Determining of Coefficient Correlation between UCS and PLI data for Various Rock Types at Batu Hijau Mine PT Amman Mineral Nusa Tenggara

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Abstract

The Batu Hijau Mine is one of the biggest gold-copper producer in Indonesia which operated by PT Amman Mineral Nusa Tenggara (PTAMNT). The mine site is located in the southwest corner of Sumbawa Island in the Sunda-Banda Archipelago in Indonesia. Based on the tectonic plate perspective, the Sumbawa Island lies along the tectonically active rock sequences.

Refers to the geological model from comprehensive study starting from the exploration up to exploitation stages, there are four rock types that formed the slope at Batu Hijau Mine, namely volcanic rock, diorite, tonalite and young tonalite. The volcanic rock as a host rock is the most dominant material among the other rocks type which expose on the north-west, west and south wall.

This study was focused on determining of the index conversion factor of the relation between uniaxial compressive strength (UCS) and point load test (PLT) data which obtained from the laboratory test result. The correlation factor for predicting UCS value from the PLT data for each rock type has shown the good correlation with the average of regression value is 0.88.

Keywords : *Batu Hijau, Uniaxial Compressive Strength, Point Load Test, Conversion Factor.*

INTRODUCTION

The Batu Hijau Mine is one of the biggest copper-gold mine in Indonesia which operated by PT Amman Mineral Nusa Tenggara (PTAMNT). The mine site is located at the south-west part of the Sumbawa Island, West Nusa Tenggara Province – Indonesia. Based on the geological perspective, the Batu Hijau Mine area is very unique due to all of the geological aspect are significantly impacted to the pit wall instability event.

The above conditions may be strongly influenced by the subduction zone from the active tectonic plates which located in the southwestern of the study. Garwin (2002) describes the Sumbawa Island lies at the major structural discontinuity in the Sunda-Banda arc, which is characterized by a reversal in polarity of recent volcanism by the intersection of northeasterly and northwesterly oriented arc-transverse tectonic lineaments (Figure 1).

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GEOLOGICAL CONDITION

In general, Batu Hijau pit consists of three different lithology namely volcanic, diorite and tonalite. According to Clode et.al. 1999, volcanic is the oldest rock and covers Batu Hijau pit walls dominantly. At the northeast part of the pit, volcanic is intruded by quartz diorite, and then followed by porphyry tonalyte intrusion at the contact zone between volcanic and diorite which is at the middle part of the pit The point load test (PLT) data was obtained from the laboratory test result that conducted by internal laboratory owned by the company at site/project area. Meanwhile, the uniaxial compressive strength (UCS) data was obtained from the external laboratory as requested by the company.

In order to define the coefficient correlation of the UCS and PLI data, the result of each test from all of the rock type was evaluated by the statistical approach. The correlation method that used in this study is squares regression analysis.

(Figure 2).

Tonalyte intrusion occurred several times, and mineralization process of Batu Hijau porphyry mostly associated with the early intrusion of tonalyte (Old – Intermediate tonalyte) which is indicated by the presence of quartz veins intensively. Meanwhile, the latest intrusion (young tonalyte) is not associated with mineralization and categorized as waste rock at the middle part of the ore body (Clode at.al. 1999).

In terms of geological structures, the main faults which control Batu Hijau area are Bambu Santong Fault and Tongoloka Fault. Bambu Santong Fault is located at the north part of Batu Hijau area and trending northeast – southwest. Tongoloka Fault on the other hand, trending relatively northwest – southeast which controls the main structures of the pit and affects mineralization process as well as wall stability.

METHODOLOGY

The core samples for this research study were collected from the Batu Hijau Mine area as shown in the Figure 1 as part of the geology and/or geotechnical drilling program. A total of three rock types were sampled and tested for this purpose as described in the Table 1 below. Collecting of the sample has been conducted by well site geologist/geotechnical engineer in line with the drilling program, meanwhile, the core preparation for both of the laboratory test requirement was performed at the geological core-shed that owned by the company.

Figure 1. Map showing the tectonic element at the Batu Hijau district on the Sumbawa Island (Modified from Garwin, 2002).

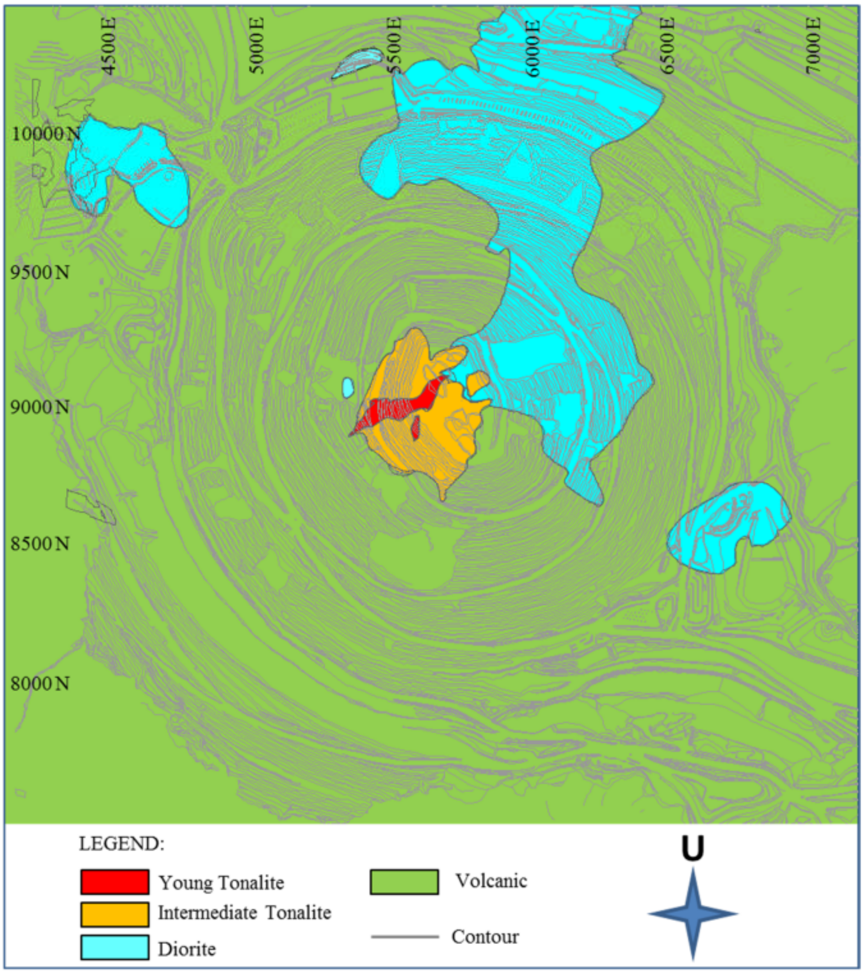

Figure 2. Geology map of Batu Hijau pit shows the lithology distribution (based on end of mine on June 2017).

Table 1. Rock type and details description

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Rock Type	Formation	Rock Description
Volcanic	Early Miocene	Volcanic is the most dominant rock type exposed in the research area (pit wall). In general, this rock type exposed on the north, west and south-west part of the pit that currently being excavated. Based on the petrographic analysis result and plotting into the rock classification as proposed by Streickeisen (1978), this rock type was classified as the andesitic. In terms of rock strength material, the UCS values range from 80 – 100 MPa.
Diorite	Mid Miocene	Diorite is the intrusion rock which exposed at the northeast part of the research area (Batu Hijau pit wall). Based on petrographic analysis, diorite is classified into two types namely equigranular quartz diorite and porphyritic quartz diorite. In terms of rock strength, the UCS value is range from 60 – 80 Mpa.
Tonalite	Mid Miocene	Tonalite is a sub vertical intrusion which located in the middle part of research area (pit wall). Based on petrographic analysis, tonalyte is divided into two types namely old-intermediate tonalite and young tonalite. These two types of rocks are distinguished by its quartz contents. Young tonalite contain more quartz and bigger grains compared to the old-intermediate tonalite. In terms of rock strength, the UCS value is range from 100 – 120 Mpa.

Data

A number of UCS and PLI tests were carried out in both internal and external lab. The data used for the analysis is the existing data from drilling project and laboratory test result within the period of 2003 to 2013.

All of core samples from the drilling result were collected by well site geologist during the drilling operation at site, and then subsequently prepared in core-shed to conduct the laboratory test requirement.

Details of the UCS and PLI data that used in this study can be seen in the appendix below.

The RESULT & ANALYSIS

The various correlations between UCS and PLI were found through the analysis of statistical regression. All functions in the graph; linear, power as well as exponential, showed similar result which is increase of PLI value will be followed by increase of UCS value (positive relationship). Index of coefficient factors to determine UCS from PLI data have been proposed by a number of previous researchers (Table 2). However, based on the geotechnical practice the value coefficient (k) will be depended on the strength parameter that may be different for each specific

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area due to influence of internal and/or external factor.

Based on the distribution of coefficient correction as shown in the Table 2 above, indicates that the values of the coefficient are varying which is possible caused by specific of rock strength material of each area and geological condition itself.

The analysis has been carried out in order to determine the coefficient correlation. Both UCS and PLI data were plotted into the graph and linear-fit curve was utilized in determining the coefficient because this function provides better prediction of the coefficient value.

Table 2. Summary of the coefficient correction factor from previous research (modified from Akram & Bakar, 2007).

No	Formula	Proposed by
1	USC = (15.3 x Is_{50}) + 16.3	D'Andrea et al (1964)
2	UCS = 24 x Is_{50}	Broch & Franklin (1972)
3	UCS = (14 + 0.175D) x Is_{50}	Bieniawski (1975)
4	UCS = (20-25) x Is_{50}	ISRM (1981)
5	UCS = (23 x Is_{50}) + 13	Cargill & Shakoor (1990)
6	UCS = (23.62 x Is_{50}) – 2.69; for coal	Rusnak & Mark (2000)
	UCS = (8.41 x Is_{50}) + 9.51; for other rock	
7	UCS = 9.08 Is_{50} +9.32	Fener et all (2005)

Furthermore, the relationship of UCS and PLI can be defined from the equation below:

UCS = k x $Is_{(50)}$

Where:
UCS = uniaxial compressive strength.
k = coefficient.
$Is_{(50)}$ = point load strength index

Conversion Factor at Volcanic Rock

The relationship between UCS and PLI of volcanic rock is shown in the Figure 3 below. According to the graph, the regression value is 0.92 and the equation of linear function is:

y = 0.0619 x.

where:
y = represent PLI value,
x = represent UCS value.
Therefore, y = 0.0619 x, is equals to PLI = 0.0619 UCS,
UCS = (1/0.0619) PLI
= 16.16 PLI

Hence, the coefficient correlation (k) between UCS and PLI of volcanic rock in Batu Hijau is 16.16.

Conversion Factor at Diorite Rock

The relationship between UCS and PLI of diorite rock is shown in Figure 4. The graph shows regression value is 0.97 and the equation of linear function is:

y = 0.0585 x.

y = represent PLI value,
x = represent UCS value.

Therefore, y = 0.0585 x, is equals to PLI = 0.0585 UCS,
UCS = (1/0.0585) PLI
= 17.09 PLI

Hence, the coefficient correlation (k) between UCS and PLI of diorite rock in Batu Hijau is 17.09.

Conversion Factor at Tonalite Rock

The relationship between UCS and PLI of tonalite rock is shown in Figure 5 below. The graph shows regression value is 0.78 and the equation of linear function is:

y = 0.0548 x.

y = represent PLI value,
x = represent UCS value.

Therefore, y = 0.0548 x, equals to PLI = 0.0548 UCS,
UCS = (1/0.0548) PLI
= 18.25 PLI

Hence, the coefficient correlation (k) between UCS and PLI of tonalite rock in Batu Hijau is 18.25.

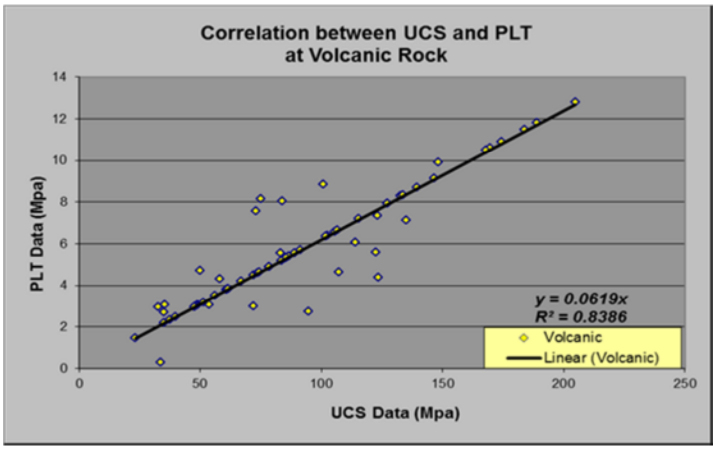

Figure 3. The relation between UCS and PLI data for volcanic rock.

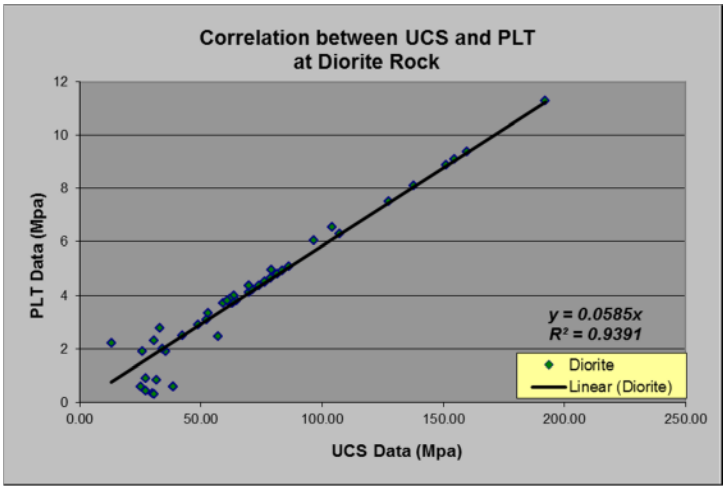

Figure 4. The relation between UCS and PLI data for diorite rock.

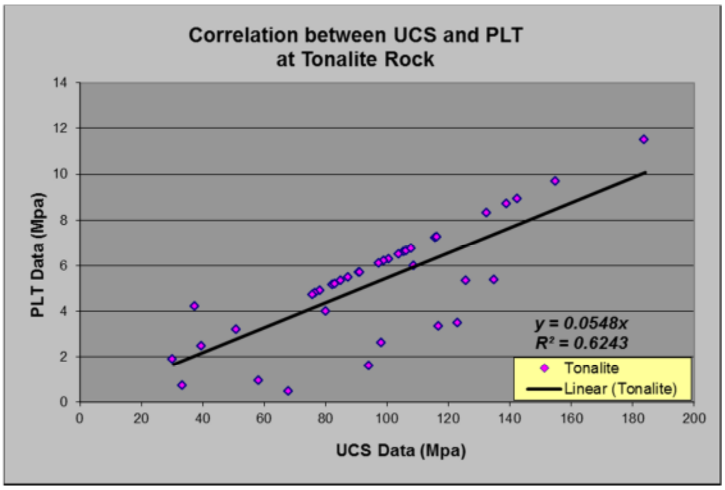

Figure 5. The relation between UCS and PLI data for tonalite rock.

CONLUSION

Based on the analysis as represent from the regression-correlation result, the conclusion of the study can be summarized as follows:

The PLT test is the most reliable practical laboratory test to determine UCS data. It is cheap, easy and quick result for supporting slope stability analysis purposes based on UCS data. At the research area, the coefficient correlation for determining UCS value from the PLI data depends on the rock type material as suggested below:

- Volcanic material; the coefficient is 16.16,
- Dirotite material; the coefficient is 17.09, and
- Tonalite material; the coefficient is 18.25.

The analysis found that the k-factor will vary subjected to the each rock type as mentioned above. Furthermore, the result of correlation between UCS and PLT data has indicated good correlation as represented by the graphs with the linier regression value more than 0.90 which can be classified as a high correlation.

The k-factor is also can used for guidance of determine of estimate intact rock strength parameter while performing scan-line geotechnical mapping on the wall exposed.

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Appendix

Table 1. List of UCS and PLT data at volcanic rock material that used in this analysis.

No	Volcanic	
	UCS (Mpa)	PLT (Mpa)
1	75	8.17
2	83	5.55
3	72	2.99
4	50	4.73
5	84	8.05
6	135	7.14
7	35.3	3.08
8	34.9	2.71
9	53.8	3.07
10	33.6	0.28
11	72.9	7.57
12	58.1	4.32
13	32.6	2.95
14	123.4	4.40
15	113.9	6.06
16	94.71	2.74
17	48.77	3.09
18	100.84	8.85
19	123.20	7.35
20	122.36	5.59
21	107.22	4.66
22	78.40	4.90
23	84.80	5.30
24	72.00	4.50
25	73.60	4.60
26	169.60	10.60
27	102.40	6.40
28	127.20	7.95
29	168.00	10.50
30	188.80	11.80
31	184.00	11.50
32	148.40	9.90
33	174.40	10.90
33	174.40	10.90
34	132.80	8.30
35	48.48	3.03
36	34.88	2.18
37	61.44	3.84
38	23.20	1.45
39	47.84	2.99
40	60.80	3.80
41	60.64	3.79
42	39.68	2.48
43	91.36	5.71
44	51.20	3.20
45	37.44	2.34
46	56.16	3.51
47	115.20	7.20
48	204.80	12.80
49	139.52	8.72
50	133.60	8.35
51	86.40	5.40
52	146.56	9.16
53	105.60	6.60
54	85.44	5.34
55	67.04	4.19
56	61.44	3.84
57	106.40	6.65
58	127.20	7.95
59	47.52	2.97
60	101.76	6.36
61	78.40	4.90
62	74.24	4.64
63	83.36	5.21
64	88.96	5.56
Average	**91.02**	**5.70**

Table 2. List of UCS and PLT data at diorite rock material that used in this analysis.

No	Diorite	
	UCS (Mpa)	PLT (Mpa)
1	33.00	2.78
2	57.00	2.44
3	30.00	0.33
4	38.60	0.58
5	30.80	2.31
6	30.70	0.29
7	27.40	0.43
8	25.00	0.57
9	38.40	0.57
10	25.90	1.89
11	27.10	0.88
12	31.70	0.83
13	35.40	1.89
14	13.10	2.21
15	104.00	6.53
16	64.60	3.80
17	69.70	4.10
18	151.30	8.90
19	59.20	3.70
20	159.80	9.40
21	62.90	3.70
22	63.68	3.98
23	137.70	8.10
24	76.16	4.48
25	192.10	11.30
26	127.50	7.50
27	34.00	2.00
28	76.50	4.50
29	86.36	5.08
30	78.96	4.94
31	107.27	6.31
32	71.23	4.19
33	154.70	9.10
34	42.50	2.50
35	62.73	3.69
36	63.24	3.72
37	81.60	4.80
38	52.19	3.07
39	73.95	4.35
40	61.81	3.86
41	69.72	4.36
42	69.92	4.37
43	60.93	3.81
44	96.68	6.04
45	53.09	3.32
46	83.47	4.91
47	78.88	4.64
48	48.96	2.88
Average	**69.20**	**3.96**

Table 3. List of UCS and PLT data at tonalite rock material that used in this analysis.

No	Tonalite	
	UCS (Mpa)	PLT (Mpa)
1	109	5.99
2	135	5.39
3	126	5.35
4	117	3.33
5	68.2	0.474
6	94.2	1.607
7	33.7	0.715
8	80.3	4.00
9	123.1	3.48
10	98.4	2.616
11	58.4	0.952
12	37.5	4.23
13	139.2	8.7
14	91.20	5.70
15	78.40	4.90
16	100.80	6.30
17	85.28	5.33
18	99.20	6.20
19	184.00	11.50
20	155.20	9.70
21	132.80	8.30
22	97.60	6.10
23	76.80	4.80
24	30.40	1.90
25	82.58	5.16
26	39.68	2.48
27	91.36	5.71
28	105.60	6.60
29	87.69	5.48
30	75.84	4.74
31	115.84	7.24
32	104.16	6.51
33	116.48	7.28
34	142.72	8.92
35	106.40	6.65
36	83.39	5.21
37	108.00	6.75
38	51.04	3.19
Average	**96.38**	**5.25**

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