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**Submission date:** 23-Dec-2022 03:23PM (UTC+0700)

**Submission ID:** 1986126059

**File name:** Determination\_of\_safety\_factor\_value\_of\_PIT\_design\_based\_on.pdf (386.31K)

**Word count:** 2959

**Character count:** 13007

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To cite this article: E D Sibala and R Langkoke 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **235** 012084

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# Determination of safety factor value of PIT design based on cohesion and friction angle

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**Abstract.** This research was conducted in East Kalimantan area. Which aims to determine the value of safety factor to know the level of the slope stability in order to make the right PIT design. The greater the SF value of a slope, the more stable the slope, so the activity of production will remain safe. This analysis uses bhisop method. This method is used by assuming the type of landslide that will occur on the high wall side is a circular landslide, while on the low wall is the planar landslide. In this analysis, the data used are slope geometry, cohesion values and friction angle resulting from direct shear and unit weight from basic test. The greater the value of cohesion and the friction angle, the value of the safety factor will also be greater, then the PIT design will be stable. Result of this research, the SF values are varied, on the high wall side of 2,050 to 8,298, on the low wall of 2,174 to 12,670 and on the end wall of 1.838.

## 1. Introduction

### 1.1 Background.

The stability of the slopes is a very important factor to be considered in open PIT mining. That is very important in the work related to excavation and stockpiling of soil, rocks and minerals, as it concerns the issues of human safety (workers), equipment security and the smoothness of production.

The stability of a slope is usually a problem that requires more attention to the continuity of mining operations on a daily basis. Not only in mining activities, slope stability is also important in various types of work, for example on road construction, dams, excavation of canals, excavation for construction and others.

### 1.2 Purpose.

The purpose of this study is to determine the lithology condition, determine the factors that influence the stability of the slope and to determine the value of safety factor in the study area.

## 2. Literature

Bowles (1984)[1] divides the three ranges of the Safety Factor (F) (Table 1) in terms of the intensity of the clutter obtained by considering the two forces acting on the slope:

$F = \text{Landslide driving force} / \text{Landslide retaining force}.$



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Where the driving force is the force that causes the mass to move so that there is a sliding, while the retaining force is the force that holds the mass from the mover in order to avoid landslide.

**Table 1.** Relationship of the value of safety factor with intensity of landslide [1]

Safety Factor (F) Value	Landslide Intensity
F < 1.07	Unstable Slope
F Between 1.07-1.25	Critical Slope
F > 1.25	Stable Slope

### 3. Research Method

The data used in this study consist of drill data, lithology description which includes physical properties of lithology, lithologic mechanical properties obtained from laboratory analysis, these data include unit weight from basic test, cohesion value and internal shear angle from direct shear test, slope geometry data from PIT design / modeling.

Slide 6 is a 2 dimensional stability slope program for analyzing circular or non-circular slope stability on soil or rocky slopes. Slide analyze slope stability using vertical wedge boundary balance method. The landslide field can be analyzed or searched by a method that can be used to determine a critical landslide for a slope. Calculation of slope stability analysis using Slide program requires previously known data i.e. slope coordinate point (slope geometry) from PIT descriptions, soil data (c,  $\phi$ ,  $\gamma$ ) from laboratory test.

The geometry data of the slope is obtained from the result of the PIT design which is then made into several sections which are considered to represent the entire slope.

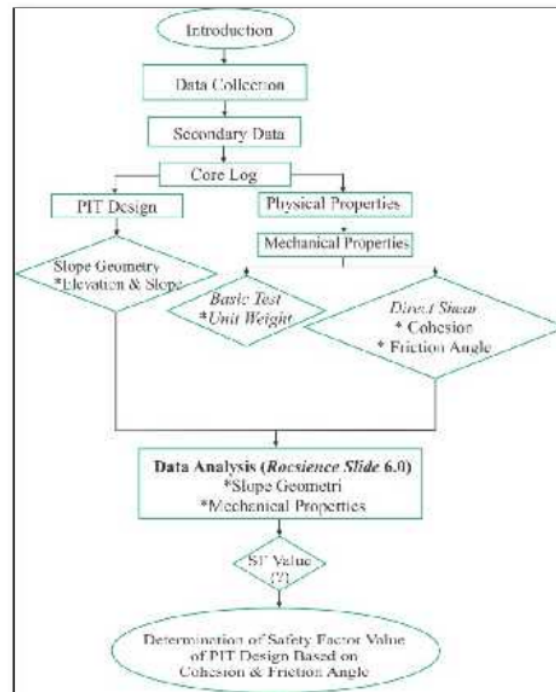
The slope analyzed to determine the SF value consists of three parts, slope on the side of high wall, low wall and end wall. The slope on the high wall side is divided into 2 parts, slope without road and slope with the road / inter ramp. While on the low wall is also done two times analysis. End wall is the end point of the mining process.

The method used in this research is bishop method, Safety Factor (F) slope of soil can be calculated by various methods. Landslide with slip surface, F can be calculated by slice method [2].

$$F = \frac{cL + \tan \theta \sum (W_i \cos \alpha_i - \mu_i \times I_i)}{\sum (W_i \sin \alpha_i)}$$

- C : Cohesion (kN/m<sup>2</sup>)
- $\theta$  : Friction Angle ( $^{\circ}$ )
- $\alpha$  : Angle of slip area of each slice
- $\mu$  : Pore water preassure (kN/m<sup>2</sup>)
- l : Long field of slip on each slice (m)
- L : The number of the length of the slip field
- $\mu_i + I_i$  : Pore preassure on each slice (kN/m)
- W : The area of each slice (m<sup>2</sup>) x unit weight ( $\gamma$ , kN/m<sup>3</sup>)

This research used bishop method because in the analytical process this method is more accurate and read as a whole the field or layer of rock on the slope to be analyzed. To further understand this series of research, then made the flow diagram of research (figure 1) as follows:



**Figure 1.** Flow diagram of research.

#### 4. Result and Discussion

##### 4.1 Geology of Research Areas

Regionally the research area is included in the geological map of the Longiram sheet. This area is composed of the Pulubalang Formation and is located on the wing of the Lunga sinklin (N. Suwama & Apani, 1994). Based on the morphographic and morphometric approaches, geomorphology of the research area is wavy hills (figure 2).



**Figure 2.** Morphology of the research area.

In general, the lithology that makes up the research area is divided into claystone consisting of silty claystone, carbonaceous claystone. Siltstone consisting of clayey siltstone, sandy siltstone. Sandstone

which consists of silty sandstone and coal. The naming of this lithology is based on the difference in its grain size using the Wenworth classification, 1922.

#### 4.2 Cross section of PIT A.

Cross-section made on PIT design (figure 3) aims to facilitate in analyzing the value of safety factor. In this design, 15 sections are considered to be representative to know the value of SF slope.

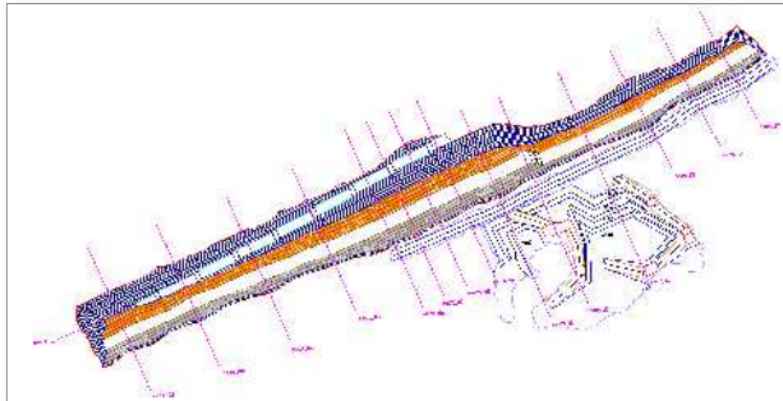


Figure 3. PIT A design.

Table 2. Slope Geometry PIT A

Section	Over All Slope ( $^{\circ}$ )	High Over All (m)	Bench Width (m)	Bench Hihg (m)
15-15'	51	44.52	5	10
14-14'	48	39.58	5	10
13-13'	51	66.3	5	10
12-12'	54	46.21	5	10
11-11'	42	64.77	5	10
10-10'	50	84.5	5	10
9-9'	40	89.66	5	10
8-8'	42	106.13	5	10
7-7'	39	82.49	5	10
6-6'	38	72.84	5	10
5-5'	38	70.73	5	10
4-4'	37	68.15	5	10
3-3'	50	63.58	5	10
2-2'	48	85.82	5	10
1-1'	50	102.56	5	10

#### 4.3 Analysis Safety Factor value.

**Table 3.** Calculation of mechanical properties of lithology of research area

<i>Layer</i>	<b>Unit Weight (KN/m<sup>3</sup>)</b>	<b>Cohesion (kPa)</b>	<b>Friction Angle (deg)</b>	<b>Thick (m)</b>
<i>Top Soil</i>	18	10	34	2 - 3
<i>Weak Layer</i>	20	2	20	0.11 - 1.24
<b>Lapisan 1</b>	21.59	366.63	20.79	29.36
<b>Lapisan 2</b>	21.71	470.72	23.15	12.21
<b>Lapisan 3</b>	21.71	434.24	22.43	23.92
<b>Lapisan 4</b>	22.23	596.62	24.72	18.32
<b>Lapisan 5</b>	21.07	316.6	21.24	11.48
<b>Lapisan 6</b>	21.49	279.27	19.06	7.39
<b>COAL</b>	13	150	36	0.48 - 5.85

Based on the results of the analysis that has been done by using rocsience slide 6.0, then the SF value is obtained on **High Wall side, low wall (Non Inter Ramp)**; Section 2: high wall (2,084), low wall seam 4 (2,174), low wall seam 5 (2,275); Section 3: high wall (2,794), low wall seam 4 (3,563), low wall seam 5 (3,340); Section 10: high wall (2,006), low wall seam 4 (3,384), low wall seam 5 (2,071); Section 11: high wall (2,549), low wall seam 4 (5,767.), Low wall seam 5 (8,612); Section 12: high wall (2,970), low wall seam 4 (3,284), low wall seam 5 (4,589); Section 13: high wall (2,450), low wall seam 4 (3,135), low wall seam 5 (3,818); Section 14: high wall (3,837), low wall seam 4 (4,500), low wall seam 5 (5,019); Section 15: high wall (3,826), low wall seam 4 (8,517), low wall seam 5 (12,670). **High Wall, low wall (Slope with Inter Ramp)**; Section 4: high wall (2,828), inter ramp (8,298) low wall seam 4 (3,515), low wall seam 5 (3,747); Section 5: high wall (2,679), inter ramp (2,844) low wall seam 4 (3,540), low wall seam 5 (3,815); Section 6: high wall (2,702), inter ramp (2,803) low wall seam 4 (2,531), low wall seam 5 (3,410); Section 7: high wall (2,391), inter ramp (2,526) low wall seam 4 (2,390), low wall seam 5 (2,807); Section 8: high wall (2,050), inter ramp (2,382) low wall seam 4 (2,239), low wall seam 5 (2,503); Section 9: high wall (2,202), inter ramp (2,727) low wall seam 4 (2,562), low wall seam 5 (3,249). **End Wall: high wall** (1.836).

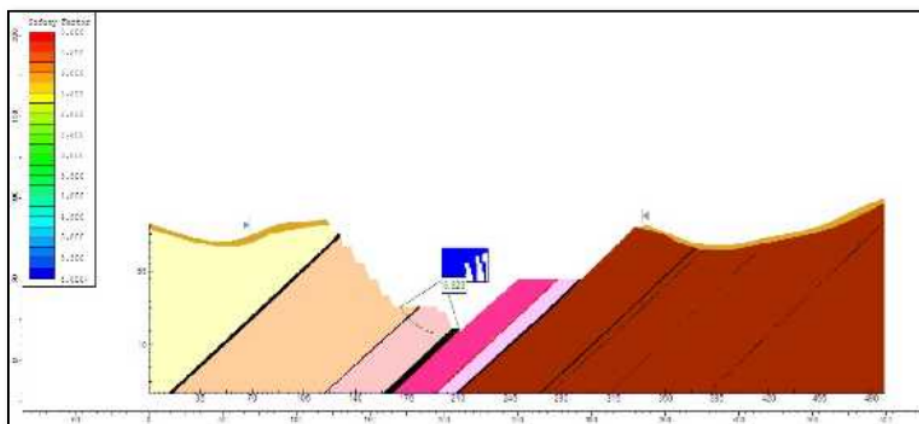
#### 4.4 Recommendation.

From the results of the table above can be seen that there are several slopes that are used as access road. This can be done because the slope on the side of this high wall has a slope that is under 45°. The slope of this slope is considered relatively safe to pass by the vehicle, so that when the process of transporting coal and over burden layer will remain relatively safe even under the slope of the vehicle this is ongoing mining activities (table 4).

In section 4 (figure 4) the slope below the inter ramp has a very high SF value of 8,289, this is influenced by slope (37°) and also high from the V cut condition of 68.15 m. This indicates that the geometry of the slope also greatly determines the stability of a slope. On the high wall side, the type of landslide that will occur is assumed to be a circular landslide because on this side the slopes / bench is intersected with the direction of the bedding of the rock, so that the rock layers will not become slip planes.

**Table 4.** SF value of slope design on the high wall side

Section	Slope geometry		Min.Factor of safety (FS.)		Remarks
	High (m.)	Angle (degr.)	All Slope (°)	Inter ramp (°)	
Sec 15	44.52	51	3.826		Relatively stable
Sec 14	39.58	48	3.837		Relatively stable
Sec 13	66.3	51	2.450		Relatively stable
Sec 12	46.21	54	2.970		Relatively stable
Sec 11	64.77	42	2.549		Relatively stable
Sec 10	84.5	50	2.006		Relatively stable
Sec 9	89.66	40	2.202	2.727	Relatively stable
Sec 8	106.13	42	2.050	2.382	Relatively stable
Sec 7	82.49	39	2.391	2.526	Relatively stable
Sec 6	72.84	38	2.702	2.803	Relatively stable
Sec 5	70.73	38	2.679	2.844	Relatively stable
Sec 4	68.15	37	2.828	8.298	Relatively stable
Sec 3	63.58	50	2.794		Relatively stable
Sec 2	85.82	49	2.084		Relatively stable

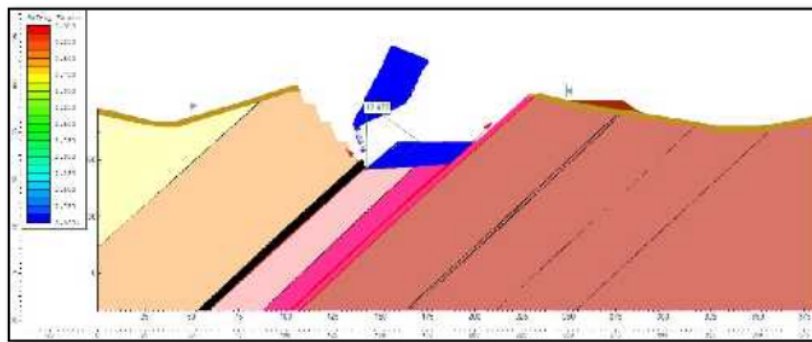


**Figure 4.** Section 4 slope under access road on the high wall side.

Analysis on the low wall side also produces a large sf value, this is because the geometry on the side is more gentle than the geometry on the high wall side (table 5), especially in seam 5 section 15 (figure 5). The sf value obtained is 12.670. On the low wall side will form an avalanche of planar types, this is due to the low wall side of the slope is formed in the direction of or follow the field of rock layers, so that in the event of avalanche, which will be the field of slippage is the field of rock layering itself.

**Table 5.** SF value of slope design on the low wall side

Section	Slope geometry		Min.Factor of safety (FS.)		Remarks
	High (m.)	Angle (degr.)	Seam 4	Seam 5	
Sec 15	40.90	24	8.517	12.670	Relatively stable
Sec 14	46.42	28	4.500	5.019	Relatively stable
Sec 13	58.45	29	3.135	3.818	Relatively stable
Sec 12	40.42	24	3.284	4.589	Relatively stable
Sec 11	55.59	26	5.767	8.612	Relatively stable
Sec 10	96.62	32	3.384	2.071	Relatively stable
Sec 9	85.33	30	2.562	3.249	Relatively stable
Sec 8	87.47	30	2.239	2.503	Relatively stable
Sec 7	95.10	31	2.390	2.807	Relatively stable
Sec 6	84.27	30	2.531	3.410	Relatively stable
Sec 5	66.01	28	3.540	3.815	Relatively stable
Sec 4	66.34	28	3.515	3.747	Relatively stable
Sec 3	68.40	30	3.563	3.340	Relatively stable
Sec 2	71.45	31	2.174	2.275	Relatively stable



**Figure 5.** Section 15 Slope seam 5 on the low wall side.

Based on the results of the analysis on the end wall of the PIT A modeling, without any loading obtained the value of safety factor of 1.836 (table 6). This value is in relatively stable condition [1]. In case of landslides on this side, then the type of landslide that will occur is a circular landslide.

**Table 6.** SF value of slope design on the end wall side

Section	Slope geometry		Min.Factor of safety (FS.)
	High (m.)	Angle (degr.)	
Section 1	102.56	51	1.836
<u>Average</u>	-	-	1.836

**5. Conclusion**

Based on the results of slope stability analysis of modeling / design of PIT A Block C-E, PT. Trubaindo Coal Mining, East Kalimantan, the following conclusions can be drawn:

- Based on the coring results, the research area is composed of lithology of claystone with the size of 1/256 mm grain consisting of silty claystone and carbonaceous claystone. Siltstone (1/16 mm) of clayey siltstone and sandy siltstone. Sandstone (1 / 8-2 mm) which consists of silty sandstone and coal.
- Factors affecting slope stability in the study area, however, are lithologies whose finer grain size (clay) will have smaller cohesion values when compared with lithology whose grain size is grainier (sand) so that the safety factor will also be smaller. Similarly, the geometry of the slope, the smaller the slope, the greater the value of the safety factor.
- The value of SF in the study area > 1.839, this indicates that the slope is in a relatively safe / stable condition. On the high wall side with inter ramp also obtained a relatively stable value of 2,050 - 2,898 (slope 37<sup>0</sup>-42<sup>0</sup>) so that the design of PIT A Block C-E can be applied to the pit planning.

#### Reference

- [1] Bowles J E 1984 *Physical and Geotechnical Properties of Soil: Second Edition* (McGraw Hill: New York USA).
- [2] Bishop A W 1955 The use the slip circle in the stability analisis of slopes *Geotechnique* **5** 7-17.
- [3] Suwarna N and Apandi T 1994 *Peta Geologi Lembar Longiram, Kalimantan Timur* (Bandung: Center for Geological Research and Development Directorate General of General Mining Mining and Energy Depatemen).

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