RMR and SMR as Slope Stability Preliminary Studies of Rajamandala Limestone Mine Area

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Abstract

Rajamandala Limestone in Padalarang area in Indonesia has a long history of mining and exploitation. Most Rajamandala Limestone mining is performed in open-pit. Slope stability is often a major issue in an open-pit mine. The stability of the open-pit mine slope must be maintained so as not to disrupt the mining process. Rock Mass Rating (RMR) has been widely used as a method of classifying the strength of the rock mass. RMR values in this study derived from observations of the rock mass characteristics directly in Padalarang area at three different mine sites and testing of the materials of intact samples in the laboratory. RMR values are then correlated into Slope Mass Rating (SMR) which is a system of classification of a rock slope. The study showed that the Rajamandala Limestone Mine area has RMR values of 66-71 and included in the class II or Good Rock and SMR ranged between 61° - 72° and belong to Good Slope class.

Keyword: Rajamandala Limestone, Open Pit Mining, RMR, SMR

1. Introduction

Rajamandala Limestone in Padalarang area in Indonesia has a long history of mining and exploitation. Most Rajamandala Limestone mining is performed in open-pit. Slope stability is often a major issue in an open-pit mine. The stability of the open-pit mine slope must be maintained so as not to disrupt the mining process. This paper aimed to perform how to correlate rock mass observations data from field to RMR and SMR and use it as mining slope stability preliminary studies.

2. RMR and SMR

The RMR (Rock Mass Classification) was developed By Bieniawski during 1972 - 1973 (Bieniawski, 1973). It was modified over the years as more case histories became available and to conform with international standards and procedures (Bieniawski, 1979). Due to the RMR system having been modified several times, and since the method is interchangeably known as the Geomechanics Classification or the Rock Mass Rating system, it is important to state that the system has remained essentially the same in principle

despite the changes (Bieniawski, 1989). The following discussion is based upon the 1989 version of the classification (Bieniawski, 1989). The following six parameters are used to classify a rock mass using the RMR system :

1. Uniaxial compressive strength of rock material.
2. Rock Quality Designation (RQD).
3. Spacing of discontinuities
4. Conditions of discontinuities
5. Groundwater conditions
6. Orientation of discontinuities

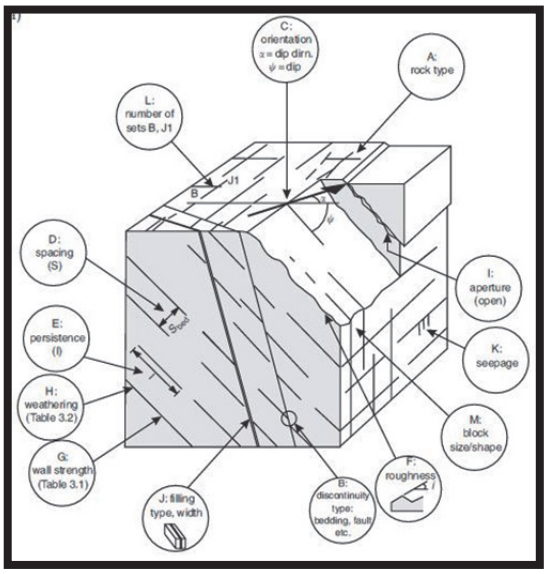

Fig 1. Sample of a rock mass with discontinuities (Hoek and Bray, 1981, in Wyllie 2005)

The RMR system is presented in Table 2. Each of six parameters is assigned a rating corresponding to the characteristic of the rock. These ratings are summed to give a value of RMR which lies between 0 - 100.

The Slope Mass Rating (SMR) is the application of the RMR to estimate the angle of slope stripping. Some methods of mathematical calculation of the SMR from RMR value has been developed by several authors, here are some theme :

1. Hall (1985, in Djakamihardja & Soebowo, 1996), providing the SMR value as follows :

$$SMR = 0.65\ RMR + 25 \qquad (1)$$

2. Orr (1992, in Djakamihardja & Soebowo, 1996) suggest the SMR value as follows :

$$SMR = 35\ \ln RMR\text{-}71 \qquad (2)$$

3. Laubscherr (1975, in Djakamihardja & Soebowo, 1996) discusses the relationship of RMR and SMR as follows :

Table 1. Laubscherr relationship of RMR and SMR

RMR Total Value	SMR, recommended slope angle
81 - 100	75°
61 - 80	65°
41 - 60	55°
21 - 40	45°
0 - 20	35°

2. Methodology

RMR values in this study derived from observations of the rock mass characteristics directly in Padalarang area at three different mine sites (X01, X02, X03) and testing of the materials of intact samples in the laboratory.

Fig 2. Study area (Courtesy of Google Maps, 2015)

Figure 1 shows the spacing, conditions, and orientation of discontinuities in a jointed rock mass.

Table 2. Classification parameters for RMR

A. CLASSIFICATION PARAMETERS AND THEIR RATINGS									
Parameter			Range of values						
1	Strength of intact rock material	Point-load strength index	>10 MPa	4 - 10 MPa	2 - 4 MPa	1 - 2 MPa	For this low range - uniaxial compressive test is preferred		
		Uniaxial comp. strength	>250 MPa	100 - 250 MPa	50 - 100 MPa	25 - 50 MPa	5 - 25 MPa	1 - 5 MPa	< 1 MPa
	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 (See E)		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 walls	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/m)	None	< 10	10 - 25	25 - 125	> 125		
		(Joint water press)/ (Major principal σ)	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		

The strength value of rock material in this study is obtained from point load test to each samples of intact rock from field observation in laboratory. The RQD value in this study is also obtained by direct measurement in field using scan-line method which is introduced by Hudson, 1979 (Wyllie, 2005), the calculation is :

$$RQD = 100\ (0.1\ \lambda + 1)\ e^{-0.1\lambda} \qquad (3)$$

Where λ is ratio between the amount of discontinuities passed by scan-line and the length of scan-line

The obtained RMR values then correlated into

Table 3. Summary of RMR Value

		SLOPE X01	SLOPE X02	SLOPE X03
	Lithology Description	Limestone, medium size grained, dark grey, very hard, low permeability, low slacking potential	Limestone, fine grained, pale brown, very hard, low permeability, low	Limestone, fine grained, pale brown, very hard, low permeability, low slacking potential
	Strenght of Intact Rock Material (Point Load Strenght Index (Mpa))	1.04	3.41	1.38
	RATING	4	7	4
	RQD (Hudson, 1979, in Djakamihardja & Soebowo, 1996))	98.56%	73.40%	98%
	RATING	20	13	20
	Spacing of Discontinuities (m)	3.16	1.95	1.2
	RATING	20	15	15
Conditions of Discontinuities	**Discontinuity Length (m)**	5.45	2.49	5.35
	RATING	2	4	2
	Separation (cm)	4.45	0.5	4.18
	RATING	0	0	0
	Roughness	Slightly Rough	Smooth	Slightly Rough
	RATING	3	1	3
	Infilling (gouge)	Soft (<5mm)	None	Soft (<5mm)
	RATING	2	6	2
	Weathering	Slightly Weathered	Slightly Weathered	Slightly Weathered
	RATING	5	5	5
Ground Water	**Flow**	No Water Flow	No Water Flow	No Water Flow
	General Conditions	Completely Dry	Completely Dry	Completely Dry
	RATING	15	15	15
	TOTAL	71	66	66

SMR using Hall, Orr, and Laubscherr method. So, in each slope we have three values from three different method that can be used to estimate the slope stripping angle for each slope.

3. Result

From the observations of the Rajamandala Limestone characteristics directly at three different mine sites (X01, X02, X03), we obtain that the study area based on RMR classification system is consist of same rock class, which is Class II or Good Rock, and

Table 4. RMR and SMR value in study area

RMR	**X01**	**X02**	**X03**
Ratings	71	66	66
Class	II	II	II
Description	Good Rock	Good Rock	Good Rock
SMR	**X01**	**X02**	**X03**
Laubscherr	60	55	55
Hall	66	67.3	67.3
Orr	61	72.9	72.9

based from three method (Laubsherr, Hall, Orr) the SMR value range between 55° - 72.9° (Table 3). The descriptions and weighting for each RMR parameters in each sites can be seen in Table 4.

From those three sites (X01, X02, X03), the obtained RMR and SMR values are similar. This can be explained if we think geologically. We already know that these sites are consist of Limestone Members of Rajamandala Formation, which geologically they were deposited together and had experienced the same tectonic periods, this made this three sites has similar physical characteristic from their strength into their discontinuities properties.

4. Conclusion

Based on RMR clasiffication system, in three different sites, The Rajamandala Limestone mining area has classified into Class II or Good Rock and has the SMR value range between 55° - 72.9°. The SMR value can not be the main criterion in determining a safe slope angle, it proved by the fact in the field on sites X02 and X03 that their overall slope ranges between 52° - 55° (Photo 1)

As the RMR and SMR value in this study is obtained from preliminary study based on surface data, further investigation is required to obtain more conclusive results.

Photo 1. Local failure at Site X03 with 53° slope angle

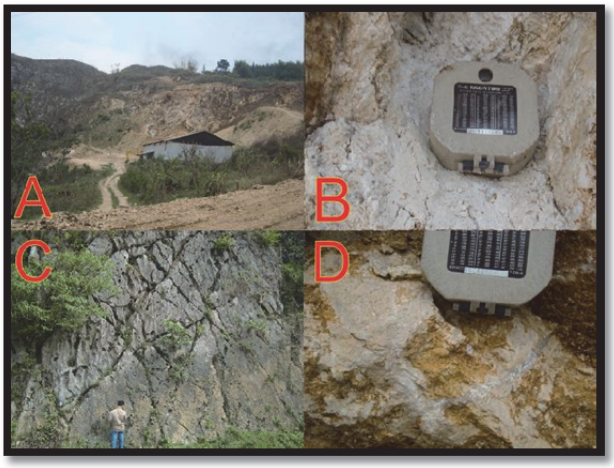

Photo 2. Field documentation. (A) Site X02, (B) Fault gauge at Site X02, (C) Joint sets in Site X01, (D) Calcite vein in site X03.

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