The Analysis of Rock Mass Characteristics Used for Design on Slope Cutting at Sections of Liwa Roadway, Sumatera, Indonesia

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ABSTRAK *Analisa yang dilakukan berdasarkan observasi lapangan dan uji laboratorium, dimana data ini akan digunakan dalam mendapatkan tingkat kestabilan masa batuan dan juga digunakan untuk menentukan disain kemiringan lereng batuan. Metode evaluasi yang diaplikasikan merupakan pendekatan empirik dari klasifikasi masa batuan (Rock Mass Rating) dan klasifikasi kemiringan lereng (Slope Mass Rating). Pendekatan ini akan bermanfaat untuk memperoleh pengertian yang lebih baik, hubungannya dengan pengaruh geologi dan parameter kekuatan batuan serta mekanisme keruntuhan masa batuan. Penelitian lapangan dilakukan pada lima segmen sepanjuang jalan raya yang menghubungkan Liwa dan Krui, dimana terjadi beberapa keruntuhan lereng masa batuan. Secara geologi daerah ini tersusun oleh intrusi batuan andesit, breksi vulkanik, batupasir dan batulempung. Sedangkan pengaruh tektonik di daerah ini sudah membentuk struktur geologi yang komplek. Dari hasil perhitungan memperlihatkan bahwa pada seksi LK-2 kondisi masa batuan termasuk sedang, tetapi memerlukan perhatian untuk lebih memastikan kestabilan masa batuannya. Masa batuan pada seksi LK-1, LK-4 dan LK-5 diklasifikasikan sebagai kondisi baik dengan rekomendasi sudut pengupasan antara* 65^o*-*75^o*. Masa batuan pada seksi LK-3 dapat diklasifikasikan sebagai kondisi sangat baik dengan rekomendasi sudut lereng antara* 75^o*-*89^o*. Berdasarkan pengklasifikasian masa batuan ini, kemungkinan keruntuhan dapat diprediksi dan upaya penguatan dapat diperhitungkan pada awal perencanaan pengupasan.*

Kata kunci*: metoda empiris, klasifikasi masa batuan, klasifikasi kemiringan lereng batuan, keruntuhan batuan, penelitian lapangan, uji laboratorium, kekuatan batuan*

ABSTRACT This analysis is carried out by field observation and laboratories testing to assess the stability of rock mass and to design rock slope. The evaluations have applied an empirical method of Rock Mass Rating and Slope Mass Rating. This estimation will be beneficial for gaining a better understanding of the influence of geological and rock strength parameters, and the mechanisms of rock failure. Field observations were carried out at five sections along the road way connecting Liwa–Krui, where some rock slope failures have occurred. Geologically, this area consists of andesitic intrusion, breccias, sandstone and claystone. Tectonically this area has complex geological structures. The results of this study shows that rock mass at the section LK-2 is classified as fair condition, but special care is required to ensure stability of the slope. The rock mass at LK-1, LK-4 and LK-5 indicated that the rock mass are classified as good with recommended slope angle of between 65^o-75^o. The rock mass at LK-3 is classified as very good with recommended slope angle of between 75^o-89^o. Based on the results above, the possible failure could be predicted and the supporting slopes could be estimated early in the life of the developing excavation.

Keywords: empirical method, rock mass rating, slope mass rating, rock failure, field observation, laboratory tests, rock strength

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Tabel 1. The Rating values of rock parameters, After Bieniawski (1978).

Parameter	Ranges of Values				
U.C.S	> 250 Mpa	100 - 200 Mpa	50 - 100 Mpa	25 - 50 Mpa	5 - 25 / 1 - 5 / < 1 Mpa
Rating	15	12	7	4	2 / 1 / 0
R.Q.D	90 - 100%	75 - 90%	50 – 75%	25 – 50%	25%
Rating	20	17	13	8	3
Joint Spacing	>2 m	0.6 -.2.0 m	200 – 600 mm	60 – 200 mm	< 60 mm
Rating	20	15	10	8	5
Joint Condition	Very rough surfaces, un-continuus, no separation, un-weathered wall	Slightly rough surfaces, separation < 1mm, Slightly weathered wall	Slightly rough surfaces, separation < 1mm, highly weathered wall	Slickensided surfaces, separation < 5 mm, Slightly weathered wall	Soft Gauge > 5 mm Or Separation > 5 mm Continous
Rating	30	25	20	15	0
Groundwater Condition	Completely Dry	Damp	Wet	Dripping	Flowing
	15	10	7	4	0

INTRODUCTION

The road connecting Liwa–Krui, West Lampung area, in which the study was carried out, includes the busiest road in West Lampung, Sumatra, Indonesia. Some short term measures at road section of Liwa–Krui, Km 9 to km 12.5 have been taken by the Public Works Department to avoid the risk of rock failure during a road widening project. In order to facilitate the development of the road widening, steep cuts will be made in the hill slopes which mainly consist of andesit (intrusion), volcanic breccias, and interbeded layers of sandstone and claystone. A better understanding of the development and mechanism of rock failure in this area will play an important role in selecting the best alternative for road cutting. On the other hand, the investigation of geological, geotechnical, and geomorphological parameters under which the slope cuts are being made constitute an important key to formulate a suitable design for the cuttings.

The Rock Mass Rating (RMR) System was presented by Bieniawski (1976, 1978). This is an empirical design method applied for assessing the stability of rock cuttings. The basic theory of RMR is based on the statistical analysis of field observation of rock discontinuities, groundwater conditions, and laboratory tests for rock strength parameters. These rock mass classifications are usually applied and used with observational methods and analytical studies to gain a better background for designing rock cuttings. The objectives of RMR may be summed up as the identification of the most significant parameters influencing the behavior of a rock mass, that are used to classify and understand the characteristics of each rock mass, and provide basic information for a better engineering judgement in cutting slopes. The application of RMR in slope stability is known as Slope Mass Rating (SMR) which was presented by Laubsher (1975), Hall (1985), Romana (1988), Orr (1992).

Table 2. Rock Mass description based on SMR Value, After Romano (1980).

CLASS NO	V	IV	III	II	I
S.M.R	O - 20	21 - 40	41 - 60	61 - 80	81 - 100
Description	Very Bad	Bad	Fair	Good	Very Good
Stability	Fully Instable	Instable	Partially Stable	Stable	Fully Stable
Failures	Big Planar or Soil-like	Planae or Big Wedges	Some Joints or Many Wedges	Some Blocks	None
Support	Re-Exavation	Important Corrective	Systematic	Occasional	None

Table 3. Joint adjustment rating for joints, After Romano (1991).

CASE	Section LK-1	Section LK-2	Section LK-3	Section LK-4	Section LK-5
Planar / αj - αs /	> 30^o	30^o - 20^o	20^o - 10^o	10^o - 5^o	< 5^o
Toppling / αj – αs-180^o					
P/T **F 1**	0.15	0.40	0.40	0.40	0.40
Planar / ßj /	> 20^o	20^o - 30^o	30^o - 35^o	35^o - 5^o	< 45^o
Planar **F2**	0.15	0.40	0.70	0.85	1.00
Toppling **F 2**	1.00	1.00	1.00	1.00	1.00
Planar / ßj - βs /	> 10^o	10^o - 0^o	0^o	0^o - (-10^o)	> -10^o
Toppling / ßj + βs /	< 110^o	110^o - 120^o	20^o	20^o	20^o
P/T **F 3**	0.00	- 6.00	- 25.00	- 50	- 60

Table 4. Adjustment factor for method of excavation, After Romano (1991).

AJUSMENT FACTOR	METHOD OF EXCAVATION					
	Natural Slope	Presplitting	Smooth Blasting	Normal Blasting	Deficient Blasting	Machanical Blasting
F4	+ 15	+ 10	+8	0	- 8	0

STABILITY ANALYSIS AND ASSESSMENT

A procedure to classify a rock mass RMR proposed by Bieniawski may be summed up as the identification of the most significant parameters influencing the behaviour of a rock mass, that are used to classify and understand the characteristics of each rock mass classification. There are six parameters which should be determined to evaluate the RMR. Those are Uniaxial Compressive Strength (UCS); Rock Quality Designation (RQD); Spacing of discontinuities; Condition of discontinuities; Orientation of discontinuities; and Groundwater condition (water flow through discontinuities). After structural region has been identified (defined as rock exhibiting, similar jointing, and strength characteristics), the classification parameters for each structural region are determined from site measurements and laboratory tests, and then entered onto the input

Table 5. Result observation geological of rock mass.

Parameter	Section LK-1	Section LK-2	Section LK-3	Section LK-4	Section LK-5
Mean UCS (Mpa)	140 MPa	56 MPa	164 MPa	166 MPa	7 MPa
Joint Spacing	0.20 – 0.50 m	0.25 – 0.80 m	0.20 – 0.60 m	0.15 – 0.50 m	1.00 – 2.5 m
Joint Roughness	Planar surface Slightly rough	Planar surface	Planar surface Slightly rough	Planar surface Slightly rough	Planar surface Slightly rough
Joint Aperture	Distance 1-10 mm, infilled by quartz	Distance 1-10 mm, infilled by quartz	Distance 1-10 mm, infilled by quartz	Distance 1-10 mm, infilled by quartz	Distance 1-10 mm, infilled by quartz
Joint Orientation	Dip 59°, Dip direction 248°	Dip 74°, Dip direction 218°	Dip 38°, Dip direction 141°	Dip 54°, Dip direction 158°	Dip 12°, Dip direction 268°
Slope Orientation	Dip 54°, Dip direction 178°	Dip 49°, Dip direction 226°	Dip 56°, Dip direction 265°	Dip 79°, Dip direction 272°	Dip 82°, Dip direction 252°
Groundwater	Damp	Damp	Damp	Damp	Damp
Method of Exavation	Blasting and mechanical	Blasting and mechanical	Blasting and mechanical	Blasting and mechanical	Blasting and mechanical

data sheet. To obtain the average typical condition, those data are plotted onto above Rating Charts.

RESULTS AND DISCUSSION

Detailed geological mapping including minor structural mapping were done in the investigated area, at Liwa–Krui road section of Km 9.0–12.5. The fresh cuttings at section of Km 9.0–12.5 (5 - 20 m height) constitute the best outcrops for lithology and discontinuity mapping. The surface geological work was mainly directed to determining the lithological, mineralogical, weathering, and structural geological characteristics of the outcrop and rock excavation to record discontinuities and joint patterns (Tables 5 – 10).

The determination of the stability factor for the slope cutting using empirical estimation gives information about some possible factors involved in the rock failure mechanism. The stability estimation for rock slope cutting at km 9.0–12.5 has been determined by using an empirical method applied through the Rock Mass Rating Classification introduced by Bieniawski (1976).

At km 9.0–12.5 Liwa-Krui, on the other hand, the rock forming slope is divided into five rock units which have different geotechnical characteristics.

The slopes have very steep bedding (70° - 85°) with a developed system of joints and bedding planes and is covered by a thin layer of top soil. Based on the geomorphology conditions and the detailed geological mapping, the slope shows a specific condition where the dip of the bedding plane is opposite to the dip of the slope. Such slopes are stable enough to support the load of material making up the slope. Consequently, the predominant potential of failure mode on rock cuts slope will be by sliding plane, toppling or falling, where the plane is oriented opposite to the dip of bedding. In such cases, failure will occur along the bedding plane. For classifying the rock mass, Bieniawski (1976) and Romana (1980) have given a standard rating for rock parameters as shown in Tables 1, 2, 3 and 4. A basic rock mass rating could be computed by plotting the five basic parameters namely uniaxial compressive strength, rock quality designation (RQD), spacing of disconti-

Table 6. Result analysis of petrographic.

Rock Properties	Rock Sample				
	Section LK-1	Section LK-2	Section LK-3	Section LK-4	Section LK-5
Description	Grey to dark, hard resistant, grain size : silt grain	Grey to dark, hard resistant, grain size : silt grain	Grey to dark, hard resistant, grain size : silt grain	Grey to dark, hard resistant, grain size : silt grain	Grey to dark, hard resistant, grain size : silt grain
Mineralogy and texture	Trachytic, pla-gioklase, quartz, silica, opac, altered serisite infill-ing fractures	Trachytic, pla-gioklase, quartz, silica, opac, altered serisite infill-ing fractures	Trachytic, pla-gioklase, quartz, silica, opac, altered serisite infill-ing fractures	Trachytic, pla-gioklase, quartz, silica, opac, altered serisite infill-ing fractures	Trachytic, pla-gioklase, quartz, silica, opac, altered serisite infill-ing fractures
Rock type	Andesite	Lava andesite	Lava andesite	Lava andesite	Breccias
Strength parameter (UCS)	133 – 148 MPa	36 – 75 MPa	185 – 192 MPa	136 – 195 MPa	7 MPa

Table 7. Rock mass parameter used for application of RMR.

Parameter	Section LK-1	Section LK-2	Section LK-3	Section LK-4	Section LK-5
U.C.S	140 MPa	56 MPa	164 MPa	166 MPa	7 MPa
Rating	12	7	12	12	2
R.Q.D	97%	98%	97%	99%	99%
Rating	20	20	20	.20	20
Joint Spacing	20 – 50 cm	20 – 50 cm	20 – 50 cm	20 – 50 cm	20 – 50 cm
Rating	10	10	10	8	20
Joint Condition	See Table 1	See Table 1	See Table 1	See Table 1	See Table 1
Rating	15	15	20	15	15
Groundwater Rating	Damp	Damp	Damp	Damp	Damp
R.M.R.	**65**	**59**	**82**	**65**	**61**

Table 8. Joint adjustment rating for joint and method of excavation

CASE	Section LK-1	Section LK-2	Section LK-3	Section LK-4	Section LK-5
Planar / αj - αs / Toppling / αj – αs-180°	70°	8°	124°	114°	16°
P/T **F 1**	0.15	1.00	0.15	0.15	0.15
Planar / ßj /	59°	74°	38°	114°	16°
Planar **F2** Toppling **F 2**	1.00	1.00	0.85	1.00	0.85
Planar / ßj - βs / Toppling / ßj + βs /	5°	25°	-18 °	- 25°	- 70°
P/T **F 3**	- 6.00	0.00	- 60.00	- 60.00	- 60.00
Method of Excavation **F 4**	Normal blasting and Mechanical excavation 0-.00	Normal blasting and Mechanical excavation 0-.00	Normal blasting and Mechanical excavation 0-.00	Normal blasting and Mechanical excavation 0-.00	Normal blasting and Mechanical excavation 0-.00

Table 9. Description condition rock mass

CASE	Section LK-1	Section LK-2	Section LK-3	Section LK-4	Section LK-5
Description of Rock Mass	This rock mass is classified as good condition, stable, failure may be blocked, needs occasional supporting	This rock mass is classified as normal condition, partially stable, failure may be some joint or many wedges, needs systematic upporting	This rock mass is classified as very good condition, stable, no failure, may be blocked, no supporting	This rock mass is classified as good condition, stable, failure may be blocked, needs occasional supporting	This rock mass is classified as good condition, stable, failure may be blocked, needs occasional supporting

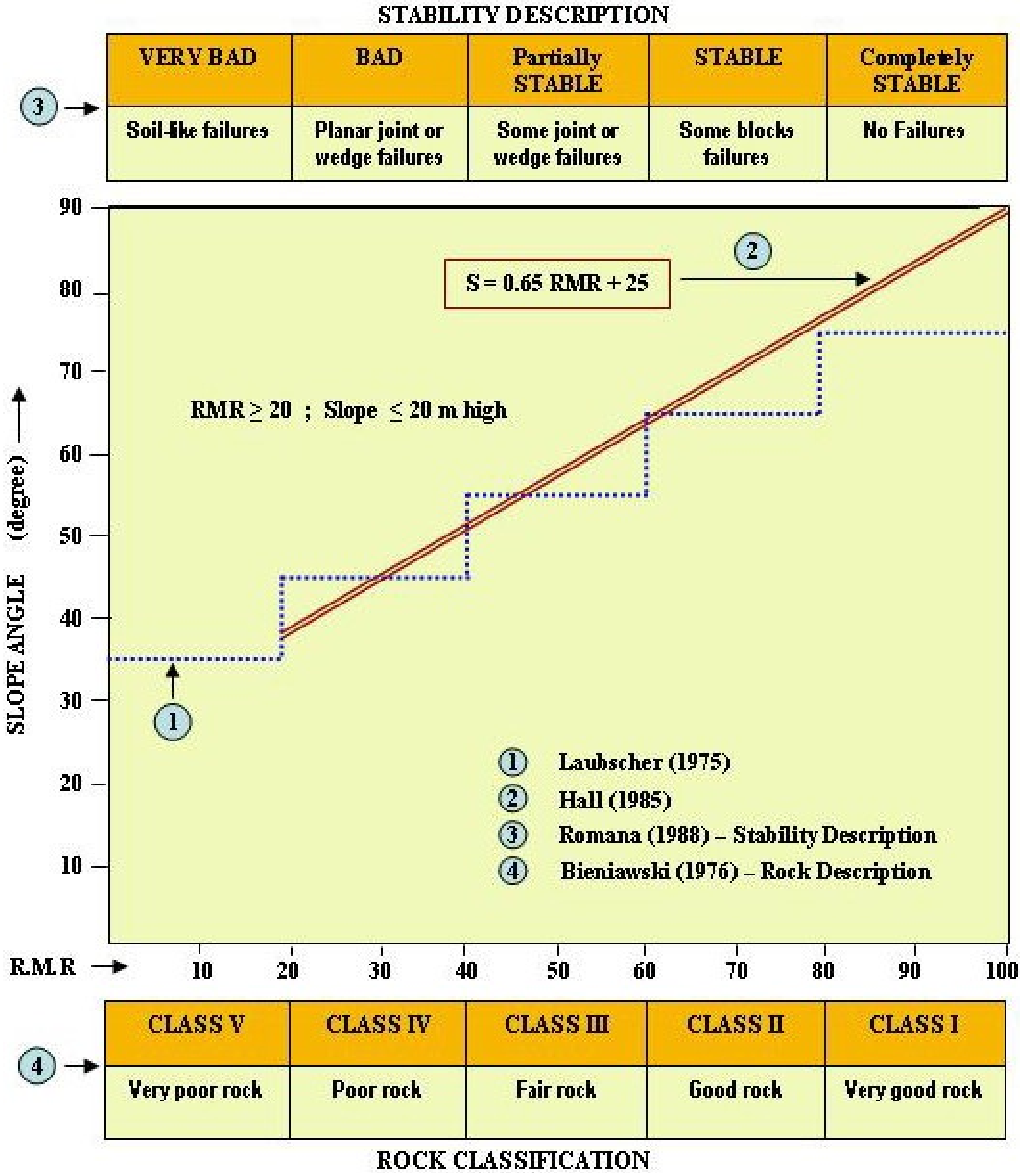

Figure 1. Rock Mass Rating versus Slope Angle Relationship (After Orr, 1992)

Table 10. The recommended angle of slope rock cutting at study area (based on the graph in Figure 1).

Reccomended Angle of Slope	Section LK-1	Section LK-2	Section LK-3	Section LK-4	Section LK-5
Romano (1980) SMR = RMR – (F1 x F2 x F3) + F4	66^o	58^o	89^o	74^o	65^o
Laubscher (1975)	65^o	55^o	75^o	65^o	65^o
Hall (1985) SMR = 0.65 RMR + 25	67^o	63^o	78^o	67^o	65^o
Orr (1992) SMR = 35 ln RMR - 71	75^o	72^o	83^o	75^o	73^o

nuities, condition of discontinuities and ground water conditions (water flow within the rock mass).

The influence of the orientation of discontinuities is applied for final adjustment of the rock mass rating value. According to the standard rock classification of Bieniawski and the total rating value of the observed rock parameters, the section LK-2 shows that the rock mass condition is fair but it needs special care about the stability of slope, the rock mass at section LK-1, 4 and 5 which have total rating value of 65, 65, 61 can be classified as good rock. The rock mass at section LK-3 with a rating value of 82, may be defined as very good rock.

The application of RMR and SMR system at the section LK-2 shows that the rock mass condition is fair but it needs special care about the stability of slope. The rock mass at three section LK-1, 4 and 5 indicated that the rock massed could be classified as good conditions with recommended slope angle in between 65^o-75^o. Whereas the rocks mass at section LK-3, could be classified as very good condition with recommended slope angle in between 75o-89o. According this classification system, the possible failure could be predicted and the supporting slopes could be estimated early in the life of a developing excavation (Table 6). Based on the tentative description of SMR classes presented by Romana (1988), the rock mass at all sections which has SMR value between 81 - 100, could be classified as a very good rock, completely stable with anticipated no failures, and the rock does not need artificial support.

CONCLUSION

There are many factors that influence the stability of rock slopes in the different ways and to different degrees. The sensitivity factor used in this work is based on an empirical approach of Rock Mass Rating and Slope Mass Rating that can indicate the degree of influence on the stability of slope at the study area. The aim of these methods are to provide a link between the influence of geology, strength characteristic, weathering, slope orientation, method of excavation, and water condition to be applied in stability analysis.

The rock mass at three section LK-1, 4 and 5 indicated that the rock massed could be classified as good with recommended slope angle in between 65^o-75^o. Whereas the rocks mass at section LK-3, could be classified as very good condition with recommended slope angle of between 75^o-89^o. According to this classification system, the possible failure could be predicted and the supporting slopes could be estimated early in the life of the developing excavation.

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