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Software Analysis on Slope Stability of Gunung Banyak in Batu City

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Abstract *– Gunung Banyak and its surrounding area are prone to landslide because of high rainfall. Disaster management program such as land slide analysis and evaluation should be implemented in the area in order to avoid any casualties. The analysis was conducted with the help of software called Slope Stability Geo5 for two dimensions. The method used in the two-dimensional analysis was the limit equilibrium method. Objective of the analysis is to determine slope stability by installing a stone said "Shining Batu" in Gunung Banyak. The data were obtained from laboratory, geoelectric and sondir tests. The data from the laboratory test were used as input for the software, while those from the geoelectric and sondir analyses were used to determine soil geometry layer. Based on the two-dimensional software, the Bishop, Fellenius, Spencer, Janbu, Morgenstern price and shahunyants's method, the minimum FS (shahunyants method) was 1.26 for A-A cut and 1.01 for B-B cut. It means B-B has the most critical safety level compared to AA.*

Keywords *– Slope Stability GEO5, limit equilibrium method, factor of safety, slope stability.*

I. Introduction

Gunung Banyak and its surrounding are prone to landslide because of high rainfall, weather, topographical conditions, and land conversion. The highest disaster index in this area will occur in the rainy season, between October and April. Disaster management program such as land slide analysis and evaluation should be implemented in the area in order to avoid any casualties.

The analysis was conducted with the help of software called Slope Stability Geo5 for two dimensions. The method used in the two-dimensional analysis was the limit equilibrium method. Objective of the analysis is to determine slope stability by installing a stone said "Shining Batu" in Gunung Banyak.

II. Theoretical Basis

Landslides occur when the gravitational component is so large that it exceeds ground resistance [4]. In other words, a slope will erode if the balance of the force is disturbed or when the driving force exceeds the retaining force. Slope stability analysis refers to analysis on sloping land surfaces. Land slide can be categorized into rotational, translational and combination between the two.

Slope stability depends on several parameters, namely physical and mechanical characteristics of soil. Physical characteristics of the soil are soil mass (γ), water content in the soil (w) and texture of the soil while mechanical characteristic of the soil is shear strength represented by cohesion (c) and shear angle (ϕ).

Factor of Safety (FS) is represented as follow:

$$\text{Factor of Safety (FS)} = \frac{\text{Retaining Force}}{\text{Driving Force}} = \frac{\tau_f}{\tau_d}$$

where
FS= Factor of Safety against Soil Strength
τ_f = Average shear strength (kN/m3)
τ_d = Average shear stress along an area where landslide occurs (kN/m3)

TABLE I. Relationship between factor of safety and landslide possibility.

SF Slope	Landslide Possibility
< 1.07	Land slide may take place
1.07 < SF < 1.25	Land slide took place in the past
> 1.25	Land slide rarely takes place

The method used to analyze slope stability is limit equilibrium. Limit equilibrium is method that uses force equilibrium. The assumption used in this method is circular and non-circular landslide (Fig. 1)

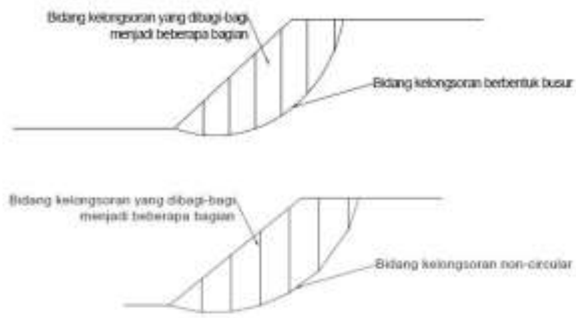

Fig. 1. Circular and non-circular limit equilibrium methods [1].

Analysis is conducted by categorizing the area where landslide occurs into several criteria (see Fig. 2).

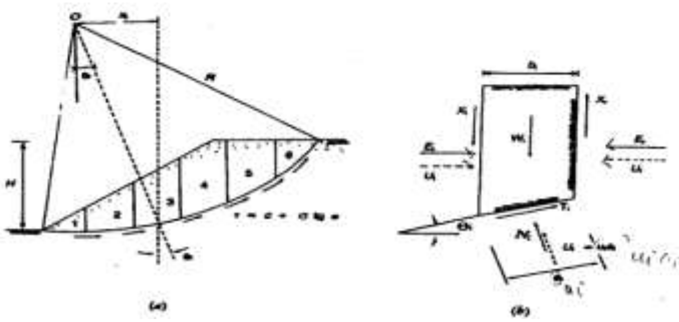

Fig. 2. Force that works in soil/land cutting [3].

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GEO5 consists of several elements, for example soil analysis. GEO5 applies analysis method and limit equilibrium method (LEM). In order to analyze slope stability, minimum Factor of Safety (SF) level used for the software is 1.5

The Bishop method is used to identify circular landslide area automatically and calculate critical factor of safety. Figure 3 showed the Bishop method.

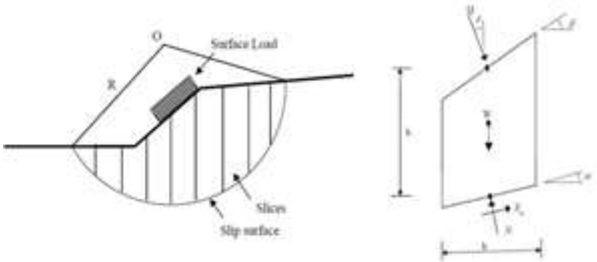

Fig. 3. Bishop method [2].

Bishop's Factor of Safety:

$$FS_b = \frac{\Sigma\left[c' bi + Wi(1-ru)\,tg\,\phi'\right]\left(\dfrac{1}{\cos\theta i(1+tg\,\theta i\,tg\,\phi' / FSb')}\right)}{\Sigma\,[W \sin\alpha]}$$

Where :

FSb	=	Bishop's Factor of Safety
c'	=	Effective Soil Cohesion (kN/m2)
ϕ'	=	Friction angle in the effective soil (degree)
b'	=	i^{th} cut width (m)
Wi	=	i^{th} cut weight (kN)
αi	=	angle (degree)
ui	=	i^{th} cut pore water pressure (kN/m2)

III. Research Method

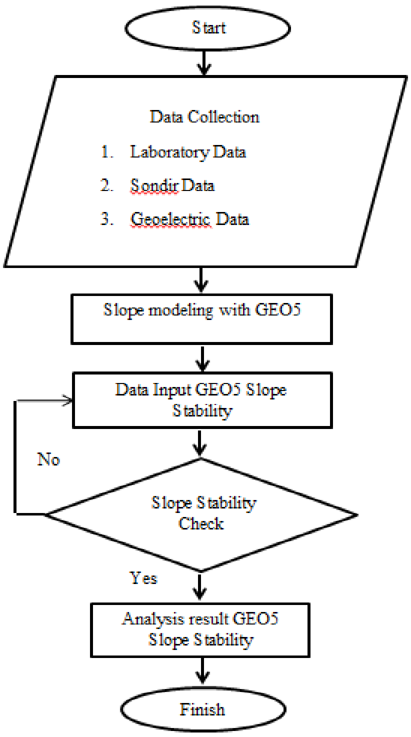

Fig. 4. Analysis flowchart.

The first procedure of the analysis is to conduct geoelectric and sondir tests to determine soil layer and slope geometry. Fig. 5 described the soil geometry.

Having described both soil layer and slope geometry, the next step is to determine soil parameter. Type of soil parameters used is soil parameters obtained from laboratory tests as seen in Table II. The final step is data analysis using two-dimensional software (GEO5 Slope Stability) to analyze A-A and B-B soil cutting.

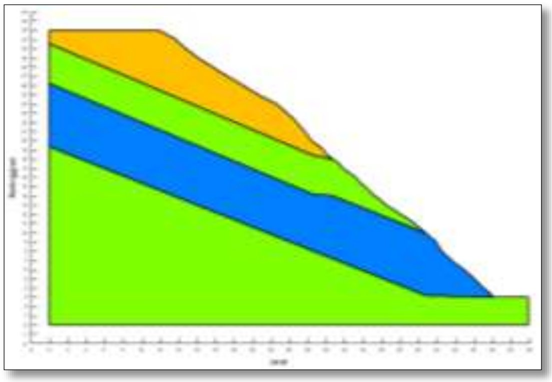
Fig. 5. Slope geometry.

TABLE II. Soil parameter.

Layer	Soil Type	γ	c	ϕ	Description
		(kg/m3)	(kg/m2)	°	
1	SW-SM	1792,7	1307	38,44	well graded sand-sandy silt
2	SP-SM	1935,3	1550	24,99	poor graded sand-sandy silt
3	SM	1769,3	660	21,15	sandysilt
4	SP-SM	1935,3	1550	24,99	poor graded sand-sandy silt

IV. Results and Discussion

Table II showed inputs used for the two-dimensional software analysis. The researchers did not have to convert the inputs to match the software because the parameters used in GEO5 Slope Stability software are the same as the soil parameters obtained from the laboratory test.

The methods used for the two-dimensional analysis are the Bishop, Fellenius / Petterson, Spencer, Janbu, Morgenstern-Price, Shahunyants. Fig 6 and 7 and Table III summarized result of the software analysis towards A-A and B-B cut.

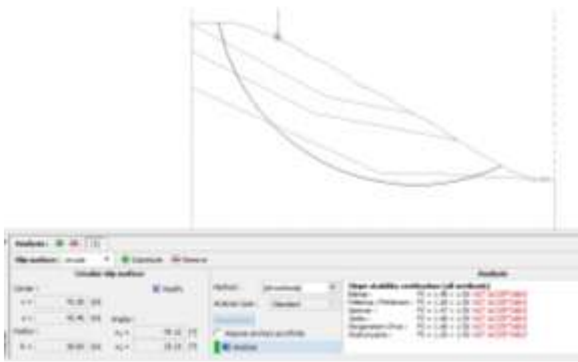
Fig. 6. Dialog analysis of A-A cut.

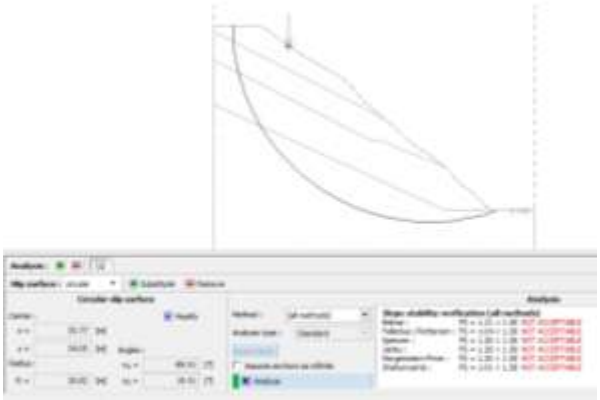

Fig. 7. Dialog analysis of B-B cut.

TABLE III. Factor of safety level based on slope stability software.

Method	FS Slope	
	A-A Cut	B-B Cut
Bishop	1.48	1.21
Fellenius/ Petterson	1.28	1.04
Spencer	1.47	1.2
Janbu	1.48	1.2
Morgenstern-Price	1.48	1.2
Shahunyants	1.26	1.01

V. CONCLUSION

Based on the analysis result, it can be concluded that:

Based on the two-dimensional GEO5 slope stability software, the Bishop, Fellenius, Spencer, Janbu, Morgenstern price and shahunyants's method, the minimum FS (shahunyants method) was 1.26 for A-A cut and 1.01 for B-B cut. Therefore, B-B has the more critical safety level compared to AA.

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