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Application of Slope Mass Rating System In Slope Stability Class Evaluation

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Abstract: The rock slope stability analysis is a challenging task in geotechnical engineering. The metasedimentary cut slope at Putrajaya-Cyberjaya Link was assessed using Slope Mass Rating (SMR) system in this study. The results of SMR calculation obtained in this study is 23.3. The results shows that, the slope stability class obtained is IV and the cut slope of the study area is in bad condition. The stability is known to be unstable and the probability of failure is 0.6 or 60%.

Keywords: Slope Mass Rating System, Slope Stability, Rock Mass Rating, Intact Rock Material, Rock Quality Designation (RQD) And Spacing Of Discontinuities

I. INTRODUCTION

Rock mass classification system is one of the common method used to evaluate the stability of the rock slope and its design in geotechnical engineering [1, 2]. This classification used to assist in assessing a problem and to indicate areas where additional information must be sought to obtain the required answer.One of the effective classifications is developed by Bieniawski (1973) which is known as Rock Mass Rating (RMR) [3]. The purpose of geomechanics classification, on the other hand, is to determine the rock mass quality into a time where the rock mass can be stable and remain unsupported, and the type and of support if necessary. To implement the geomechanical classification, the site information should be examined first and divided into several structural units in such a manner that each sort of rock mass is depicted by a distinct geological structural unit [4]. Bieniawski in 1989 has developed a modified rating that consists of five classification parameters and one rating adjustment. The parameters include the intact material strength, Rock quality designation (RQD), the discontinuities spacing, discontinuities condition and condition of groundwater while the rating adjustment is the orientation of discontinuities [5]. The sum of the five parameters and one rating adjustment, however, is mainly for tunnels and dams foundations, thereforeRomana (1985) has developed a modified classification for slope [6, 1].

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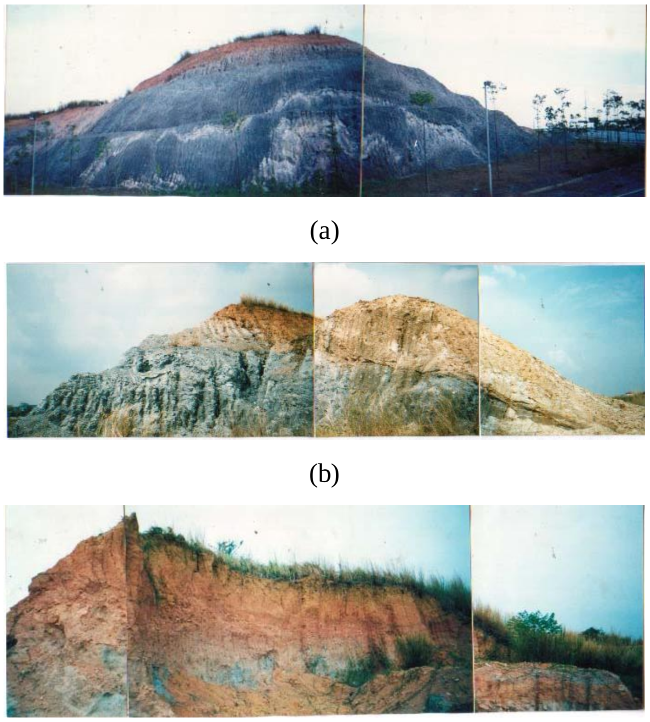
Site Condition

The cut slope is being a complex mix of weathered rock – soil meta sediments slope which predominantly consists of graphitic schist. Figure 1 shows the cut slope of the study area in a different direction.



(a)

(b)

(c)

Fig. 1 View of a cut slope; (a) Front view of the cut slope; (b) Side view of the cut slope; (c) Behind view of the cut slope

II. METHODOLOGY

Two main steps involved in this study including rock mass rating and slope mass rating as shown in Fig. 1.

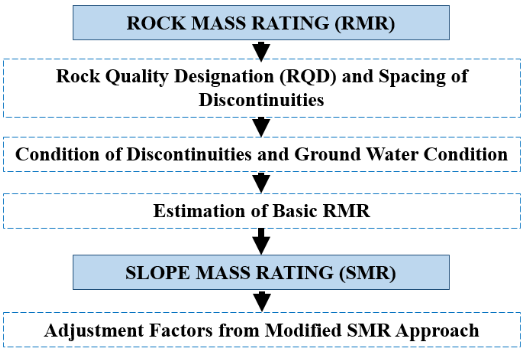


Fig. 2 Methodology of the Study

Rock Mass Rating (RMR)

1) Strength of Intact Rock Material

The strength of the rock materials is determined by referring to the suggested method proposed by ISRM (1981, 1985) shows as Table I. The unconfined compressive strength from laboratory testing is 10.125 Mpa,therefore, the rating is 2. Therefore, the rating of Strength of Intact Rock Material parameter equals to 2.

2) Rock Quality Designation (RQD) and Spacing of Discontinuities

RQD is obtained from the direct method (borehole result) which is76 (CSL 2002). Therefore the rating of RQD parameter equals to 17.

For all sets of discontinuities, the spacing of discontinuities based on the linear distance between two neighboring discontinuities is measured and the rating for most critical discontinuity should be acquired from Table I. The major join sets available at the cut slope are equal to 6 sets which the spacing of each joint set is shown in Table II. From Table II, the critical joint set spacing is set no 2 in which the joint spacing is 0.25m. Therefore the rating of spacing of discontinuities parameter equals to 10.

3) Condition of Discontinuities and Ground Water Condition

The average conditions of the discontinuities can be described as rough and slightly weathered, wall rock surface separation < 1mm. Therefore the rating of Condition of Discontinuities parameters equals to 20.The rating of the groundwater condition parameter base on the packer test shows that the rates are 8 (l/min). Therefore the rating of the groundwater condition parameter equals to 10.

4) Estimation of Basic RMR

The sum of the above five parameters will generate a basic Rock Mass Rating which is shown as below:

RMR_{basic} = Sum of five classification parameter

$RMR_{basic} = 2 + 17 + 10 + 20 + 10$

$RMR_{basic} = 59$

Slope Mass Rating (SMR)

From Bieniawski's Rock Mass Rating, Romana (1985) took the basic RMR value, removing the basic RMR with adjustment factors of the joint-slope relationship and adding factors to the excavation technique. This is:

$SMR = RMR_{basic} - (F_1 . F_2 . F_3) + F_4$

The values of adjustment factors for different joint orientations are described in Table III and Table IV. A modified SMR approach applies the same technique to planar failure and the strike and dip of the plane are used for the analysis. However, the plunge and direction of the crossing line of the unstable wedge are used in the case of wedge failures. This consideration is more critical than the initial version of SMR in the calculated value of the modified SMR.

1) Adjustment Factors from Modified SMR Approach

Refer to the slope stability analysis in Fig. 2, the stereo-plots show the potential wedge failure. Hence, the plunge and the direction of the line of intersection of the unstable wedge can be obtained. The slope is orientated at $338^o/50^o$. The plunge direction and plunge of the line of intersection is oriented at $346^o/35^o$. Besides, the cut slope is built by normal blasting and mechanical excavation. With this information, the adjustment factors can be obtained easily. The adjustment factor for the cut slope is shown in Table V.

Table. 1 (A)Geomechanics Classification Of Jointed Rock Masses Base On [7] (Cont….)

Parameter			Range of values						
1.	Strength of intact rock material	Point Load Strength index	>10MPa	4 - 10Mpa	2-4MPa	1-2MPa	For this low range, uniaxial compressive test is preferred		
		Uniaxial Compresive Strength	>250MPa	100-250MPa	50-100MPa	25-50MPa	5-25MPa	1-5MPa	<1MPa
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	>2m	0.6 – 2m	200 – 600mm	60 – 200 mm	< 60 mm	
Rating		20	15	10	8	5	
4.	Condition of discontinuities	Very rough, surfaces, not continuous, no separation, unweathered	Slightly rough surfaces, separation < 1mm, slightly weathered wall	Slightly rough surface, separation < 1mm, highly weathered wall	Slickensided surfaces or gouge < 5 mm or separation 1 – 5 mm, continuous	Soft gouge > 5mm or separation > 5mm continous	
Rating		30	25	20	10	0	
5.	Groundwater	Inflow per 10m tunnel length (L/min)	None	<10	10 – 25	25 – 125	>125
	$Ratio\frac{Joint\ Water\ Presure}{MajorprinsipalStress}$		Or	Or	Or	Or	Or
			0	<0.1	0.1 – 0.2	0.2 – 0.5	>0.5
		General Condition	Or	Or	Or	Or	Or
			Completely Dry	Damp	Wet	Dripping	Flowing
Rating			15	10	7	4	0

(B) Rating Adjustment For Discontinuity Orientation

Strike and dip orientations of discontinuities		Very Favorable	Favorable	Fair	Unfavorable	Very unfavorable
Rating	Tunnels and Mines	0	-2	-5	-19	-12
	Foundations	0	-2	-7	-15	-25
	Slopes	0	-5	-25	-50	-60
(c) Rock mass classes determined from total ratings						
Ratings		100 -81	80-61	60-41	40-21	<20
Class no		I	II	III	IV	V
Description		Very Good Rock	Good Rock	Fair Rock	Poor Rock	Very Poor Rock
(d) Meaning of rock mass classes						
Class no		I	II	III	IV	V
Average stand-up time		20 yr for 15m span	1 yr for 10m span	1 week for 5m span	10h for 2.5m span	30 min for 1 min
Cohesion of rock mass (kPa)		>400	300 - 400	200 -300	100 - 200	<100
Friction angle of the rock mass (^{o})		>45	35 - 45	25 - 35	15 - 25	<15

Table. 2 The Average Joint Spacing

No of Set	Dip (^{o})	Dip Direction (^{o})	Spacing (m)
1	70	360	1.23
2	75	5	0.25
3	80	205	1.86
4	70	10	0.63
5	80	20	6.05
6	70	35	6.40

Table. 3 Values of Adjustment Factors For Different Joint Orientation [6]

Case of Slope Failure		Very Favorable	Favorable	Fair	Unfavorable	Very Unfavorable
P T W	|αj – αs| |αj – αs – 180| |αi – αs|	>30^o	30-20^o	20-10^o	10-5^o	<5^o
P/W/T	**F_1**	0.15	0.4	0.7	0.85	1.0
P W	|βj| |βi|	<20^o	20-30^o	30-35^o	35-45^o	>45^o
P/W	**F_2**	0.15	0.4	0.7	0.85	1.0
T	**F_2**	1.0	1.0	1.0	1.0	1.0
P W	|βj – βs| |βi – βs|	>10^o	10-0^o	0^o	0 – (-10^o)	<-10^o
T	|βj + βs|	<110^o	110 – 120^o	>120^o	-	-
P/W/T	**F_3**	0	-6	-25	-50	-60

Note: P-planar failure; T – toppling failure; W – wedge failures; αs – slope strike; αj – joint strike; αi – plungedirection of line of intersection; βs – slope dip and βj – plunge of line of intersection

Table. 4 Values of Adjustment Factor F4 For Method of Excavation [6]

Method of Excavation	**F_4 Value**
Natural Slope	+15
Pre-spliting	+10
Smooth blasting	+8
Normal blasting or mechanical excavation	0
Poor blasting	-8

Table. 5 Values of Adjustment Factors For The Cut Slope of Study Area

Methods of Excavation	Normal blasting and mechanical excavation	Methods of Excavation
W	|αj – αs|	8^o
F_1	0.85	
W	|βi|	35^o
F_2	0.70	
W	|βi – βs|	-15^o
F_3	-60	
F_4	0	

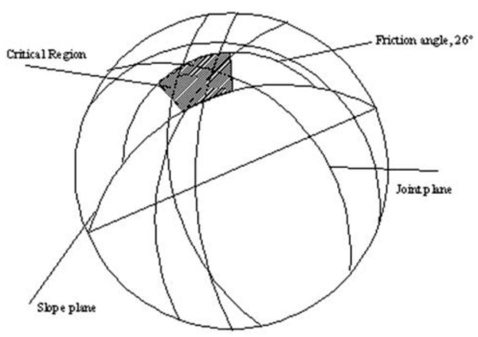


Fig. 2 Kinematic Slope Stability Analysis

III. RESULTS AND ANALYSIS

Slope Stability Class

Slope stability classes of the cut slope at Putrajaya-Cyberjaya link, the SMR values are calculated by calculating the summation of RMR_{basic} – ($F_1.F_2.F_3$) + F_4. Hence, the calculation of SMR values is shown as following:

SMR = RMR_{basic} – ($F_1.F_2.F_3$) + F_4.

SMR = 59 – (0.85 x 0.70 x 60) + 0

SMR = 23.3

Romana (1985) described five stability classes according to SMR scores as shown in Table VI.

Table. 6 Stability Classes As Per Smr Values (Romana 1985)

Class No	V	IV	III	II	I
SMR Value	0 – 20	21 – 40	41 – 60	61 – 80	81 - 100
Rock Mass description	Very Bad	Bad	Normal	Good	Very Good
Stability	Completely Unstable	Unstable	Partially Stable	Stable	Completely Stable
Failures	Big Planar or soil like or circular	Planar or big wedge	Planar along some joint and many wedges	Some block failure	No Failure
Probability of failure	0.9	0.6	0.4	0.2	0

The value of SMR shows that, the slope stability class obtained is IV and the cut slope of at Putrajaya-Cyberjaya Link is in bad condition. The stability is known to be unstable and the probability of failure is 0.6 or 60%. Stability is known to be unstable. The probability of failure is 0.6 or 60%.

IV. CONCLUDING REMARKS

The geomechanics classification of the cut slope firmly indicates that the slope materials which mainly consists of metasediments, can exhibits slope failures in planar or wedge type failure is proven by slope stability analysis. The rock mass of that cut slope can describe as bad materials or specifically known as a weak rock since it has the unstable condition and probability 60% of to fail.

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