IB) B1–B2, seam B2, interburden (IB) B2–C, seam C, and under C. Test results from each drilling sample were subsequently grouped and statistically analyzed by layer, yielding maximum, minimum, mean, and standard deviation values in accordance with the layer nomenclature used in the company data.

The rock compressive strength values were obtained from multiple borehole locations within the study area, with an average uniaxial compressive strength (qu) of 1,545.85 kPa, which was then converted to 1.545 MPa.

Rock Quality Designation (RQD)

The Rock Quality Designation (RQD) value was calculated directly in the field using Equation (3). The data processed in the equation consisted of joint data and scanline length at the study site. The RQD value obtained from this study is 97.91%.

Joint Spacing

Joint spacing measurements were carried out directly at the study site by measuring the perpendicular distance between two joint planes intersecting the scanline. The average joint spacing obtained was 0.45 m.

Joint Condition

Discontinuity or joint surface conditions exhibit several characteristics used in assessing joint conditions, including persistence, roughness, infilling, degree of weathering, and aperture. In this study, the joint conditions were classified as rough with apertures less than 1 mm and slightly weathered joint walls, according to Bieniawski's (1989) classification.

Groundwater Condition

Groundwater condition data were obtained through direct observation of the general conditions on the jointed slope at the study site. The groundwater conditions of the slope were classified as damp.

Rock Mass Rating

Table 4. Results of Parameter Weighting for the Rock Mass Rating (RMR) Classification of the Slope at the Study Site

Parameter	Value	Rating
Uniaxial Compressive Strength (UCS).	1,54	1
Rock Quality Designation (RQD)	97,91	20
Joint Spacing	0,45	10
Joint Condition	Rough, aperture <1 mm, slightly weathered joint walls	25
Groundwater Condition	Damp	10
Total Rating		66

Based on Table 4, the Rock Mass Rating (RMR) score of 66 indicates that the rock mass falls into the good category. The RMR classification method is used to determine the rock mass rating for assessing slope quality without considering other stability-related parameters such as slope geometry, seismic factors, and others.

Furthermore, the classification description is determined as presented in Table 13. The total rating value falls within Class II, corresponding to good rock mass, in accordance with the classification proposed by Bieniawski (1989).

Table 5. Description of the Rock Mass Rating (RMR) Classification for the Slope at the Study Site

Class	I	II	III	IV	V
Rock Mass Rating Range	81 - 100	61 - 80	41 - 60	21 - 40	<21
Desc.	Very Good	Good	Fair	Poor	Very Poor

8. Conclusion

The Rock Mass Rating (RMR) analysis of the open-pit mine slopes in Tanjung Enim, South Sumatra yielded a rating value of 66, classified as Class II, indicating a good rock mass quality. The results indicate that the rock mass quality of the open-pit mine slopes in Tanjung Enim, South Sumatra is relatively good when evaluated based on the RMR parameters.

References

- Abdillah, R. A., P, M. S., & W, D. D. (2017). *Analisa Stabilitas Pada Lereng Tambang*. 6(2), 281–283.
- Aprilia, R., Fidayanti, N., & Putrawiyanta, I. P. (2024). *Analisis Keselamatan Kerja Pada Kegiatan Penambangan Batubara Menggunakan Metode Hiradc Pada PT. Mega Multi Energi Desa Sikui Kecamatan Teweh Baru Kabupaten Barito Utara Provinsi Kalimantan Tengah*. 4, 5538–5556.
- Bieniawski, Z. T. 1989. *Engineering Rock Mass Classifications*. New York, Wiley: A Wiley Interscience Publication.
- Gobel, A. P., & Rikumahu, M. V. (2016). *Neraca Sumberdaya dan Cadangan Mineral di Provinsi Jawa Tengah Dalam Rangka Peningkatan Penerimaan Pajak dan Investasi*.
- Hoek, E. 2007. *Practical Rock Engineering*. North Vancouver, British Columbia: 102-3200 Capilano Creseent.
- Hudson, J. A., dan Harrison, J. P. 2005. *Engineering Rock Mechanics an Introduction to The Principles*. London: Pergamon.
- Irianto, & Afasedanya, M. M. T. (n.d.). *MENGGUNAKAN METODE LIMIT EQUILIBRIUM DAN STABILITY OF OPEN MINE SLOPE USING THE LIMIT EQUILIBRIUM METHOD AND RISK ANALYSIS TO SUPPORT MINING*. Golongan C.
- Irwandy. 2006. *Geoteknik Tambang, Mewujudkan Produksi Tambang yang Berkelanjutan dengan Menjaga Kestabilan Lereng*. Jakarta: Gramedia pustaka Utama.
- ISRM. 2006. Rock Mass Characterization and Rock Mass Property Variability Considerations For Tunnel and Cavern Design. *Int. Rock Mechanics in Underground Construction*. pp. 207, 207.
- Pangaribuan, M. P., & Retongga, N. (2022). *Analisis Kestabilan Lereng Menggunakan Metode Rock Mass Rating (RMR) dan Slope Mass Rating (SMR) untuk Menentukan Faktor Keamanan Lereng Pada Tambang Tuf Desa Candirejo , Kecamatan Semin , Kabupaten Gunungkidul , 5(November)*.
- Priest, S. D. 1993. *Discontinuity Analysis for Rock Engineering*. Australia: Springer Science Business Media, B. V.
- Syam, M. A., Heryanto, dan Trides, T. 2018. Analisis Kestabilan Lereng berdasarkan Nilai Slope Mass Rating di Desa Sukamaju, Tenggara Seberang, Kutai Kartanegara, Kalimantan Timur. *Jurnal Geoelebes Vol. 2 No. 2, Oktober 2018, 53-63*, 55.
- Wulandari, A., Devy, S. D., dan Umar, H. 2016. Analisis Kesatbilan Lereng dengan Menggunakan Metode Rock Mass Rating dan Slope Mass Rating pada Tambang Terbuka Batupasir di Samarinda, Provinsi Kalimantan Timur. *Jurnal Teknologi Mineral FT UNMUL, Vol. 4, No. 1, Desember 2016 :8-14*, 9.