Slope Stability Analysis in Andesite Stone Mining Rolas Nusantara Tambang ltd. in Pasuruan Regency

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Abstrak

Aktivitas penambangan PT. Rolas Nusantara Tambang perlu dilakukan analisis kestabilan lereng karena pada lokasi tersebut belum pernah dilakukan kajian terhadap kondisi lerengnya. Selain itu, terdapat beberapa masalah yang dapat menyebabkan lereng tidak stabil seperti geometri lereng yang terlalu tegak, adanya bidang diskontinuitas dan lokasi penambangan yang dekat dengan beberapa gunung aktif di Jawa Timur yaitu Gunung Semeru dan Gunung Bromo sehingga potensi gempa dan getaran yang dihasilkan tinggi dan dapat mempengaruhi kestabilan lereng pada lokasi tersebut. Penelitian ini bertujuan untuk menganalisis kestabilan lereng dengan menggunakan Metode Janbu dalam perhitungan faktor keamanan dan metode Monte Carlo untuk probabilitas kelongsoran. Dari hasil penelitian diperoleh nilai faktor keamanan (FK) lereng aktual sebesar 1,703 dan probabilitas kelongsoran (PK) sebesar 0,000% dengan tinggi lereng 12 meter dan kemiringan 850. Kemudian diberikan rekomendasi untuk lereng keseluruhan dengan tinggi keseluruhan 36 meter dan overall slope 570 diperoleh nilai faktor keamanan (FK) sebesar 2,170 dan probabilitas kelongsoran (PK) sebesar 0,000%. Dari hasil tersebut dapat disimpulkan bahwa kondisi lereng dalam kategori aman.

Kata kunci: *Andesite rock; Stabilitas lereng; Metode jambu; Monte-carlo*

Abstract

Mining activities in Rolas Nusantara Tambang Ltd. need to conduct slope stability analysis because in that location, there has never been a study in the condition of the slopes. In addition, there were several problems which could cause unstable slopes such as slope geometry which was too upright, discontinuity fields presence and mining locations where are close to several active volcanoes in East Java, the name are Mount Semeru and Mount Bromo. So, the potential for earthquakes and vibrations was high and it could be affected to the stability of the slopes in that location. The aim of this study was analyzing the slope stability using *Janbu method* to calculate the safety factors and the *Monte Carlo method* for the landslides probability. The study results stated that the actual slope safety factor (FK) was 1.703 and the probability of landslide (PK) was 0.000% with a slope height of 12 meters and a slope of 850. Then recommendations were given for the overall slope with an overall height of 36 meters and an overall slope of 570, the factor value was obtained, safety (FK) of 2.170 and landslide probability (PK) of 0.000%. From these results, it could be concluded that the slope conditions were in the safe category.

Keywords: *Andesite rock; Slope stability; Janbu method; Monte-carlo*

1. Introduction

Mining activities with an open pit mining system will always be faced with geotechnical problems which will certainly affect to the stability of the slopes in the mining site [1], [2]. The open-pit mining system was implemented by mining companies and generally and it had a tiered mining pattern that had the potential to experience landslides. Therefore, it was necessary to conduct a technical study on slope stability analysis in the mining time and at the end of mining [3]. Slope stability is a condition which was stable on a slope shape and dimension. Where the stability of this slope could be influenced by internal and external factors. Internal factors include rock mass conditions, mine design used, and geological conditions of the mining site, while external factors include climate, weathering degrees and external forces. It needs to be a concern for mining companies which implements an open pit mining system.

Rolas Nusantara Tambang Ltd. is one of the mining companies which is currently carrying out andesite mining activities with the quarry method in Ambal-Ambil Village, Kejayan District, Pasuruan, East Java with an IUP area of 20 hectares. In mining activities, it was necessary to analyze the stability of the slopes because there has never been a study of the condition of the slopes in that location. In addition, there were several problems which might cause unstable slopes. The problems included slope geometry which were too upright, the presence of discontinuity areas, and mining locations close to several active volcanoes in East Java; Mount Semeru and Mount Bromo. So, the potential for earthquakes and vibrations is high and it could affect to the stability of the slopes in that location [4]. Based on these problems, it was feared that the slope conditions would become unstable in the future and allow the landslides to occur on the slopes. In this study, slope stability analysis was carried out using the *Janbu method*. This method assumed a circular and noncircular landslide area which have been divided into several slices [5].

As an effort to prevent future landslides, it was necessary to analyze or study slope stability by knowing the classification of rock mass as initial information on rock class or rock quality in the mining site [6] and determining the type of landslide which might occur. Besides, it took into account the value of the safety factor with the aim of obtaining information on slope conditions and knowing the slope geometry according to these conditions. In addition, it aims to prevent work accidents which could achieve in losses to the company [7].

2. Method

In this slope, stability analysis used slide v6.0 software with the resulting output and it was called the value of the factor of safety (FK) and the probability of sliding (PK). The failure criteria used Mohr – Coulomb failure criteria for soil materials and Hoek – Brown for andesite stone materials and the method of calculating the safety factor (FK) used the Janbu method and probability analysis used the Monte – Carlo method. In this research activities, there were several stages of research include:

Preparation stage, in this stage, preliminary study activities were carried out including the collection of initial information and literature studies related to research activities.

Research stage, in this research stage, the activities carried out field observations by taking primary data. The research was conducted in the mining area of Rolas Nusantara Tambang Ltd. Ambal-Ambil Village, Kejayan District, Pasuruan Regency, East Java.

Laboratory Testing Stage, this stage would test the physical properties of the rock by producing the bulk density of the rock.

Data Processing Stage was carried out after the researchers collected the data from field and rock testing in the laboratory. Where data processing activities were carried out with software tools.

Data Analysis Stages, this stage contained rock mass classification analysis, landslide type analysis, actual slope analysis, and overall slope recommendations.

Conclusion Drawing Stage, after the researcher analyzed the data, conclusions was drawn according to the problem formulation and research objectives

3. Results and Discussion

3.1. Laboratory Test Results

Rocks samples were taken in the field and carried on to the laboratory for rock preparation and testing. The tests carried out were in the form of physical properties testing of rocks. One of the parameters of the physical properties test results was to produce the bulk density of the rock [8]. Meanwhile, the mechanical properties data; the shear strength test and the uniaxial compressive strength test, were obtained from company data. The data was obtained from the results of this laboratory test would then be used as input parameters in conducting slope stability analysis. The results of rock testing could be seen in the Table 1.

Table 1. Laboratory test results

No	Litologi	Density (kN/m^3)	Cohesi (kN/m^2)	Friction Angel (^{0})	UCS (MPa)
1	Soil	19,73	22,631	31,495	-
2	Andesit	24,68	-	-	142,184

3.2. Statistical Distribution Parameters

In analyzing slope stability and landslide probability, one of the parameters needed was the statistical distribution. Statistical distribution was needed in the input parameters to assess the probability of mine slope landslides [9]. The results of the statistical distribution could be seen in the Table 2.

Table 2. Statistic distribution

Material	Parameters	Mean	SD	Rel.Min	Rel.Max	Type of Distribution
Soil	Cohesion	22,631	4,9322	4,8930	4,8930	Gamma
	Friction angle	31,495	3,3513	3,3450	3,3450	Gamma
	Unit Weight	19,32	0,5657	0,4	0,4	Gamma
Andesite	Unit Weight	24,68	18,0391	18,768	24,69	Gamma
	Hoek-brown a parameter	0,500327	0	0	-	Normal
	Hoek-brown m parameters	11,5842	0	0	-	Normal
	Hoek-brown s parameters	0,13147	0	0	-	Normal
	UCS	142,184	52,8447	93,614	89,006	Normal

3.3. Rock Mass Rating (RMR)

In assessing slope stability, it was very important to know the rock mass characteristics of the slope-forming material because rock mass classification was very precise method for representing rock mass characteristics [6]. Based on the results of the Rock Mass Rating (RMR), calculation used RMR classification. It was found that the research area had a total RMR value or weight of 91 which consisted of a UCS value of 142.184 MPa and a weight of 12. The average RQD value was 95.45% had a weight of 20. The average discontinuity distance was 0.6184 m and a weight of 15. The discontinuity condition was discontinuous, the surface was very rough, not weathered, no filler material, very tight joint spacing < 1 mm had weight of 30. Groundwater conditions which were dominated by dry conditions had a weight of 14. And a very favourable discontinuity orientation with a dip between 450-900 had a weight of 0. From the results of these calculations, it could be seen that the rock mass classification (Rock Mass Rating) in the location was included in the very good category.

3.4. Landslide Type

Based on the results of plotting the strike/dip joint data on the Dips v5.0 software, it could be seen that in the research location there were types of landslides which might occur; wedge avalanches with the avalanche direction of N 214^0 E and the direction of the force that affected the landslide was N 304^0 E. The results analysis of t avalanche type could be seen in the Figure 1 and Figure 2.

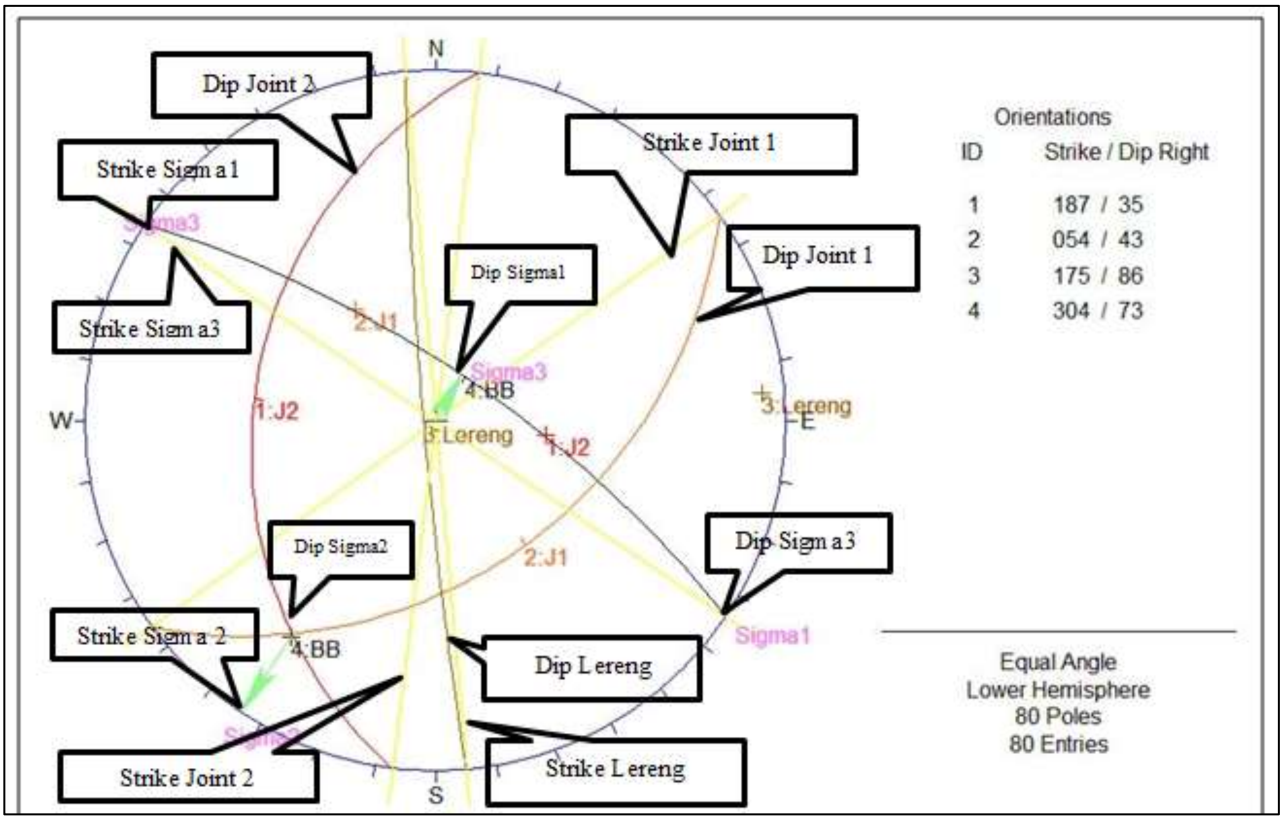

Figure 1. Landslide type analysis results

3.5. Actual Slope Safety Factor Analysis

To analyse the stability of a safe slope, it was necessary to conduct a mine slope design modelling [10]. Analysis results of the actual slope safety factors were carried out based on the results of laboratory tests, statistical distributions, and calculations of Rock Mass Rating. The Rock Mass Rating data was used to determine the GSI value which was used as an input parameter in the slope stability analysis using the failure criteria or Hoek and Brown type strength on andesite rock material [11], [12], [13]. While the soil material used the failure criteria or strength type; Mohr – Coulomb [14]. Furthermore, the analysis of the safety factor and the probability of avalanches used the boundary equilibrium method using the SLIDE 6.0 software. While the probability analysis used a Monte Carlo simulation with a total of 1000 iterations [9]. The results of the calculation of the safety factor and the probability of avalanches could be seen in the Table 3:

Table 3. Calculation of the safety factor and probability on the actual slope

Slope Geometry		**Water Condition**	**Safety Factor**					
Height	Slope		Janbu Simplied			Janbu Corrected		
			Deterministic	Mean	PK	Deterministic	Mean	PK
12	85^o	Dry	2,243	2,238	0,000%	2,348	2,343	0,000%
		Half Saturated	2,243	2,238	0,000%	2,348	2,343	0,000%
		Saturated	1,617	1,612	0,000%	1,708	1,703	0,000%

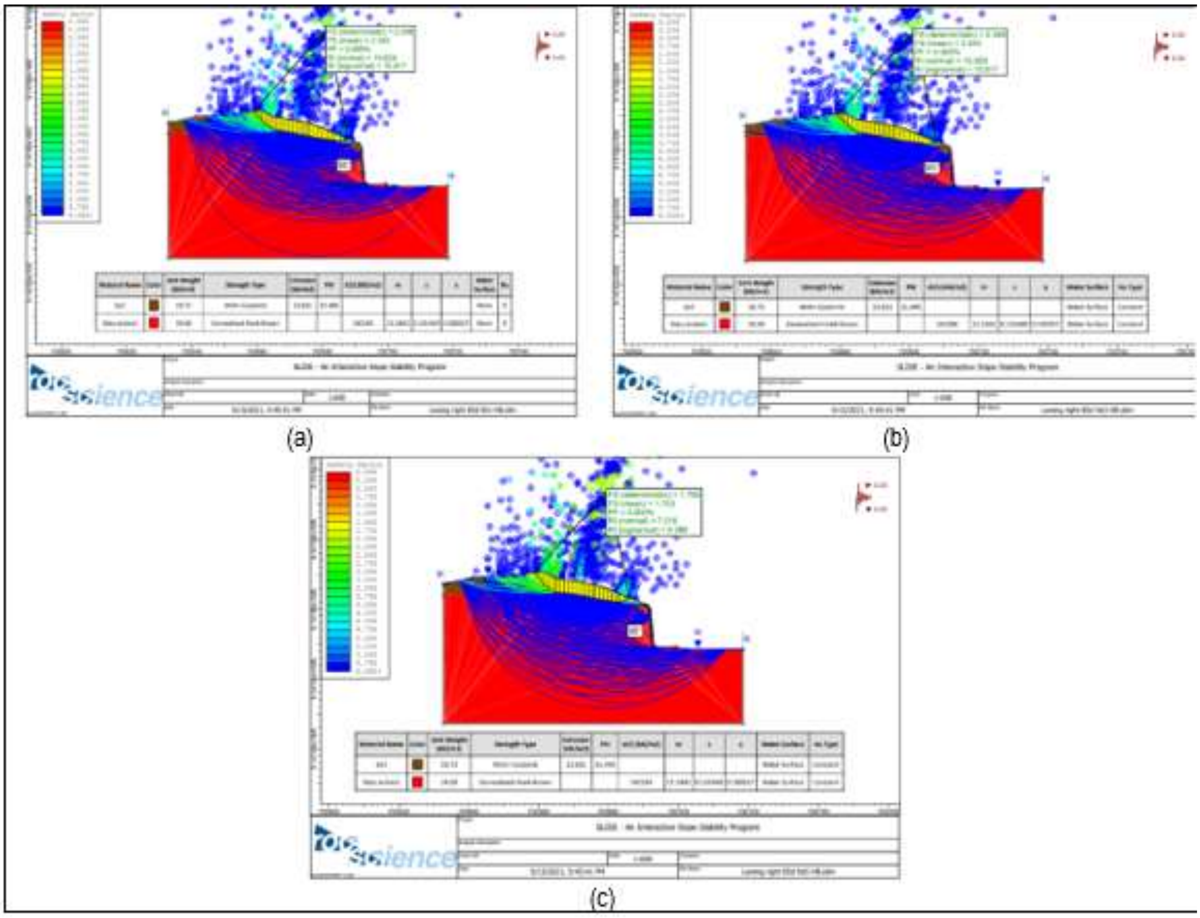

Figure 2. (a) Actual slope analysis results in dry conditions; (b) The results of the actual slope analysis in the semi-saturated condition; and (c) The results of the actual slope analysis in saturated conditions

Based on the results of running the actual slope model on slide v6.0 software, it could be seen that the slopes of the eastern and western research locations were included in the safe category, although the existing slope could be said to be quite steep. Where the safety factor (mean) of the actual slope obtained more than 1.0, namely 2.343 in dry and semi-saturated conditions and 1.703 in saturated conditions. From these results it could be seen that dry and semi-saturated water conditions did not affect slope stability. It could be seen from the constant value of the Safety Factor (FK) from the two water conditions. Meanwhile, in saturated water conditions, a decrease in the value of the Safety Factor was seen. This condition was influenced by the groundwater level touching the soil material so that the value of the Safety Factor was reduced.

3.6. Overall Slope Recommendation

The overall slope recommendation was based on the value calculation of safety factor and the landslides probability in accordance with the provisions of the Decree of the Minister of Energy and Mineral Resources No. 1827 of 2018 concerning Good Mining Engineering Principles. The calculation of slope safety factor used the Janbu method and the probability of avalanches used the Monte-Carlo probability statistic, a geotechnical recommendation for the overall slope was obtained, namely an overall height of 36 meters based on the lower limit of correlated andesite rock deposits consisting of 3 levels and an overall slope of 57^0 with a slope level of 70^0. This slope geometry produced FK (mean) value of 2.170 with a landslide probability (PK) of 0.000% see Table 4 and Figure 4.

Table 4. The results of the calculation of safety factor and probability on the overall slope recommendation

Slope Geometry		**Water Condition**	**Safety Factor**					
Height	Slope		Janbu Simplied			Janbu Corrected		
			Deterministic	Mean	PK	Deterministic	Mean	PK
12	85^0	Dry	2,481	2,476	0,000%	2,498	2,493	0,000%
		Half Saturated	2,481	2,476	0,000%	2,498	2,493	0,000%
		Saturated	2,132	2,126	0,000%	2,176	2,170	0,000%

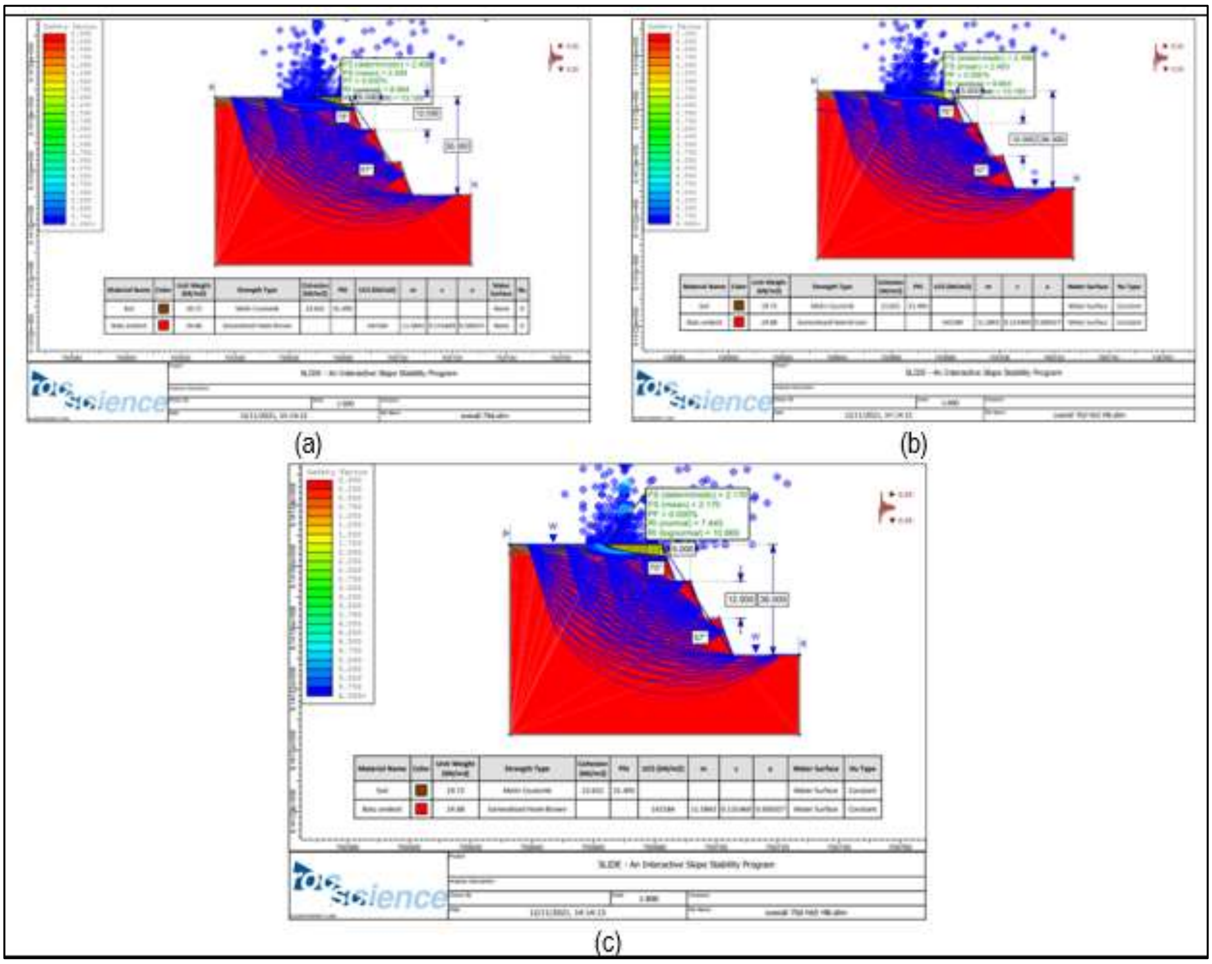

Figure 4. (a) Results of analysis of overall slope recommendations in dry conditions; (b) The results of the analysis of the overall slope recommendation in the semi-saturated condition; and (c) The results of the analysis of the overall slope recommendation in saturated conditions

4. Conclussion

From the results of the study, it could be concluded that the slope conditions at PT. Rolas Nusantara Tambang was included in the safe category. The calculation of the Safety Factor (FK) on the actual slope obtained 2.343 in dry and semi-saturated conditions and 1.703 in saturated conditions with a landslide probability (PK) of 0.000%. While the recommended slope was 36 meters high and the overall slope was 57^0, the Safety Factor (FK) was 2,493 in dry and semi-saturated conditions and 2,170 in saturated conditions with a slide probability (PK) of 0.000%.

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