Use of Field Data in Determining Rock Slope Stability: Case Study North – South Malaysia Highway

Abdul Rahman Huraisen Masri
Politeknik Sultan Abdul Halim Mu'adzam Shah
arhm_amn@yahoo.com

Abstract
This study was conducted to assess the rock mass classification and to evaluate the stability of a slope at the North – South highway (KM 173.7 between the Parit Buntar interchange and interchange at Jawi). A number of field data were collected at the site which include dip direction, dip angle, type of fractures, weathering state and length of fractures, ground water condition and uniaxial compressive strength of rock. The classification of rock mass is based on the Bienawski and Laubscher classification method while stereographic projection is used to assess the rock slope stability. It can be concluded that based on Bienawski the existing rock slope is in a very good condition (1st class) and while Laubscher dictates the rock as in good condition (2nd class). The contour density in the stereographic projection also indicates that the overall rock blocks are in stable condition geometrically. There are three sets of fractures present in the slope which generally dip in the NW – SE, N – S and E – W directions. The type of failure, if it were to occur, would be a wedge type. However, this study does not take into account factors like the shear strength of a joint and the dip of the intersecting line between two joints.
Keywords: Field Data, Rock Slope Stability, North – South Malaysia Highway

Introduction

Engineering geology is a field that links geology and construction engineering where the concepts and aspects of engineering is applied to understand the effects that building structures and their geological elements have on the geological environment.

The engineering geological data/ information depends on the characteristics of the soil at the site concerned, the materials and the building structure and the geological elements which may be the cause of instability and early warning signs of risks attributed to natural occurrences. This may assist in the prediction and prevention of risks of structural failure in event of an earthquake, soil erosion, heavy rainfall, floods and other forms of natural disasters in that with adequate information regarding these elements it may help in the development of steps to prevent such risks from happening. In the event that they do still happen, it will help in the process of reparation and restoration in the event of a geological disaster.

Background Problem

In the slope design, the engineer faces two main problems, i.e., the cost and its accompanying effect. The problem of cost can be mitigated by reducing the gradient or steepness of the slope which reduces the volume of the earth to be removed while the effect of a steeper slope may result in instability resulting in the possibility of having to incur costs in terms of repairs to the slope, lives and property in the event of rock falls or landslides.

Therefore, it is pertinent to consider and analyze the costs and the optimum gradient for a slope beforehand before the project is implemented. These two factors will determine the cost-effectiveness, suitability and the stability of the slope for a specific duration.

In most mining operations, the cutting of a slope, the civil engineering and structural construction work to be carried out, involves guidelines following the concept of geological engineering and will help to determine rock strength, condition of discontinuity, the condition of ground water and rock quality designation (RQD) for classification purposes. All these data and information is of great importance for the analysis of the capacity of the site such as its bearing capacity and the stability of a certain rock mass. Geological engineers are responsible for the collation of such relevant data and to render the information in a form that is easily understood by all parties involved in the construction of a slope to ensure a proper and optimum design is achieved.

Problem Statement

The instability of a slope is a major issue and a critical engineering problem in highway construction in Malaysia, especially in the East-West Highway, the North-South Highway and the Kuala Lumpur – Karak Highway. Studies on slope failures along these highways between the months of November-December 2014 have found 128 slope failure incidents. From this number 85 of these cases involved rock-cut slopes. The presence of discontinuities is one of the main causal factors of the problem of rock-cut slope instability. Other factors identified includes the weathering rate, the actions of surface running water and underground water, unsuitable method employed in slope stabilization and poor design of slope design (Tajul Anuar Jamaluddin, 2014).

This study attempts to explain in detail the condition of discontinuity, the orientation and its presence in the rock mass, and also to predict the uniform potential of failure in a rock slope. From the study, a prediction is made regarding the condition of the slope and the probability of a slope failure. In this study the rock quality is determined whether it is good, average or poor. This is based on a number of rock mass classification systems currently available.

Objective and Research Methodology

Objective

This study was conducted to assess the rock mass classification and to evaluate the stability of a slope at the North – South highway (KM 173.7 between the Parit Buntar interchange and interchange at Jawi). A number of field data were collected at the site which includes dip direction, dip angle, type of fractures, weathering state and length of fractures, ground water condition and uniaxial compressive strength of rock.

From the classification of rocks which is based on both the Bienawski and Laubscher classifications as well as the stereographic analysis the stability of a slope may be determined. The result is that the stability or instability of a slope and the block of rock under analysis is ascertained and safety is ensured or otherwise. At the same time the concentration contours in the stereographic projection will indicate the type of slope failure from a geometric angle (Anon, 2015).

Location

Two slopes have been selected along Highway N4 Changkat Jering – Jawi. The location of this study is as follows:

a) Slope A - 5 km from the intersection at Parit Buntar (KM 173.7 – in the North direction)
b) Slope B - 5 km from the intersection at Parit Buntar (KM 173.7 – in the South direction)

Figure 1: Map of location of study at KM 173.7 North-South Highway

Study Equipment

The equipment used in this study and data collection are as listed below:

i) Measuring Tape

ii) Schmidt Hammer (L-type)
iii) Geology Compass (de Silva Inclinometer-Switzerland)

Picture 1: Showing a section of the study location Slope A : KM 173.7 – in the North direction

Picture 2: Showing a section of the study location Slope B: KM 173.7 – in the South direction

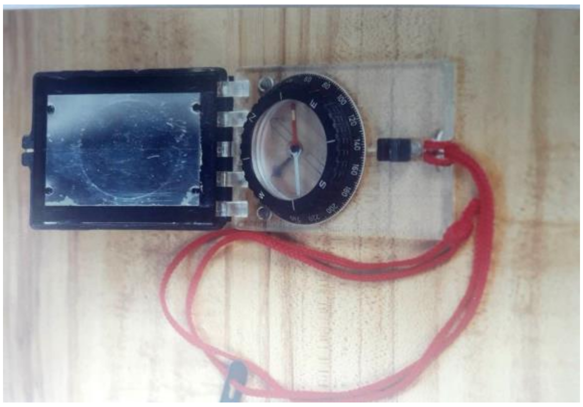
Procedure for Field Data Collection

The procedure for field collection is a process that takes up a considerable amount of time in a study. The data collected includes determination of the direction of dip of the rock fracture, its angle of dip, the distance between the fractures, direction of slope, the uniaxial compressive strength (UCS) of rock and a few other parameters that will be required in the analysis and classification of the rock mass.

The geology compass or clinometer compass is used to measure the direction of dip and the value of the angle of dip of the rock fractures that is present in the site under study. The distance between the fractures on a horizontal line is measured with a measuring tape. The uniaxial compressive strength (UCS) of the rock is measured using the Schmidt Hammer.

Picture 3: Measurement of fracture distance. Measuring tape is used to determine the distance between fracture section

Picture 4: Geology Compass Instrument is used to measure the angle of dip and the slope direction of fracture



Picture 5: Geology Compass. This instrument is used to measure the angle of dip and the slope direction of fracture

Picture 6: Schmidt Hammer Equipment used to measure the uniaxial compressive strength on fracture wall

Picture 7: Schmidt Hammer Equipment is used to measure the uniaxial compressive strength of the fracture wall

Picture 8: Field orientation methods of data collection and geological observation have to be carried out in great detail during the study

Results and Discussion

Rock Mass Classification

There are two slopes under this study. For both of these slopes, the distance between fractures is taken at intervals of 30 meters in the area under study. The evaluation for each criteria is done using the Bieniawski and Laubscher classification tool and is averaged. Every parameter at intervals of 30 meters on the slope under study will give a certain rate and this value is used in the determination of the class and grade of the rock, (Bieniawski, 2015).

Sample Result:
Name of Location: KM 173.7, South direction (N4 Changkat Jering-Jawi) Reading : 30 meters Project : ARHM – Case Study of Rock Slope Stability Hill : B No.2 No. Form:DL/8/15

No.	**Distance (m)**	**Distance between fractures (m)**	**Fracture distance >0.1m**	**Condition of fracture**	**Condition of ground water**	**Schimdt Hammer Reading (MPA)**	**Angle of dip**	**Direction of dip**	**Fracture condition, including ground water**				
									A	**B**	**C**	**D**	**Average**
1	1.70	1.7	YES	COARSE	MOIST	30	83	58	78	89	100	100	27.768
2	3.30	1.6	YES	COARSE	DRY	37	84	346	78	88	100	100	27.456
3	5.30	2.0	YES	COARSE	DRY	42	87	334	77	90	100	100	27.720
4	7.30	2.0	YES	COARSE	DRY	32	68	172	75	92	100	100	27.600
5	8.90	1.6	YES	COARSE	DRY	42	70	130	78	90	100	100	28.080
6	13.50	4.6	YES	COARSE	DRY	28	76	148	75	85	100	100	25.500
7	17.90	4.4	YES	COARSE	MOIST	46	60	80	74	86	100	100	25.456
8	20.30	2.4	YES	COARSE	MOIST	46	66	132	75	87	100	100	26.100
9	1.80	1.5	YES	COARSE	MOIST	42	80	122	75	86	100	100	25.800
10	23.90	2.1	YES	COARSE	MOIST	40	62	112	74	85	100	100	25.160
11	27.90	4.0	YES	COARSE	MOIST	46	72	128	75	85	100	100	25.500
12	29.90	2.0	YES	COARSE	MOIST	44	74	240	75	88	100	100	26.400

Appendix A : Field Data obtained, Slope B – 30 meters No. 2
Field Data Tabulation form

Sample Result:

Sequenced Data
Name of Location: KM 173.7, South direction (N4 Changkat Jering-Jawi) Reading : 30 meters Project : ARHM – Case Study of Rock Slope Stability Hill:B No.2 No. Form:DL/8/15

No.	**Distance**	**%**	**% Cumulative**	**Schimdt**	**Average**

	between fractures (m)	**Distance**	**distance between fractures**	**Hammer Reading (MPA)**	
1	1.50	5.02	5.02	42.00	25.80
2	1.60	5.35	10.37	37.00	27.46
3	1.60	5.35	15.72	42.00	28.08
4	1.70	5.69	21.40	30.00	27.77
5	2.00	6.69	28.09	42.00	27.72
6	2.00	6.69	34.78	32.00	27.60
7	2.00	6.69	41.47	44.00	26.40
8	.10	7.02	48.49	40.00	25.16
9	2.40	8.03	56.52	46.00	26.10
10	4.00	13.38	69.90	46.00	25.50
11	4.40	14.72	84.62	46.00	25.46
12	4.60	15.38	100.00	28.00	25.50
Total	29.90	100.00		475.00	318.54

Overall average reading	Schimdt hammer (MPA)	39.58
	Fracture condition reading	26.55
	rqd (%)	100.00
	Distance between fractures	2.49
Distance between fractures (m)	Maximum	4.60
	Median	2.00
	Minimum	1.50
Fracture condition	Coarse	
Ground water condition	dry	

Appendix B: Calculation of Sequenced Data, Slope B – 30 meters No. 2

Analysis of Slope Failure

The analysis of rock slope failure using stereographic plotting is obtained when the big curve is drawn with the contour plotting. This curve is drawn using the slope face angle and the direction of the block face under study. Analysis of the area of probable failure is done by input of the friction angle of the discontinuity section (area under study is granite rock, therefore $\theta = 30^0$ is used, *Approximate values for the basic friction angle θ for different rocks,* (Barton, 2015). If it is found that the normal pole (marked 'x') lies within the θ range and the big curve of slope face, then the slope in question may face probable failure.

Example:

Hill B (KM 173.7 – South direction)

For the area under study the angle of dip for the slope face and its direction of dip is taken over a distance of 120 meters. The slope is divided for every 30 meters into 4 segments and named accordingly as Slope B-1 (for first 30 meters), Slope B-2 (for the 2nd 30 meters), Slope B-3 (for the 3rd 30 meters) and Slope B-4 (for the 4th 30 meters). Figure 2 illustrates the division of the slope. A number of readings are taken and the values of the angle of dip and the direction of dip for the slope face for every segment and this is shown in Figure 1.

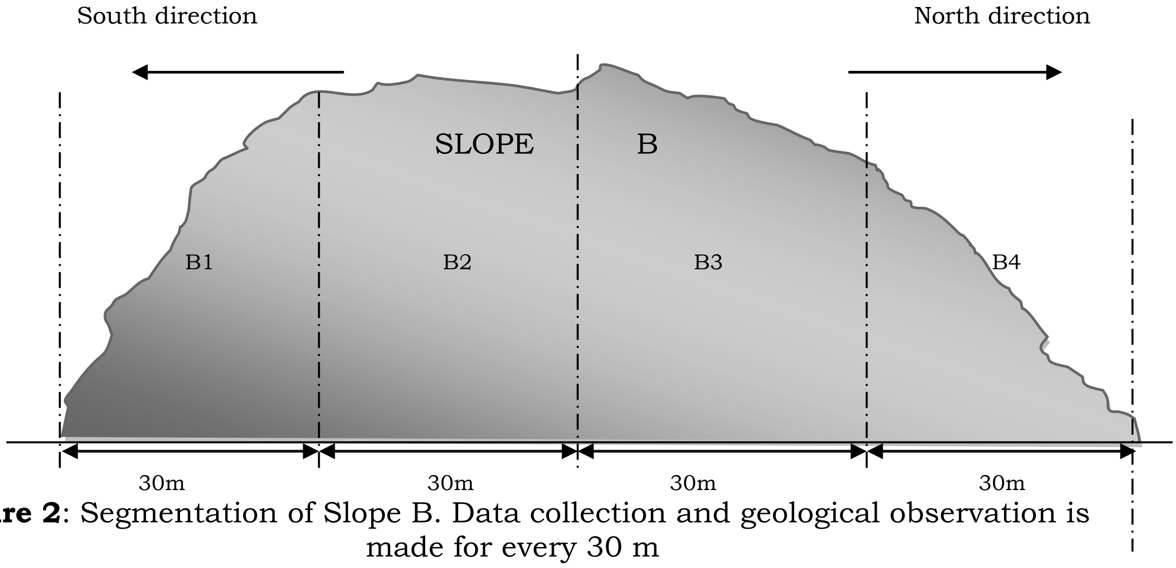


Figure 2: Segmentation of Slope B. Data collection and geological observation is made for every 30 m

Sample Result:

Table 1: Values of dip angle and average direction of dip of slope face B

Segmentation of Slope	Angle of slope (^{0})	Average direction of slope (^{0})
B - 1	84	200
B - 2	88	220
B - 3	86	126
B - 4	86	32

Based on the plotting of the angle of dip and the direction of dip coupled with the contour from combination of points of these two parameters and the drawing of the circle on the stereographic net and the friction angle, θ, plotting (Figure 3), therefore the result of the analysis of the rock slope stability is tabulated in Table 2. This table also shows the types of probable failure.

Table 2: Result of analysis of failure of slope B

Segmentation of Slope	Result	Type of probable failure	Direction of probable slope failure (dip angle/direction of dip)
B - 1	Not within the region of	wedge failure	72^0 / 134^0

	failure		
B - 2	Not within the region of failure	wedge failure	84^0 / 64^0
B - 3	Not within the region of failure	wedge failure	84^0 / 32^0
B - 4	Not within the region of failure	wedge failure	88^0 / 70^0

Sample: Plotting Of Analysis of Slope Stability

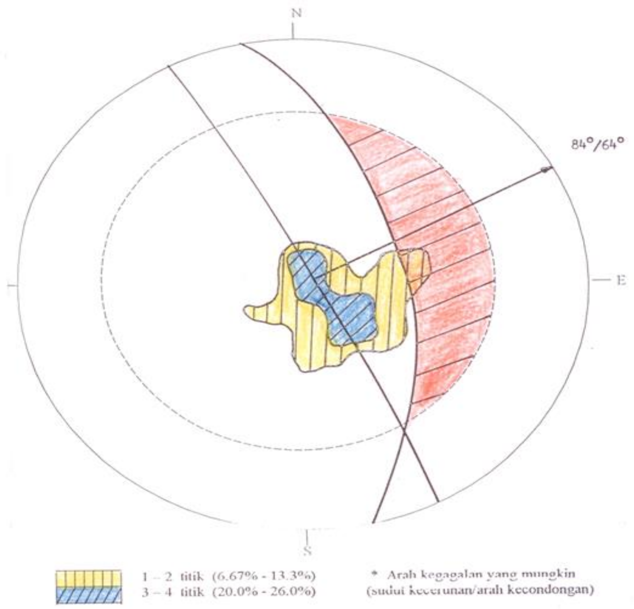


Figure 3: Plotting of the analysis of slope stability: Slope B (30 m No.2)

Discussion on the Results Obtained

Based on the Bienawski classification system, it was found that the classification for both rock slopes were in Class 1 (very stable and safe), while using the Laubscher system provided a result in Class 2 (good).

The contouring and plotting demonstrate that the slope is in a stable condition and the type of failure if it happens is the wedge type. The contouring results from the dip angles and the direction of dip for every 30 meter slope block show that the high intensity distribution contour for both rock slopes are out of the area of the danger of failure *(Red Zone)*. The high intensity contouring shows that the rock slope is in a stable and safe condition.

Granite rock at the location of study shows three sets of fractures criss-crossing one another. This fracture exists in the discontinuity set which have a similar orientation. These three sets of fractures has very similar orientation in the direction of North-west – South-west, North – South and North - East.

Based on these two results, it is possible to suggest that both the two rock slopes under study are stable and safe and would not require any method of strengthening for the present time. However their condition in the future may change depending on the effects of a number of factors such as ground water, weathering and earth movements (earthquakes).

The different values obtained from the two types of classification systems used depend much on the rate values used for the distance between fractures for each system. The rate used in the Bieniawski classification is too simplified compared to the Laubscher system which is more sophisticated. In addition the Laubscher system looks at the condition of a rock fracture closer and in more detail in comparison with that of Bienawski's. The Laubscher system is employed in the construction of tunnels which demands a stricter and higher demand for safety compared to the Bienawski system which is primarily for slope construction. These may be the factors that differentiate the two classification systems for rock mass employed in this study.

Sample Result:

Table 3: Difference between the Bienawski and Laubscher Classification Systems for Slope B

(a) Bienawski Classification Systems for Slope B

No	Parameter	1st 30 meters	2nd 30 meters	3rd 30 meters	4th 30 meters	Overall Average
1	Schmidt Hammer Reading	40.8	39.6	33.4	38.7	38.1
	UCS (MPa)	76.0	76.0	52.0	72.0	69.0
	Rating	7.0	7.0	7.0	7.0	7.0
2	RQD	100.0	100.0	100.0	100.0	100.0
	Rating	20.0	20.0	20.0	20.0	20.0
3	Distance between fractures (m)	3.3	2.5	3.0	2.7	2.8
	Rating	20.0	15.0	20.0	20.0	18.8
4	Fracture condition	Coarse	20.0	20.0	20.0	20.0
	Rating	30.0	30.0	30.0	30.0	30.0
5	Ground water condition	Dry	Dry	Dry	Dry	Dry
	Rating	15.0	15.0	15.0	15.0	15.0
	Total Rating	92.0	87.0	92.0	92.0	90.8

(b) Laubscher Classification for Slope B

Bil	Parameter	1st 30 meters	2nd 30 meters	3rd 30 meters	4th 30 meters	Overall Average
1	Schmidt Hammer Reading	40.8	39.6	33.4	38.7	38.1
	UCS (MPa)	76.0	76.0	52.0	72.0	69.0
	Rating	8.0	8.0	6.0	6.0	7.0

Politeknik & Kolej Komuniti Journal of Engineering and Technology, Special Issues on CoT 2018
eSSN 0128-2883

2	RQD	100.0	100.0	100.0	100.0	100.0
	Rating	15.0	15.0	15.0	15.0	15.0
3	Distance between fractures (m)	3.3	2.5	3.0	2.72	2.8
	Rating	25.0	25.0	23.0	23.0	24.0
4	Fracture condition with ground water	Dry	Dry	Dry	Dry	Dry
	Rating	36.6	26.5	27.0	28.4	27.1
	Total Rating	74.6	74.54	71.0	72.37	73.1

Conclusions

From the results of the study carried out, a number of conclusions may be made of the site under study:

1. The classification of the rock mass in the area under study, that is, two rock slopes facing each other at KM 173.7 on the North-South Highway is in class 1 (very good) based on the Bienawski system and class 2 (good) using the Laubscher classification system.
2. The slope is in a stable region based on the plotting on the stereographic net and the possible type of failure is the wedge type. The prediction of slope failure may be obtained from the plotting of the angle of dip and the direction of dip of fracture and the contour obtained from the stereographic plotting.
3. There exist three sets of fracture orientations for the granite rock criss-crossing one another. This fracture is present in the discontinuity set and each set has a similar orientation. These three sets of fractures have very similar orientation in the direction of North-west – South-west, North – South and North - East.

Among the suggestions proposed are as follow:

1. The study of slope stability on the North-South Highway has been an interesting one and it will be good for other students to continue this academic exercise. Because this is the first time such a study has been carried out in the area, it is hoped that follow-up studies be carried out on these rock slopes in the future and to compare with the results obtained in this study.
2. From the study on both slopes at the KM 173.7 of the North-South Highway, it was found that both the slopes are in a good condition. However good continuous maintenance by the highway authorities, namely, PLUS will go a long way to ensure the stability of the rock slope for a long time to come.

References

Anon, (2015). Rock and Soil Description and Classification for Engineering Geological Mapping. Report by the IAEG Commissionon Engineering Gelogical Mapping. *Bulletin of the International Association of Engineering Geologi,* No. 24, 235 – 274.

Barton, N., (2015), *Suggested Methods For The Quantitative Description of Discontinuities In Rock Masses.* ISRM Commission on Standardization of Laboratory and Tield Test, 319 pages.

Bieniawski, (2015). *Engineering Rock Mass Classification.* New York : John Wiley & Sons. Ltd, 251 pages.

Bieniawski, (2015). The Geomechanics Classification in Rock Engineering Application. *Int. Cong. Rock, Mech, ISRM, Montreux,* Vol . 2.

Tajul Anuar Jamaluddin, (2014). Geologi Kejuruteraan Lebuhraya Timur-Barat, Semenanjung Malaysia – Penekanan Terhadap Kegagalan Cerun Batuan. *Buletin Persatuan Geologi Malaysia,* No. 29, 207 – 245.