

Feasibility Study of Crushing Plant Location at Quarry Andesite, West Java, Indonesia, using Rock Mass Classification and Kinematic Analysis

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Abstract. In engineering of open pit mine, safety is the most basic thing to be focused on, especially the slopes in the mining area. Hence, characteristic of rock slopes need to be determined precisely and accurately to identify the stability of the slopes. This study is done in andesite quarry slope in Jelesong, Bandung District, West Java, Indonesia, which is the location of crushing plant construction by Widaka Indonesia Inc. The purpose of this research is to determine the mass characteristic of andesite quarry slope in order to know the slope feasibility level as a construction location of crushing plant. The method used to determine the mass characteristic is by identifying the rock mass based on RMR (Rock Mass Rating) by Bieniawski (1989) and also the type of failure, which could potentially happen based on kinematics analysis. The slope condition is analyzed based on field investigation and laboratory test results. RMR value shows that the rock mass is between 63-78, which is included into class II (Good Rock). Kinematics analysis also gives result that the rock slope will not have a failure or in other words, in a stable condition. Based on the research results, the location is suitable to construct a crushing plant.

1. Introduction

Technological developments require people to continue to improve all their needs, every form of development affect the system of human life, one of which is the development of Indonesian mining companies, Indonesian mining companies are now constantly moving and evolving in line with the progress of the era, in every sector of mining provides benefits both material and non-material to the public. However, in the operation of mining companies are required to uphold the safety values of work that will be able to support performance in order to achieve maximum results. Security analyzes are mandatory for each mining sector, especially at operating points with high disaster risk. It should be noted that in the mining industry there are parts of the slopes that are highly susceptible to sliding so that further analysis of the slope stability and safety conditions is required.



Analyses on the mining slopes, both new and old slopes, can be done by analyzing the discontinuities found on the slope. This is because the collapse of a slope can start from and follow the areas of discontinuity on the slope. The discontinuity field can be a joint, fault, fracture, and so on. Other analyzes should also be conducted to determine the potential problems on the slopes.

The object of research is the slope of andesite, Jelesong, West Java, Indonesia. With a slope length of 49.75 m and a slope of $\pm 76^\circ$. On the slope the rock mass is divided into three parts based on the stout intensity and weathering conditions. This paper explains how the condition of the slope as a whole so it can be known the type of improvement which is recommended to reduce the potential failure that may occur.

2. Research Location

Based on the regional geological map of Garut-Pamempeuk [1], its location is in the Old Andesite Formation Malabar Waringin-Bredil. This formation consists of lava, tuff, and breccia. On the observed slopes overall experience weathering at slightly weathered to moderately weathered levels. Andesite weathered in slightly weathered weather, where at this weathering level, texture and mineral rocks can still be identified and rocks are still in harsh conditions, which occur only partial color changes in the andesite, whereas in moderately weathered color changes occur almost throughout the rock body. Based on figure 1, the research location in Andesit Quarry Jelesong site, Widaka Indonesia Inc., Bandung District, West Java, Indonesia.

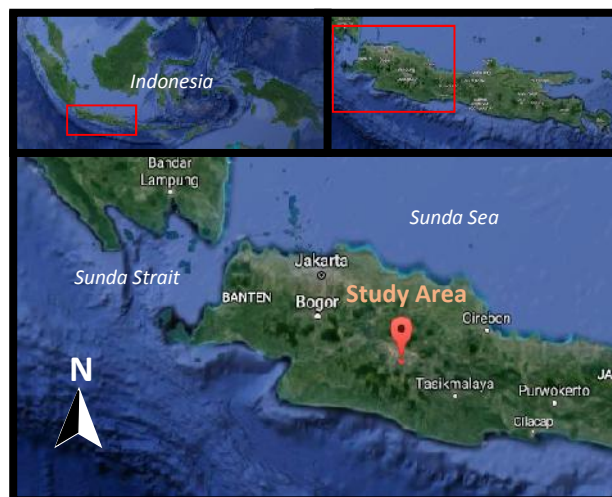


Figure 1. Research location in Andesit Quarry Jelesong site, Widaka Indonesia Inc., Bandung District, West Java, Indonesia.

3. Methods

Research was conducted through field data collection, laboratory test, and studio analysis. Field data collection was in the form of rock description and weathering level, mapping of discontinuity plane, description of groundwater condition, and geometry measurement of the slope. Mapping the discontinuity plane used the scanline mapping method. Laboratory tests included measurement of physical properties of rocks, and point load index test. Results of field and laboratory data collection was studio analyzed by using Rock Mass Rating (RMR), Slope Mass Rating (SMR), SMR Modification, and Kinematic Analysis.

3.1. Rock mass classification

Geomechanics Classification or Rock Mass Rating is an empirical method used for weighting a rock mass. Rock Mass Rating proposed by [2] uses several parameters to assess the rock mass, namely; uniaxial compressive strength (UCS), rock quality designation (RQD), discontinuity spacing, discontinuity conditions, and groundwater conditions. The Slope Mass Rating (SMR) method proposed by Romana is a method used to determine the level of slope stability along with its support type in accordance with the conditions of the slope [3]. The SMR value is derived from the RMR Bienieawski value by the addition of several adjustment factors F1, F2, F3, and F4 from the discontinuity and slope orientation as well as the excavation type used on the slope.

$$SMR = RMR_{basic} + (F_1 \times F_2 \times F_3) + F_4 \quad (1)$$

With,

- F1 depends on the angle difference between strike of discontinuity plane (α_j) and strike of slope (α_s), $F_1 = [1 - \sin(\alpha_s - \alpha_j)]^2$.
- F2 is the tangential value of the tilting angle of discontinuity plane, with β_j is the tilting angle of discontinuity, $F_2 = \tan^2 \beta_j$.
- F3 reflects the relationship between the slope surface and the tilting of the discontinuity plane.
- F4 is the alignment factor associated with the excavation method.

Some previous researchers sought for relationship of RMR value to SMR value with angle ($^\circ$) units. SMR with angle units is used as the critical angle allowed on a mine slope in order to make the slope stable. Laubscher discusses the relationship between RMR and SMR [4] (see **Table 1**).

Table 1. The relationship between RMR and critical slope angle recommended by Laubscher [4].

RMR Value	Recommended slope critical angle($^\circ$)
81-100	75
61-80	65
41-60	55
21-40	45
0-20	35

Hall (1985) gave SMR value as follows:

$$SMR (^\circ) = 0.65 RMR - 25 \quad (2)$$

and Orr (1992) suggested the relationship between SMR and RMR as follows:

$$SMR (^\circ) = 35 \ln RMR - 71 \quad (3)$$

3.2. Kinematic analysis

Kinematic analysis for rock slope stability deals with single - faced slopes with planar surface of constant strike [5]. Analysis of the rock failures potential includes planar, wedges, and toppling. Potential rock failures based on Hoek and Bray [6].

4. Results and Discussion

In this study 217 discontinuities were depicted and their orientation was calculated. Based on different degrees of weathering, the slope is divided into 3 parts, namely SC-1, SC-2, and SC-3 (see **Figure 2**). In the SC-1 and SC-3 segments, partial color changes occur in the andesite (discoloration) due to oxidation, with massive structure, and weathering at the Slightly weathered level. In the SC-2 segment, the andesite undergoes a very high discoloration, the phenocryst on the plagioclase has been altered. The rock structure shows that the sheeting joint has a strike/dip N 220° E/57°, with aperture ranging

from 0.1 to 1 mm and is generally filled with clay minerals. SC-2 is weathered at a moderately weathered level.

The rock slopes have varying RMR values from 68 to 78. Overall the rock slope segment is classified in class II (good rock) (see **Table 2**). The value of SMR romana also varies between 55 and 69.1. Based on segment, SC-1 and SC-3 are categorized in class II (Good), while SC-2 is categorized into class III (Normal) (see **Table 3**). Based on the calculation of 3 modified SMR equations, the SMR modification value by Laubscher has the lowest value, making it a critical slope angle. Based on the Laubscher equation [4], 3 stable rock segments with a maximum angle of 65° (see **Table 4**).

The laboratory results showed that the andesite at the study sites had a density of () $1,606 \text{ gr/cm}^3$, and porosity (n) 0.046. Internal friction angle determination () is performed using RocLab 1.0 software with sigci parameter (ϕ), m_i , and Geological Strength Index (GSI). The value of sigci (ϕ) is obtained from the convergence of Point Load Index value [2], the value of m_i is obtained by entering the type of lithology and the GSI value obtained from the conversion of the RMR value [6].

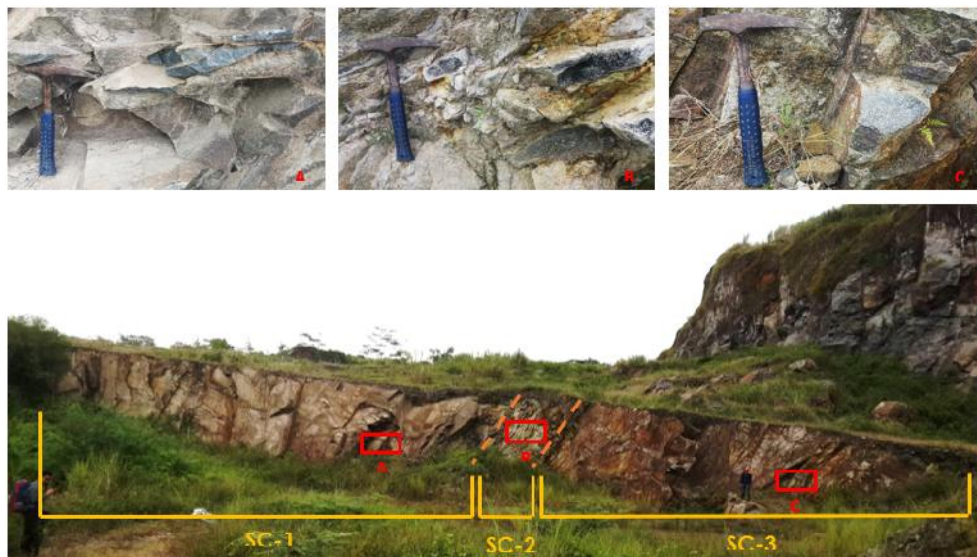


Figure 2. Rock slope is divided into three segments based on the intensity of geological structure and its weathering level, namely SC-1, SC-2, and SC-3. SC-1 and SC-3 undergo slightly weathered which characterized by color change in rocks, while in SC-2 segments moderately weathered are characterized by the large amount of clay minerals resulting from main mineral changes in the rock. Research location in Andesit Quarry Jelesong site, Widaka Indonesia Inc., Bandung District, West Java, Indonesia.

Table 2. Rock Mass Rating value in research location.

RMR Parameter	SC-1 segment (result/value)	SC-2 segment (result/value)	SC-3 segment (result/value)
Uniaxial Compressive Strength	10,69 MPa / 15	7,68 MPa / 12	8,49 MPa / 12
RQD	94,40% / 20	71,29% / 13	92% / 20
Discontinuity Spacing	14,99 cm / 8	5,08 cm / 5	17,08 cm / 8
Discontinuity Condition	Rough surface, aperture 0,1 – 1 mm, discontinuity length 1 – 3 m, soft filling, slightly weathered / 20	Rough surface, aperture 0,1 – 1 mm, discontinuity length 1 – 3 m, soft filling, moderately weathered / 18	Rough surface, aperture 0,1 – 1 mm, discontinuity length 1 – 3 m, soft filling, slightly weathered / 20
Groundwater Condition	Dry / 15	Dry / 15	Dry / 15
Total Value	78	63	75
Rock Mass Class	II (Good Rock)	II (Good Rock)	II (Good Rock)

Table 3. Slope Mass Rating value in research location.

SMR Parameter	SC-1 segment (result/value)	SC-1 segment (result/value)	SC-1 segment (result/value)
F1	79 / 0.15	92 / 0.15	81/0.15
F2	70 / 1	57/ 1	59/1
F3	6/ -6	19/ 0	17/0
F4	Deficient Blasting / -8	Deficient Blasting / -8	Deficient Blasting / -8
Total Value	69.1	55	63
Slope Mass Class	II (good)	III (normal)	II (good)

Table 4. Recommended critical angle based on modified SMR equation [4, 7, 8].

Segment / RMR Value	Laubscher (1975)	Hall (1985)	Orr (1992)
SC-1 / 78	65°	75.7°	81.48°
SC-2 / 63	65°	65.95°	74.00°
SC-3 / 75	65°	73.75°	80.11°

$$\tau_c = 23 \text{ Is}_{(50)} \quad (4)$$

$$\text{GSI} = \text{RMR}_{89} - 5 \quad (5)$$

$\text{Is}_{(50)}$ is the Point Load Index value in 50 mm diameter, the mi value for andesite is 25, RMR_{89} is the RMR value issued by Bieniawski in 1989 [2], The Disturbance Factor Value (D) of mine slope was using a value of 1, which means optimizing the blasting for the production benefit. The calculation result of internal friction angle estimation (α_{est}) can be seen in **Table 5**.

Table 5. Table calculation value of internal friction angle estimation.

Segment	σ_c (Mpa)	mi	GSI	D	$\alpha_{\text{est}}(^{\circ})$
SC-1	245.87	25	73	1	37.07
SC-2	176.64	25	58	1	28.10
SC-3	195.27	25	70	1	35.25

Figure 3 shows the strike and dip projection of all the discontinuities found in the object of this study. Stereography shows the pole point of the joint set of each segment and the intersection point of each segment is not in the daylight envelope zone.

The stereographic projection of the SC-1 segment shows that the intersection between JSC1-B and JSC1-D and the intersection of the JSC1-A joint set with JSC1-C has a smaller plunge value than the Internal friction angle estimation, while the intersection between JSC1-A and JSC1 -D has a larger plunge. This indicates that wedges, planar, and toppling failure do not occur. According to Hoek and Bray, wedges failure can occur if $\alpha_{\text{est}} > \alpha$, where α is the angle of rock slope, α_{est} is the dip of line intersection, and α is the internal friction angle [9]. In SC-2 there is only one joint set, JSC2-A which also shows no planar, wedges, or toppling failure. In the SC-3 segment, there are 2 joint sets, namely JSC3-A and JSC3-B which have smaller plunge values than the internal friction angle estimates, thus SC-3 also has no potential for wedges failure, as well as planar and toppling Failure. Based on the above kinematics analysis it can be said that the slope is in stable condition.

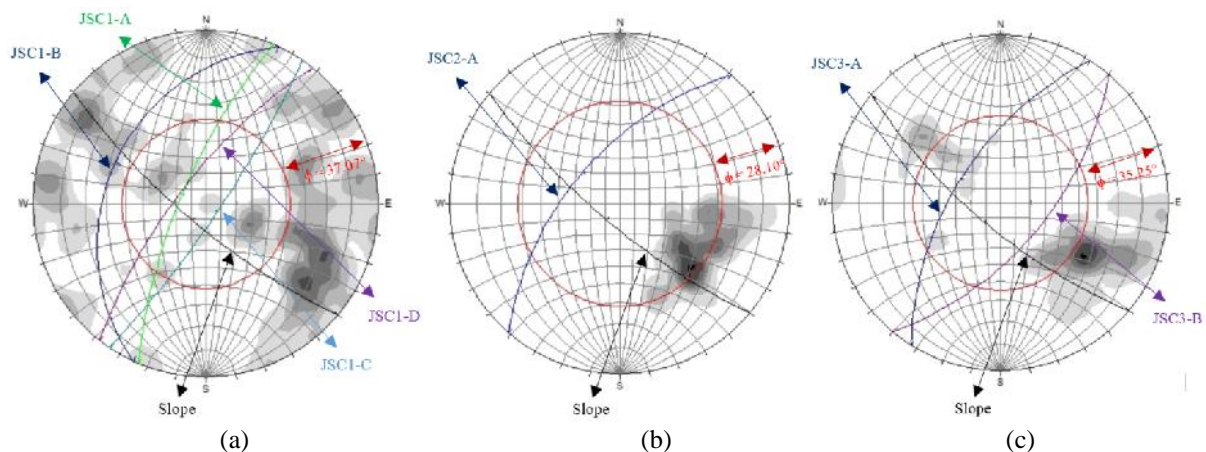


Figure 3. Stereography discontinuities plane on segment slope (a) SC-1, (b) SC-2, and (c) SC-3. Relationship between joint set, slope orientation, and internal friction angle estimation of rock does not cause failure.

Although the rock slopes are in stable condition, slope reinforcement can be used to improve the safety of the slopes. The reinforcement slope used is based on Romana, where SC-1 and SC-3 enter into class IIb with the type of reinforcement used are Toe ditch or fence, nets, spot or systematic bolting, while for SC-2 entry into the class IIIa with reinforcement type is the same as SC-1 and SC-3 but with the addition of spot shotcrete on slope surface [3].

5. Conclusions

Based on the discontinuity and level of weathering, the study area is divided into 3 sections, SC-1, SC-2, and SC-3. Overall the research area is included in the category of class II (Good rock). Based on the kinematics analysis, these rock slopes also do not provide any evidence of failure. Based on the results of research, it can be said that this slope is in stable condition and it can be used as the location point crushing plant. However, increased security should be done to support maximum security. In the SC-1 and SC-3 segments, the Reinforcement can use Toe type ditch on the slope foot combined with nets, and rock bolt systematically. In the SC-2 segment the reinforcement type is the same as SC-1 and SC-3 but with the addition of Spot shotcrete on the slope surface. In addition to mounting reinforcement on the slope, slope stability may be enhanced by minimizing sloping angle at least up to 65° .

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