Slope Stability Analysis on Muaraenim Formation, South Sumatera, Indonesia

Thaha Rizal Ulhaque[1], Nur Khoirullah[1], Irvan Sophian[1], and Zufialdi Zakaria[1]
[1]Faculty of Geological Engineering, Universitas Padjadjaran, Bandung
Corresponding author: thaha.ulhaque@gmail.com

ABSTRACT

Slope stability analysis is a necessary aspect in open mining operations. The research location is in the Muaraenim Formation, South Sumatra, Indonesia. In this study, the level of slope stability is determined by the value of the Safety Factor (FS). The method used is limit equilibrium, the Spencer method. The results of this study indicate that FS values are influenced by the angle of the slope, wherewith decreasing the degree of slope, the FS value will increase. Besides, the FS value is also directly proportional to the cohesion value of the slope materials.

Keywords: Slope stability, Safety Factor (FS), Spencer Method

INTRODUCTION

In coal extraction activities, mining is generally conducted using an open-pit mining system. To achieve high production targets while maintaining safety, slope stability analysis is needed. One method for analyzing slope stability is the limit equilibrium method. This method identifies the stability of a slope from the value of the Safety Factor (FS).

FS value is determined from the ratio between the resisting force and the driving force acting on the slope mass. However, high FS values cannot ensure that the slope conditions are genuinely safe. This is caused by random variables contained in the FS calculation parameters in the form of physical and mechanical properties of the materials that made up the slope.

This study uses Mohr-Coulomb parameters that consist of cohesion and internal friction angle of the material. These parameters are considered as random variables that can cause uncertainty in the calculation of FS values. Therefore, it is necessary to use a probabilistic approach, where statistical analysis is performed on each random variable so that the FS value that has the highest chance can be determined.

The focus of this research adjusts to the location of the study, namely the Muaraenim Formation, which is predominantly composed by claystone lithology (Gafoer, 1995). In fine-grained claystone, the physical and mechanical characteristics and their relationship to the stability of the slope are known.

LITERATURE REVIEW

Rock mass (rock mass) is in situ rock, which is discontinued by structural systems such as joints, faults, and bedding planes (Hoek and Bray, 1981 in Wyllie and Mah, 2004). The rock mass is used to classify rocks based on its strength or mechanical properties. The strength of the rock mass is influenced by the frequency of the discontinuous fields formed.

Slope stability level is obtained from the calculation of the value of the safety factor (FS), which is the ratio between the resisting force and the driving force. The resisting force is obtained from the shear strength value from the Mohr-Coulomb failure criterion. Meanwhile, the driving force is obtained from the weight of the rock mass above the slip surface acting on the inclined plane.

$$\tau = c + \sigma_n (\tan\varphi) \quad \text{........(1)}$$

$$s = w \sin\alpha \quad \text{.......(2)}$$

$$FS = \frac{c + \sigma_n (\tan\varphi)}{w \sin\alpha} \quad \text{.......(3)}$$

The method of calculating FS in this study is the Spencer method that meets the conditions of vertical force, horizontal force, and moment equilibrium (Krahn, 2017). The Spencer method is also recommended by the American Society of Civil Engineers for use in slope stability analysis with various forms of failures (SCEC, 2002).

METHOD

This research began by conducting a literature review on the geological conditions at the study site as well as the primary material that could affect this research.

Next, collecting data that is needed for slope stability analysis. Lithology, RQD, and GSI types are obtained from drilling data, while cohesion values, internal friction angles, and unit weights are obtained from laboratory test data.

E-ISSN : 2579 – 3136

The next step is the statistical test, where of the many parameters that are considered as random variables the type of distribution function is searched and the mean, standard deviation, relative maximum, and relative minimum. This statistical parameter is needed to complete the data with the Monte Carlo sampling method to obtain accurate and representative data distribution.

The final stage is to determine the FS value with some predetermined assumption, namely single slope with material that has established statistical parameters. Another limitation is the variation of the overall slope angle, so it can be determined at what angle the slope can be declared stable following the stability criteria of the slope (Stacey, 2009).

RESULTS AND DISCUSSION

Data Processing Results

- **Units of the Research-based on the Materials Characteristics**

  Based on observations of lithological types, UCS values, and GSI values in the drilling data, it can be seen that the research units that represent are TR01 and TR02 units separated by coal seam at a depth of 84.5 - 90.5 m.

- **Statistics Description**

  To overcome the uncertainty of random variables, the mean, standard deviation, maximum relative, and minimum relative values and the type of distribution function of each data per layer are determined in one unit. The random variable in question is the value of the weight, cohesion, and internal friction angle.

  Table 1. The unit weight value of each unit

Material	γsat (KN/m3)				
	Mean	**St. Dev.**	**Rel. Max.**	**Rel. Min.**	**Distribution**
TR01	20.75673	0.064524	0.1394	0.0706	Lognormal
TR02	22.67539	0.226275	0.31375	0.22625	Normal

Table 2. Cohesion value of each unit

Material	c (KN/m2)				
	Mean	**St. Dev.**	**Rel. Max.**	**Rel. Min.**	**Distribution**
TR01	41.72257	0.226107	0.364548	0.384664	Normal
TR02	41.17309	0.189932	0.174151	0.266894	Normal

Table 3. Internal friction angle value of each unit

Material	ø(˚)				
	Mean	**St. Dev.**	**Rel. Max.**	**Rel. Min.**	**Distribution**
TR01	6.878182	1.640877	4.321818	1.688182	Lognormal
TR02	8.016667	3.669985	4.673333	3.336667	Lognormal

Slope Stability Analysis

- **Safety Factor Calculation TR01**

  FS value calculation is done by assuming that the failure occurs on a single slope with the constituent material TR01. Simulated under conditions of water-saturated slopes, with and without seismic loads, and angle variations of 20 °, 25 °, 30 °, 35 °, 40 °, and 45 °. Then the FS values obtained as shown in table 4.

Table 4. TR01 FS values on each conditions

TR01				
Slope Angle (˚)	**10 m**		**14 m**	
	PS	**S**	**PS**	**S**
20°	1.09	1.658	0.901	1.324
25°	1.06	1.521	0.87	1.221
30°	1.041	1.431	0.857	1.136
35°	0.995	1.34	0.784	1.031
40°	0.969	1.279	0.748	0.962
45°	0.981	1.266	0.742	0.922

In the unit TR01, the highest FS value was found at 1.658, namely in static conditions with a design height of 10 m slope and 20 ° slope angle. While the lowest FK value was found to be 0.742, namely in pseudo-static states with a design height of 14 m slope and 45 ° slope angle.

E-ISSN : 2579 – 3136

- **Safety Factor Calculation TR02**

  The calculation of FS values on TR02 material was carried out with the same simulation conditions as TR01 material, so the results listed in Table 5 are obtained.

Table 5. TR02 FS values on each conditions

TR02				
Slope Angle (°)	**10 m**		**14 m**	
	PS	**S**	**PS**	**S**
20°	1.061	1.603	0.908	1.322
25°	1.033	1.472	0.873	1.206
30°	1.007	1.374	0.834	1.116
35°	0.967	1.353	0.767	1.007
40°	0.947	1.216	0.732	0.891
45°	0.917	1.162	0.718	0.878

The highest FS value in TR02 unit is 1.603, which is in static conditions with a design height of 10 m slope and 20 ° slope angle. While the lowest FS value was found to be 0.718, namely in pseudo-static states with a slope height design of 14 m and a slope angle of 45 °.

CONCLUSIONS

Based on the slope stability simulation, it can be known that the slope stability level can be achieved on Unit TR01 with a slope height of 10 m without seismic load and slope height of 14 m without seismic load at an angle of 20 °, TR02 with a slope height of 10 m without seismic load at an angle of 35 ° and slope height of 14 m without seismic load at an angle of 20 °.

The degree of slope stability can be influenced by the slope angle where higher FS values are obtained at a smaller slope angle. The cohesion value is also directly proportional to the FS value, where the TR01 unit, which has a higher cohesion value than the TR02 unit has a higher FK value as well.

REFERENCES

Arif, I. 2016. Geoteknik Tambang : Mewujudkan Produksi Tambang yang Berkelanjutan dengan Menjaga Kestabilan Lereng. Jakarta : PT Gramedia Pustaka Utama.

Gafoer, S., Cobrie, T., Purnomo, J. 1986. Peta Geologi 1: 250.000 Lembar Lahat, Sumatera Selatan 1012. Pusat Penelitian dan Pengembangan Geologi. Bandung.

Hackston, A. dan Rutter. 2016. The Mohr-Coulomb Criterion for Intact Rock Strength and Friction – a Re-evaluation and Consideration of Failure Under Polyaxial Stresses. Solid Earth, 7, 493-508. Manchester : University of Manchester.

Hoek E., Carranza T. C. T., Corkum B. 2002. Hoek-Brown Failure Criterion-2002 Edition.

Hoek, E. 2007. Practical Rock Engineering. Vancouver.

Krahn, J., dkk. 2017. Stability Modeling with Geostudio. Canada : GEO-SLOPE International, Ltd.

Read, J. dan Stacey. 2009. Guidelines for : Open Pit Slope Design. Australia : CSIRO Publishing.

E-ISSN : 2579 – 3136