J. SE Asian Appl. Geol., Jan–Jun 2014, Vol. 6(1), pp. 19–28

ROCK MASS RATING OF CAVITY LIMESTONE LAYER IN REMBANG, CENTRAL JAVA, INDONESIA

R. Andy Erwin Wijaya*[1], Dwikorita Karnawati[2], Srijono[2], and Wahyu Wilopo[2]

[1]*Department of Mining Engineering, Sekolah Tinggi Teknologi Nasional, Indonesia*
[2]*Department of Geological Engineering, Faculty of Engineering, Universitas Gadjah Mada, Indonesia*

Abstract

Safety of a limestone mining activity requires a good mine design. Mine design is determined by the rock mass quality, which varies from one mine location to another, depending on the geological conditions. The research area is located in limestone quarry of Sale District, Rembang Regency, Central Java Province, Indonesia. In the study area, a cavity zone is exposed at the wall of quarry bench and occurs by a solution process. The cavity layer zone is a weak zone which has caused bench failures. The objective of this research is to evaluate the quality of the cavity limestone layer for a safe mine design using Rock Mass Rating (RMR) system. Final result of the research is a rock mass characterization, specifically for the cavity limestone layer.

Keywords: *Rock mass rating, limestone, cavity layer*

1 Introduction

Limestone mining in Sale District, Rembang Regency, Center Java Province-Indonesia uses the quarry method, which is one of the surface mine methods (Hustrulid and Kuchta, 1995). Reliable estimates of the strength and deformation characteristics of rock masses are required for almost any form of analysis used for the mine design of surface excavations specifically for bench of limestone quarry. Rock mass classification systems used to be of prime importance to estimate rock mass behavior. In 1973 Bieniawski was the first who developed the rock mass rating (RMR) system (CSIR known as the South African Council of Scientific and Industrial Resarch), and sustained its development until 1989. By the available data its versions found more than 350 applications in underground opening, tunnels, underground mines, and open-pit slope designs. The RMR system is used in this research to determine rock mass strength of the surface mine, particularly the limestone quarry. Some parameters are required in the RMR analysis. The main parameters are strength of intact rock, RQD, spacing of discontinuity, condition of discontinuity and groundwater (Table 1).

2 Location and site characterization

The research area is located in limestone quarry of Sale District, Rembang Regency, Central Java Province, Indonesia. The research area is bounded by coordinates: 558000 mE – 558600 mE and 9240400 mN – 9241000 mN (Figure 1).

3 Geological condition

Rembang Zone is part of the Northern East Java Basin that runs from Tuban eastwards through Lamongan, Gresik, and almost the entire island of Madura. The morphology of the Rembang Zone can be divided into three morphological units, namely lowland, undulating hills,

*Corresponding author: R.A.E. WIJAYA, Department of Mining Engineering, Sekolah Tinggi Teknologi Nasional, Indonesia. E-mail: andy_sttnas@yahoo.com

Table 1: Rock mass rating system (Bieniawski, 1989).

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	Ground water	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		

B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F)						
Strike and dip orientations		Very favourable	Favourable	Fair	Unfavourable	Very Unfavourable
Ratings	Tunnels & mines	0	-2	-5	-10	-12
	Foundations	0	-2	-7	-15	-25
	Slopes	0	-5	-25	-50	

C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS					
Rating	100 ← 81	80 ← 61	60 ← 41	40 ← 21	< 21
Class number	I	II	III	IV	V
Description	Very good rock	Good rock	Fair rock	Poor rock	Very poor rock

D. MEANING OF ROCK CLASSES					
Class number	I	II	III	IV	V
Average stand-up time	20 yrs for 15 m span	1 year for 10 m span	1 week for 5 m span	10 hrs for 2.5 m span	30 min for 1 m span
Cohesion of rock mass (kPa)	> 400	300 - 400	200 - 300	100 - 200	< 100
Friction angle of rock mass (deg)	> 45	35 - 45	25 - 35	15 - 25	< 15

E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions					
Discontinuity length (persistence) Rating	< 1 m 6	1 - 3 m 4	3 - 10 m 2	10 - 20 m 1	> 20 m 0
Separation (aperture) Rating	None 6	< 0.1 mm 5	0.1 - 1.0 mm 4	1 - 5 mm 1	> 5 mm 0
Roughness Rating	Very rough 6	Rough 5	Slightly rough 3	Smooth 1	Slickensided 0
Infilling (gouge) Rating	None 6	Hard filling < 5 mm 4	Hard filling > 5 mm 2	Soft filling < 5 mm 2	Soft filling > 5 mm 0
Weathering Ratings	Unweathered 6	Slightly weathered 5	Moderately weathered 3	Highly weathered 1	Decomposed 0

F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING**			
Strike perpendicular to tunnel axis		Strike parallel to tunnel axis	
Drive with dip - Dip 45 - 90°	Drive with dip - Dip 20 - 45°	Dip 45 - 90°	Dip 20 - 45°
Very favourable	Favourable	Very unfavourable	Fair
Drive against dip - Dip 45-90°	Drive against dip - Dip 20-45°	Dip 0-20 - Irrespective of strike°	
Fair	Unfavourable	Fair	

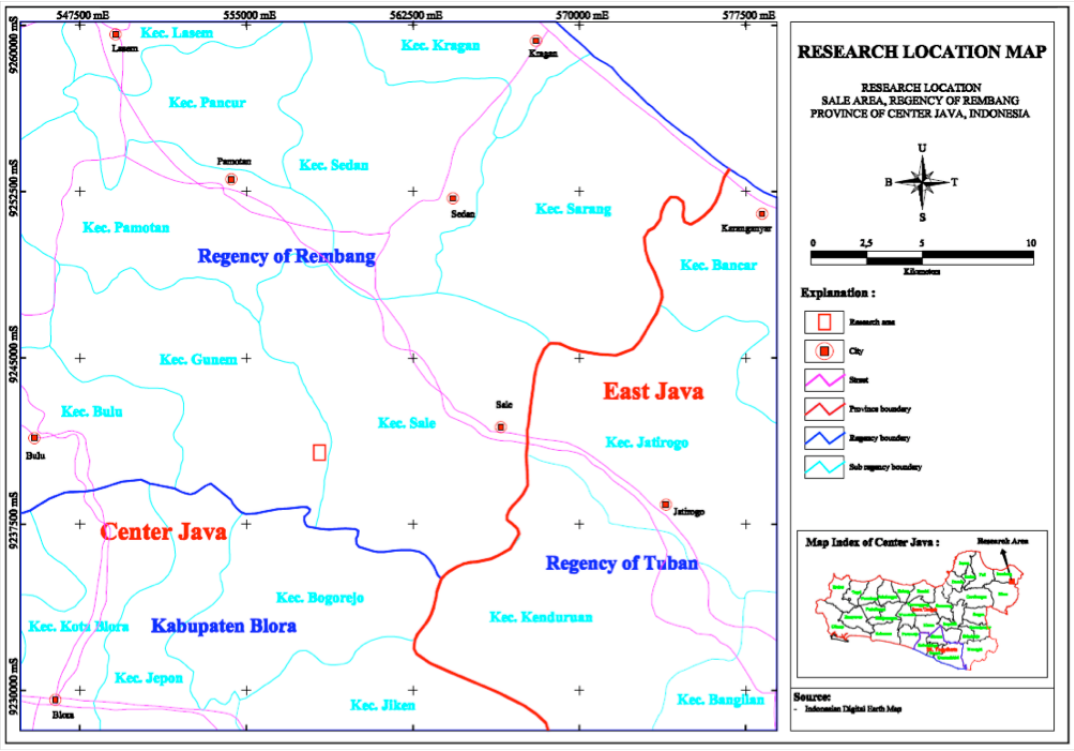

Figure 1: Location of the research area (red box).

and steep hills. Based on the geological map of Jatirogo (Figure 2), the research area is covered by Paciran Formation, which consists of massive limestone and dolomitic limestone (Situmorang, *et al.*, 1992). The rocks in the Rembang Zone have undergone intensive folding and faulting resulting in anticlines and synclines.

4 Solution cavity layer in limestone quarry

In some parts of the limestone quarry area, there is cavity zone, which is formed by solution of limestone, at the wall of quarry bench (Figure 3). The cavity zone is a potentially weak zone of bench failure. The cavity zone is from 50 to 300 cm wide and located at an elevation of approximately 389 m above sea level. The slope of quarry bench ranges from 60° to 75°. Observation of limestone cavity zone was conducted at 10 location points with A to J sample names (Figure 4). Location of each outcrop observation point in coordinates as follow (Table 2) and the cavity layer map (see Figure 5).

Table 2: Coordinates of cavity limestone layer outcrop observation.

Sampel Code	mE	mN
A	558358	9240927
B	558383	9240925
C	558404	9240928
D	558419	9240931
E	558433	9240936
F	558444	9240942
G	558459	9240952
H	558473	9240963
I	558487	9240975
J	558497	9240988

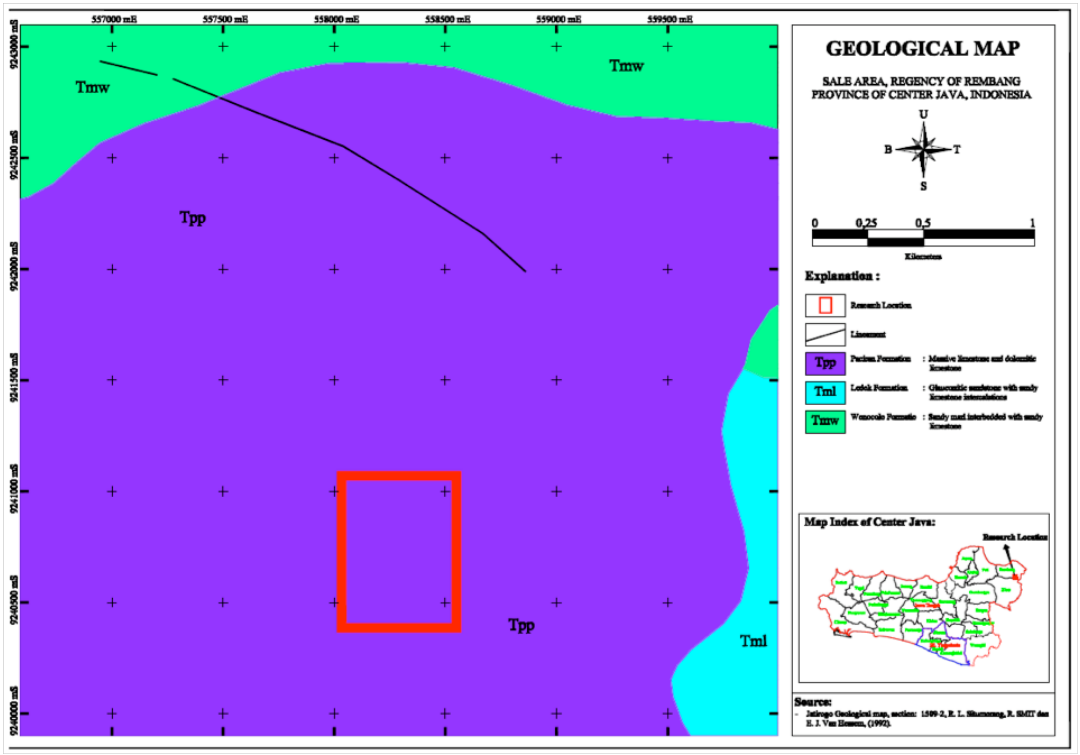

Figure 2: Geological map.

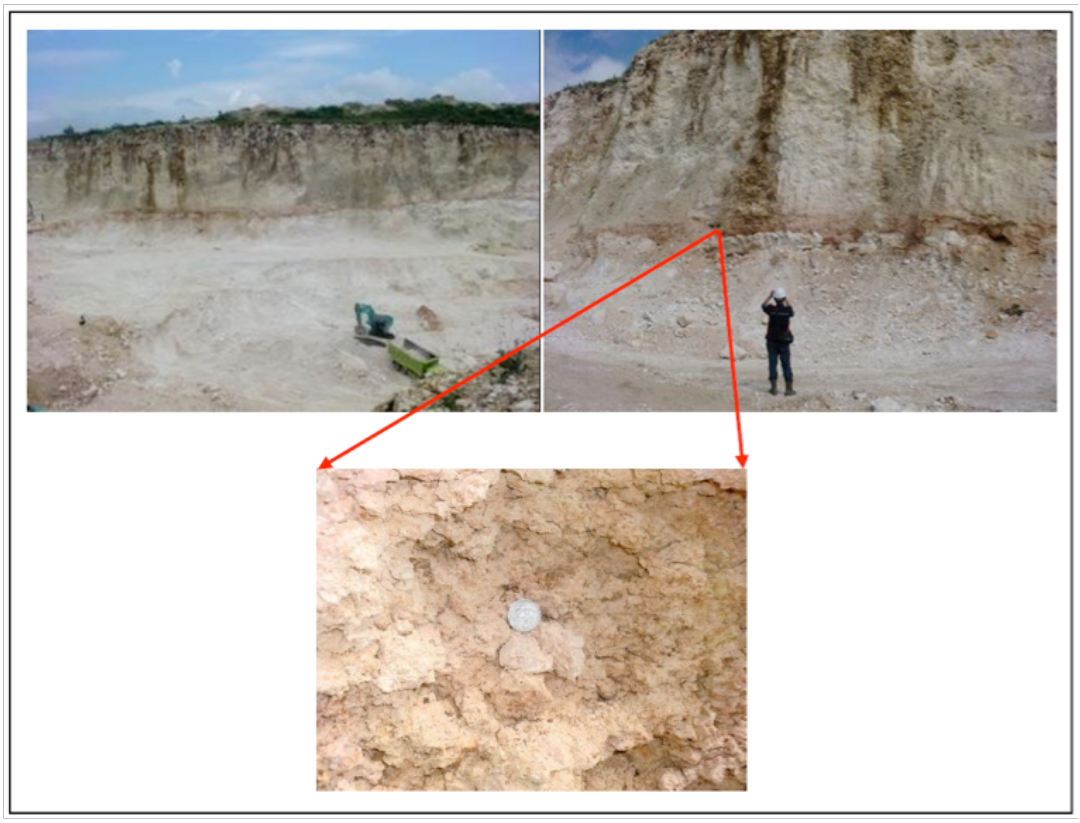

Figure 3: Cavity layer condition in limestone quarry.

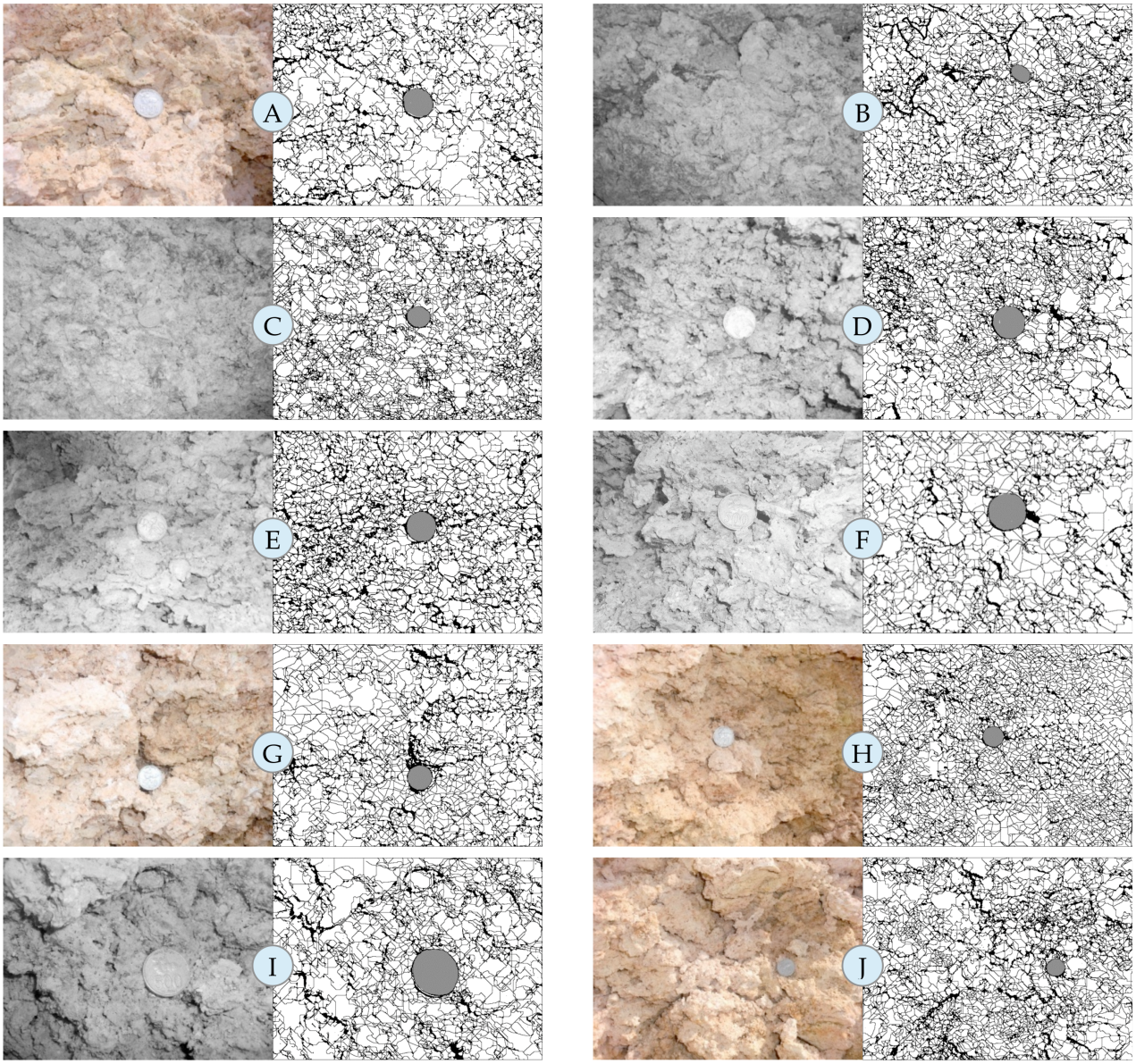

Figure 4: Limestone cavity layer outcrop.

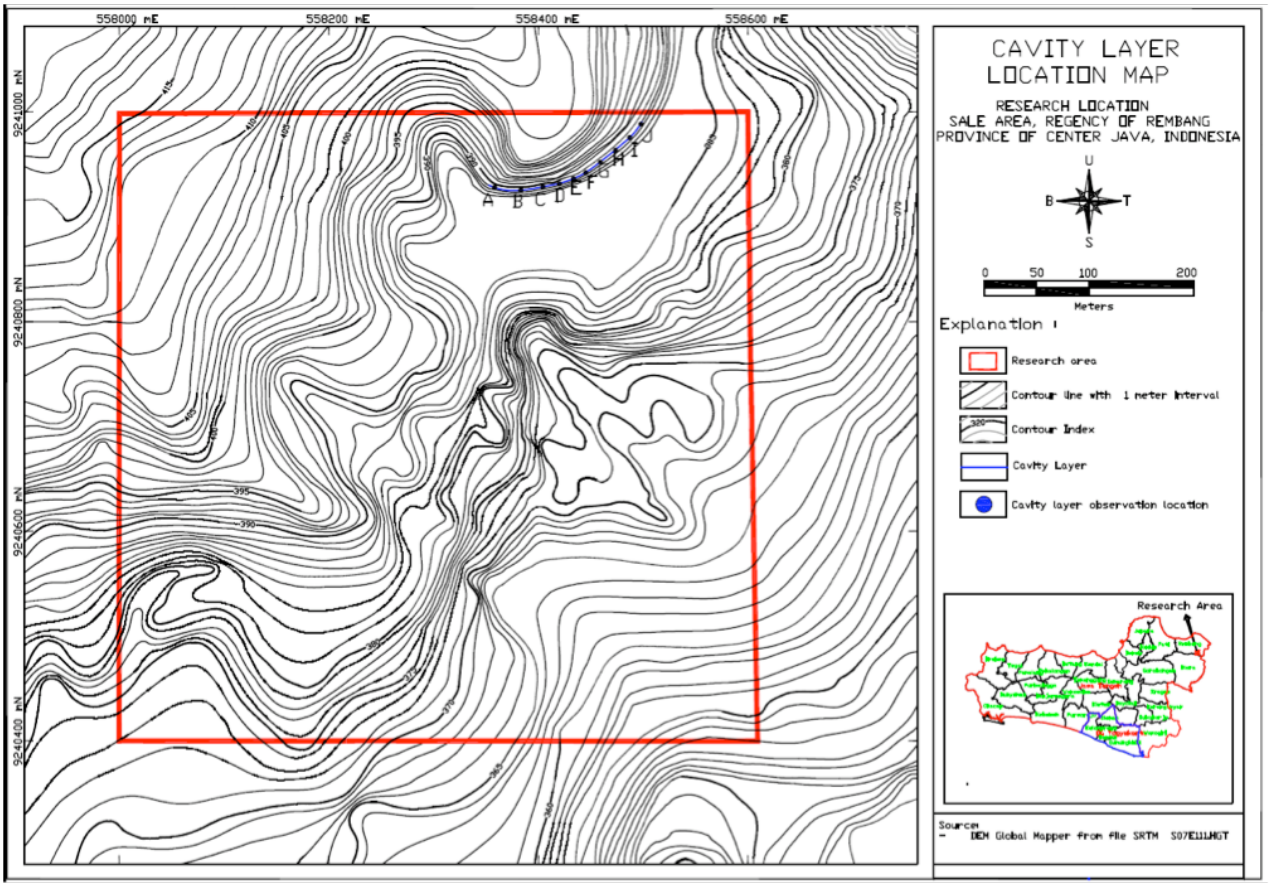

Figure 5: Cavity layer map.

Figure 6: Uniaxial Compressive Strength (UCS) equipment.

5 RMR estimation for rock mass quality of cavity zone in limestone quarry

Identification of rock mass characteristic has been proposed to determine rock mass quality. This system provides a method for estimating the reduction in rock mass strength for different geological conditions as identified by field observations. Classification of rock mass quality based on the RMR, combined 5 (five) main parameters, i.e. strength of intact rock, RQD, spacing of discontinuities, condition of discontinuities and groundwater. Based on outcrop observations in limestone quarry area, all structure condition of the cavity limestone layer are described by the term disintegrated as the rock masses are poorly interlocked, heavily broken rock mass with a mixture or angular and rounded rock pieces (see Figure 4). Based on the uniaxial compressive strength (UCS) test, they have 8-12,4 MPa rock strength (Table 3 and Figure 6). Based on field observations, most of structure and surface conditions are very small block, rough rock surface (Table 4), moderately weathered to weathered (Table 5) and soft infilling material (Table 6). Condition of groundwater is dry (Table 7). The scores of RMR estimation for rock mass strength of cavity layer zone in limestone quarry are between 40 and 46. Estimation of the RMR is described in Table 8.

6 Conclusions

The cavity limestone layer in the study area consist of very small blocks with rough surface, moderately weathered to weathered and soft infilling materials. The scores of RMR estimation for rock mass quality of cavity layer zone in the limestone quarry are between 40 and 46, indicating a poor rock mass quality. The cavity layer zone is a weak zone which has caused bench failures in the limestone quarry area.

Acknowledgment

Authors would like to thank to Management of PT. Sinar Asia Fortuna for the permit and facility provided during the research in the limestone quarry.

References

Bieniawski, Z. T. (1989) Engineering Rock Mass Classification, John Wiley dan Sons, Inc., Canada

Deere D.U. and Deere, D.W. (1967) Uniaxial Compressive Strength (UCS) after 20 years, Report manual, Contract DACW39-86-M-4273, Department of the Army, U.S. Corps of Engineers, Washington DC.

Hustrulid, W. and Kuchta, M. (1995) Open Pit Mine Planning and Design, Volume 1 Fundamental, A.A. Balkema, Roterdam, Brookfield.

Situmorang, R. L., Smit, R., dan Van Vessem, E. J. (1992) Peta Geologi Lembar Jatirogo, Jawa, 1509 – 2, Skala 1:100.000, Pusat Penelitian dan Pengembangan Geologi, Badan Geologi, Departemen Energi dan Sumberdaya Mineral, Bandung.

PT. Sinar Asia Fortuna, 2013, Rembang Limestone Quarry, Final Report, Rembang, Jawa Tengah.

Table 3: Uniaxial Compressive Strength (UCS) test.

Parameters	Sample Code									
	A	B	C	D	E	F	G	H	I	J
Force (kN)	30	24	25	25	20	22	31	30	22	31
Area (sqcm)	25	25	25	25	25	25	25	25	25	25
UCS (MPa)	12	9.6	10	10	8	8.8	12.4	12	8.8	12.4

Table 4: RQD score.

No	Sample Code	Lithology	Spacing of discontinuity (m)	Jv	RQD (%)	Score
1	A	Limestone	0.027	37.03	0	3
2	B	Limestone	0.022	45.45	0	3
3	C	Limestone	0.027	37.03	0	3
4	D	Limestone	0.025	40.00	0	3
5	E	Limestone	0.019	52.63	0	3
6	F	Limestone	0.019	52.63	0	3
7	G	Limestone	0.032	31.25	11.87	3
8	H	Limestone	0.027	37.03	0	3
9	I	Limestone	0.019	52.63	0	3
10	J	Limestone	0.032	31.25	11.87	3

Table 5: Spacing of discontinuity score.

No	Sample code	Lithology	Spacing of discontinuity (m)	Score
1	A	Limestone	0.027	5
2	B	Limestone	0.022	5
3	C	Limestone	0.027	5
4	D	Limestone	0.025	5
5	E	Limestone	0.019	5
6	F	Limestone	0.019	5
7	G	Limestone	0.038	5
8	H	Limestone	0.027	5
9	I	Limestone	0.019	5
10	J	Limestone	0.032	5

Table 6: Condition of discontinuity score.

Sample Code	Persistence (m)	Aperture (mm)	Roughness	Infilling	Weathering	Score
A	2.55	1.4	Rough	Soft filling (<5mm)	Moderately weathered	
Score	4	1	5	2	5	17
B	2.78	1.5	Rough	Soft filling (<5mm)	Weathered	
Score	4	1	5	2	3	15
C	2.63	1.6	Rough	Soft filling (<5mm)	Weathered	
Score	4	1	5	2	3	15
D	2.48	1.4	Rough	Soft filling (<5mm)	Weathered	
Score	4	1	5	2	3	15
E	2.25	1.2	Rough	Soft filling (<5mm)	Weathered	
Score	4	1	5	2	3	15
F	1.95	1.3	Rough	Soft filling (<5mm)	Weathered	
Score	4	1	5	2	3	15
G	1.84	1.7	Rough	Soft filling (<5mm)	Moderately weathered	
Score	4	1	5	2	5	17
H	1.65	1.6	Rough	Soft filling (<5mm)	Moderately weathered	
Score	4	1	5	2	5	17
I	1.77	1.8	Rough	Soft filling (<5mm)	Weathered	
Score	4	1	5	2	3	15
J	1.58	1.5	Rough	Soft filling (<5mm)	Moderately weathered	
Score	4	1	5	2	5	17

Table 7: Groundwater score.

No	Sample Code	Lithology	Condition of Groundwater	Score
1	A	Limestone	Dry	15
2	B	Limestone	Dry	15
3	C	Limestone	Dry	15
4	D	Limestone	Dry	15
5	E	Limestone	Dry	15
6	F	Limestone	Dry	15
7	G	Limestone	Dry	15
8	H	Limestone	Dry	15
9	I	Limestone	Dry	15
10	J	Limestone	Dry	15

Table 8: RMR estimation of cavity layer zone in limestone quarry.

No	Sample Code	Lithology	UCS	RQD	Spacing of discontinuity	Condition of discontinuity	Groundwater	Basic RMR	Class of rock mass
1	A	Limestone	2	3	5	17	15	42	III (fair)
2	B	Limestone	2	3	5	15	15	40	IV (poor)
3	C	Limestone	2	3	5	15	15	40	IV (poor)
4	D	Limestone	2	3	5	15	15	40	IV (poor)
5	E	Limestone	2	3	5	15	15	40	IV (poor)
6	F	Limestone	2	3	5	15	15	40	IV (poor)
7	G	Limestone	2	3	5	17	15	42	III (fair)
8	H	Limestone	2	3	5	17	15	42	III (fair)
9	I	Limestone	2	3	5	15	15	40	IV (poor)
10	J	Limestone	2	3	5	21	15	46	III (fair)