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Mine Slope Stability Analysis Using the Pseudostatic Method (Case Study: PT. J Resources Bolaang Mongondow Bakan Gold Project Mine Ridge PIT Area)

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A b s t r a c t

PT. J Resources Bolaang Mongondow is an open-pit gold mining company that experienced a landslide on one of the slopes in the Mine Ridge Pit, Bakan Gold Project. The landslide occurred in the argillic domain on one bench of the overall slope. The purpose of this study is to investigate and geotechnically analyze the slope at PT. J Resources Bolaang Mongondow Mine Ridge Pit and model the stability of the mine slope using the pseudo-static method to evaluate the factors affecting slope stability. The pseudo-static method is used in this study because it overcomes some of the limitations of conventional methods in analyzing mine slope stability. This method considers the distribution of strain and inertial force on the slope to evaluate the slope safety factor. The results of stability modeling on the actual slope with a height of 20.070 meters and a slope of 47° obtained an FK of 0.942. Based on the Minister of Energy and Mineral Resources Decree No.1827 K/30/MEM/2018, the slope is classified as unstable, where the minimum FK for pseudo-static analysis of the overall slope is 1 (FK>1). The slope geometry needs to be redesigned to get a safer geometry. Simulations were carried out by trying the appropriate height and slope until a stable FK was obtained. FK 1.035 was obtained on the slope with geometry.
The slope was reduced to 33° (single bench). The slope can still be formed into a double bench and a triple bench with FK of 1.055 and 1.042, respectively. After redesigning the slope, it is important to monitor the groundwater level and deformation of the slope.

Keywords: Mine Slope, Pseudo-static Analysis, Stability, Geotechnics.

Introduction

Avalanche is a natural process that takes place to achieve a stable state on a new slope (new equilibrium); the forces that resist are stronger than the forces that push. Slope stability can be measured through the Factor of Safety (FK). Based on the FK value, we can determine the stability of a slope (Sudinda, 2020).

Mining activities always contain potential accident hazards, such as landslides that can occur in mine cliffs. Therefore, it is important to conduct risk management to anticipate possible accidents. One way to control risks in the mining industry is to design safe and stable mine slopes; mine slope design is included in the category of geotechnical aspects (Manullang, 2020).

In order to provide safe and efficient mining operations, geotechnical issues are essential in establishing the contour of the mine slope in an open pit mine. The overall quantity of reserves retrieved will depend on the mining slope's geometry. The stability of the ideal and geotechnically safe mining slope geometry must therefore be examined. The factor of safety (FK) and the likelihood of a landslide occurring are used to gauge the slope stability outcomes. The Decree of the Minister of Energy and Mineral Resources No. 1827 K/30/MEM/2018 specifies the norm for planning mining slopes. At mild landslide severity, the total slope has a static minimum FK of 1.2-1.3 and a dynamic minimum FK of 1.1.

One of the places under the management of PT J Resources Bolaang Mongondow (PT JRBM) is Pit Mine Ridge. Since PT. J Resources Bolaang Mongondow (PT JRBM) uses an open-pit mining technique, slope stability must be taken into consideration. A disturbed (unstable) slope will affect the whole mining process, from the production outcomes to worker safety and health. According to geological modeling, this pit has a significant amount of soft material (argillic alteration). Therefore, it is crucial to design the slope geometry taking into account a number of factors, including geological structure, rock type, water conditions, seismic activity, and slope form, which can result in rock mass movement.

An open-pit mine consists of a number of slopes resulting from rock excavation and consists of single slopes, as well as whole slopes of a certain geometric size. Slope height refers to the vertical distance from the toe (bench toe) to the top of the slope (bench crest). Meanwhile, the slope angle is defined as the angle formed by the line connecting the toe and crest of the slope with the horizontal line (bench face angle). Along the slope as a whole, there are slopes connecting areas or catch berms and mine roads, commonly called ramps. In addition, there is also a slope size called berm width and an embankment known as a back break (Hardianto, A., & Heriyadi, B., 2019).

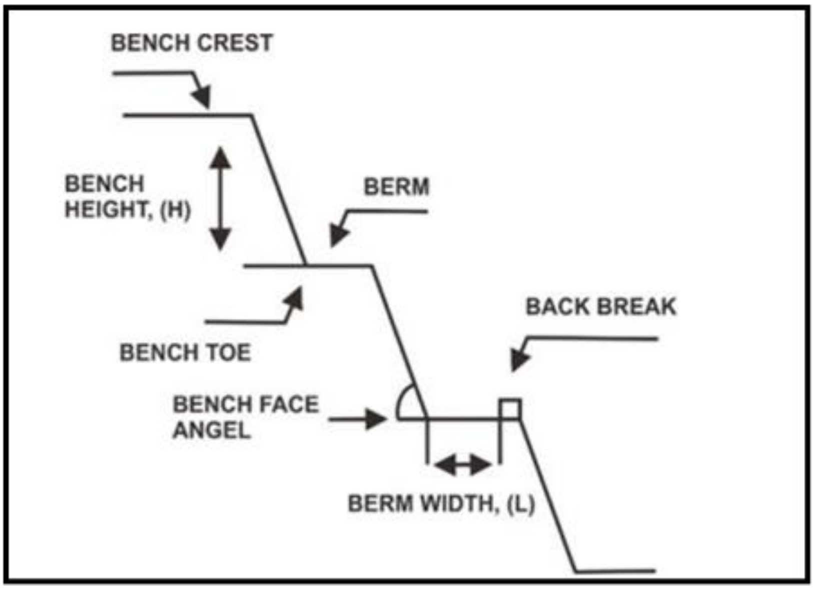

Figure 1. *Slope Geometry (Charles, A & Kliche. 2009)*

The force transformation causes the pressure distribution to be different, so the strength of the rock mass changes. This situation causes a disturbance in the stability of the slope, so the rock mass will try to find a new balance by releasing the load through landslides (Lunto and Barat, 2020 in Rifandi, 2022). The impact of disturbance on the rock mass converted into a slope can cause

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problems, namely the collapse of the tier structure. The rock mass that was previously stable and unaffected becomes disturbed due to the excavation process so the slope loses its stability and has the potential for landslides. If a landslide occurs, there is a risk that it can disrupt mining activities, resulting in production being hampered (Muchtar and Anaperta, 2020).

Methods for analyzing slope stability depend on an understanding of how slope collapse occurs, the characteristics of the material and its source, the shape of the land surface, and the existing geological environment. These factors determine the limitations in the use of a given method (SNI 8460:2017). Among other things, slope stability analysis is used for the following:

1. Stability analysis of artificial slopes;
2. Provides an overview of the potential for slope failure;
3. Analyze the landslide that occurred;
4. Provide options for planning and redesigning slopes that have experienced landslides and designing preventive measures;
5. Examined the impact of unexpected loads, such as earthquakes and traffic loads.

Meanwhile, the important aspects of rock slope stability, viz.,

1. Shear strength of rock;
2. Content weight of soil/rock;
3. Slope geometry (height and slope);
4. Pore water pressure.

Collapse analysis of a material is a method of determining the safety caused by the avalanche of a slope or tunnel, generally done by comparing the stress experienced by the material with the strength of the material. If the stress experienced by the material exceeds its strength, it can be said that the material will collapse.

Conventional slope stability analysis methods often ignore the influence of dynamic loads, such as earthquakes or local seismic activity, which can significantly affect slope stability. The pseudo-static method makes it possible to consider the influence of dynamic loads simply by using a horizontal acceleration factor that represents the inertial force due to earthquakes. This provides a realistic estimation of seismic effects on slopes. The pseudo-static method is a simple approach used to analyze the stability of slopes by considering the influence of dynamic loads, such as earthquakes, through the representation of inertial forces as equivalent static forces. This analysis assumes that earthquakes provide instantaneous acceleration, but stability can still be calculated using the concept of static forces (Terzaghi and Peck, 1967).

The purpose of this study is to investigate and analyze the geotechnical slope at PT J Resources Bolaang Mongondow Mine Ridge Pit and model its stability using the pseudo-static method. To fulfill this objective, the scope of this study includes the following:

1. The geotechnical modeling of the landslide slope is based on data obtained by PT Jresources Bolaang Mongondow;
2. The slope stability study was conducted using the Bishop Simplified limit equilibrium method and considering seismic factors (pseudo-static analysis).

Method

Research Location

The research was conducted at PT. J Resources Bolaang Mongondow Project Bakan Open-Pit Gold Mine Ridge production area. It is administratively located in the East Pinolosian Sub-district, South Bolaang Mongondow Regency, North Sulawesi Province. The research location can be seen in **Figure 2**.

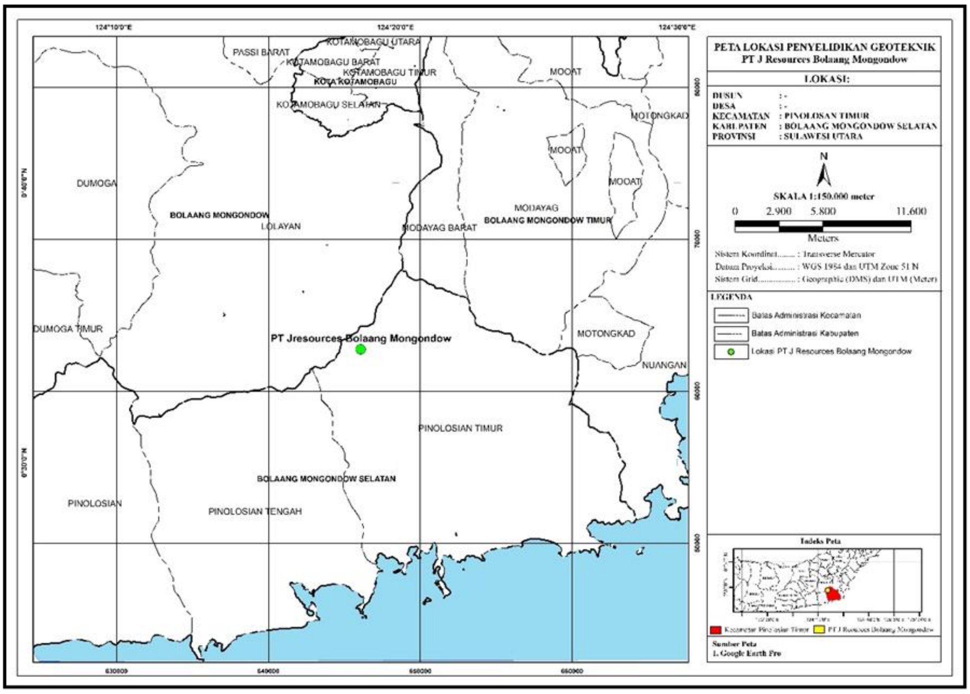

Figure 2. *Location Map of PT. J Resources Bolaang Mongondow*

Based on the Stratigraphy method, the study area has several formations, starting from the youngest Lake Deposits, Molasa Selebes Formation, Bone Diorite Intrusion, to Bilungala Volcanic Rocks. The lake deposits are scattered in the northwest part of the study area, which is composed of limestone. Molasa Selebes is located in the southeast of the study area, composed of conglomerate and breccia, which is thought to be Pliocene- Pleistocene in age. The Bone Diorite is a breakthrough rock composed of quartz diorite, diorite, granodiorite, and granite. This unit breaks through the Bilungala Volcanic Rocks and Tinombo Formation. The last one, the Bilungala Volcanic Rocks, is composed of breccia, tuff, and lava, which are composed of andesite, dacite, and rhyolite (**Figure 3**).

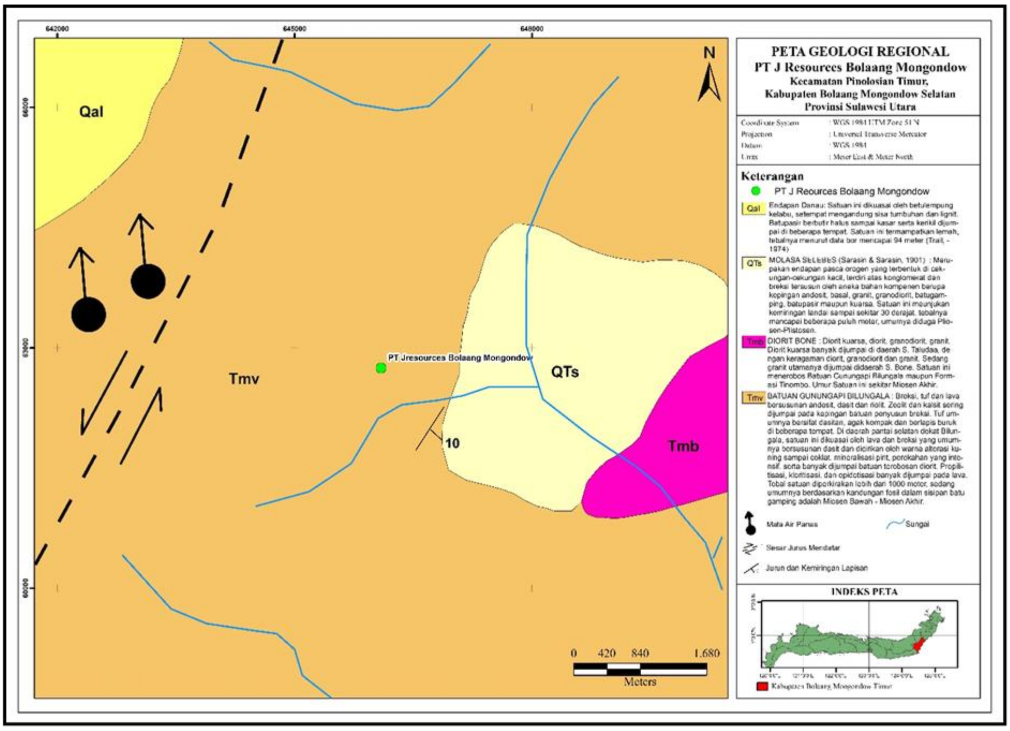

Figure 3. *Regional Geologic Map of PT. J Resources Bolaang Mongondow*

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Data Collection

Overall, there are several aspects to consider in analyzing slope stability, namely the shape of the slope, the inherent properties of rocks such as their mechanical and physical characteristics, the presence of groundwater, the state of the rock mass, static and dynamic loads, and the condition of existing structures. In geotechnical research, the recommended slope not only considers safety but also production factors. Therefore, it is necessary to make ideal slopes, or slopes with steep slope angles, but still maintain good stability.

The data to be used in the modeling comes from direct data collection. This includes the geometry of the slope to be analyzed, geotechnical data consisting of lithological boundaries or geotechnical domains, and the groundwater table, as well as sample collection to test the physical properties of rocks and shear strength (mechanical properties) used during modeling. In addition, some extra information is required to support the modeling process, such as data on seismic coefficients (earthquake loads).

The physical and mechanical properties of materials required during slope stability analysis are as follows:

1. Weight of Content (γ)
   The ratio of the mass and volume of a material is expressed in units of weight per unit volume. When a material has a heavier load, the force that produces avalanches on the slope will be higher, resulting in lower slope stability.

2. Inner Shear Angle (ϕ)
   The angle formed between the normal stress and the shear stress that occurs in a material. The higher the shear angle in a material, the better resistance the material has to the external stress applied.

3. Cohesion (c)
   Cohesion refers to the attraction that occurs between material particles, expressed in units of weight per unit area. Shear strength is directly related to the cohesion of a material; in other words, if the shear strength value is high, the cohesion value of the material will also increase. An equivalent factor of safety, or stability value, can be determined by a slope adjusted for the level of cohesion. In other words, if a soil material has high cohesion, the slope that can be formed can have a fairly steep slope angle.

The above physical and mechanical properties of the material were obtained from a series of laboratory tests. The cohesion parameter (C) and the inner shear angle (ϕ) are generated from the shear strength test. In this research, the shear strength test uses the ASTM D5607-08 reference.

Data Processing and Analysis

In general, there are many aspects to consider when analyzing slope stability, including the shape of the slope, the natural characteristics of the rock such as its physical and mechanical properties, the presence of groundwater, the state of the rock mass, static and dynamic loads, and the condition of the structure. In geotechnical studies, the recommended slopes are not only those that are considered safe but must also consider production factors. Therefore, it is necessary to design the most ideal slope angle, i.e. a slope that is as steep as possible, while still maintaining good stability.

The stability of a slope can be assessed by calculating the factor of safety or stability of the slope. The calculation of the factor of safety is determined by first forming an arch or shear plane and then calculating the total force or moment that can cause a landslide in that plane. The ratio of the resisting force and the pushing force is known as the Factor of Safety (FK).

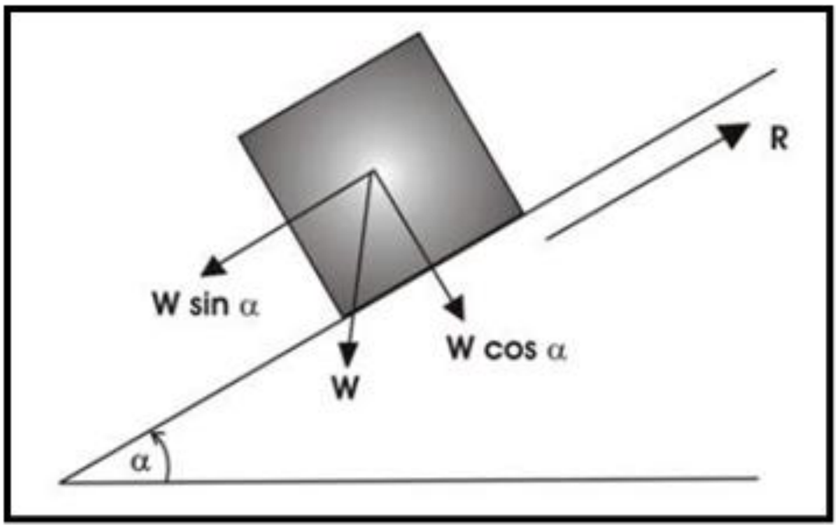

Figure 4*. Illustration of Gravitational Force, Moving Force, and Restraining Force on an Inclined Plane*

Data processing was performed by modeling the slope geometry into Slide 6.0 software and inputting material data and pseudo-static parameters into the simulation (fill weight, cohesion, inner friction angle, groundwater table, and seismic coefficient due to earthquake). The Bishop Simplified method was used as the main analysis method since it considers moment balance by assuming a curved normal stress distribution on the slip plane. After the simulation was run, Slide 6.0 software generated Factor of Safety (FK) values for static and pseudo-static conditions. A comparison of FK values gives an idea of the impact of the earthquake on slope stability. The flow of this research can be seen in **Figure 5**.

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The safety aspect can be categorized into three based on the type of slope and the severity or intensity of the landslide (Kepmen ESDM No. 1827, 2018).

Table 1.

Classification of Safety Factor Values and Landslide Probability of Mine Slopes (Minister of Energy and Mineral Resources Decree No. 1827/K/30/MEM/2018)

Slope Type	**Landslide Severity**	**Acceptable Criteria**		
		Safety Factor (FK) Static (min)	**Safety Factor (FK) Dynamic (min)**	**Landslide Probability (max) PoF (FK <= 1)**
Single Slope	Low to High	1,1	None	25-50%
Inter-ramp	Low	1,15 - 1,2	1,0	25%
	Medium	1,2 - 1,3	1,0	20%
	High	1,2 - 1,3	1,1	10%
Overall Slope	Low	1,2 - 1,3	1,0	15 - 20%
	Medium	1,3	1,05	10%
	High	1,3 - 1,5	1,1	5%

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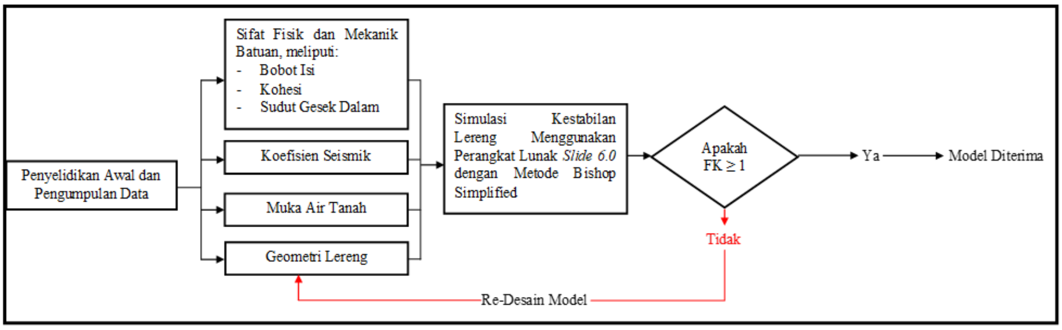

Figure 5*. Research Flowchart*

Results And Discussion

Physical and Mechanical Properties of Rocks

The avalanche at Mine Ridge Pit occurred on a slope with argillic alteration rock material and part of the overall slope, so the research will focus on this geological domain. Laboratory test results will be used in the slope analysis data as material properties, including physical and mechanical properties tests.

The physical properties test of the rock determines the density value, whether it is in a normal, dry, or saturated state. Mechanical properties testing using a direct shear strength test will produce a cohesion value and inner shear angle based on Mohr-Coulomb collapse criteria. The results of the physical and mechanical properties tests are presented in Table 2.

Table 2.
Physical and Mechanical Property Parameters

Physical Properties		**Mechanical Properties (Strong Shear)**	
Natural Density **(kN/m³)**	***Saturated Density*** **(gr/cm³)**	***Cohesion*****, C (Kpa)**	***Friction Angle*****, θ (°)**
22	**-**	**36**	**18,5**

Analyzed Slope Model

Before analyzing the stability of the slope, the authors used several approaches in the model to be used, namely:

1. Design and analysis of slope geometry recommendations using the actual domain on the Pit Mine Ridge analyzed namely the Argillic domain.
2. The geotechnical domain follows the alteration distribution in the Mine Ridge Pit Mining Area, as the alteration process affects the rock characteristics.
3. There has been a landslide in the Mine Ridge Pit with a circular avalanche shape in the form of an arc avalanche, so it would be appropriate to use the Bishop Simplified method.
4. The groundwater level is the result of actual measurement.
5. The collapse criterion in the study is the Mohr-Coulomb criterion, as the landslide is controlled by the material characteristics of the slope and is not greatly disturbed by the structure.
6. The seismic load value used in this study is 0.165 (SNI 1726:2019), in accordance with the seismic conditions of the research area.
7. The analysis follows the provisions of KEPMEN ESDM No. 1827 K/30/MEM/2018. The analysis on the overall slope is at a low landslide severity level, so Fkmin > 1 under dynamic conditions.

Several constraints on this research cause limitations that need to be considered, namely:

1. Data on the physical and mechanical properties of materials are derived from laboratory test results on specific samples. Variations in material properties in the field, such as cohesion distribution and pore water pressure, can affect the results of stability analysis.
2. The modeling does not depict discontinuity conditions that affect stability.

3. The pseudo-static coefficient (kh = 0.165) was calculated based on average seismic data. Uncertainties in the peak ground acceleration (PGA) data can affect the stability calculation results.

Slope Stability Analysis and Optimization

The stability analysis of the slope utilizes the limit equilibrium method, namely the Bishop Simplified method with the help of slide 6.0 software. The stability of the slope is based on the intricacies of the rock, including the weight of the rock content, cohesion (c), and the inner friction angle (ϕ), as well as the geometry (height and slope) of the slope. In addition, there are external factors, such as dynamic loads and groundwater, that affect the stability of the slope. If instability is found in the modeling results, it is necessary to remodel and recommend a new slope geometry until the slope is considered safe.

In **Table 2**, the test results of the physical and mechanical properties of the material show that the material with a natural density value of 22 kN/m³ and cohesion of 36 kPa has an inner shear angle of 18.5°. This value indicates that the material in the argillic domain is weak, increasing the potential for landslides. In addition, the actual geometry of the slope with a height of 20.07 meters and a slope angle of 47° resulted in a Factor of Safety (FK) value of 0.942 (**Table 3**), which is classified as unstable or unsafe according to the classification of Kepmen ESDM No. 1827 K/30/MEM/2018. Since the actual slope was unsafe, a new recommendation was needed. Experiments were conducted by lowering or leveling the slope geometry both in height and slope. Changes were made by lowering the slope from an overall slope of 47° to 33°. From these changes, a new FK of 1.035 was obtained (safe based on FK according to Kepmen ESDM K/30/MEM/2018). The recapitulation of FK values is presented in **Table 3**.

Table 3.
Recapitulation of Actual Slope FK and After Changes

Model	Height (m)	Angle (°)	FK Value
Actual Slope	20,07	42	0,942
Slope After Change	20,07	33	1,035

Based on the results of the stability analysis on the actual slope, it can be seen that the new recommendation has a factor of safety value that is classified as safe. Changes in slope geometry and redesign results show that reducing the slope angle significantly improves the stability of the slope. However, there are other options for changing the geometry or cutting the slope. The slope can be made into a double bench or a triple bench with a fixed slope height of 20.07 meters and a slope of 33°. The cutting is done on slopes that are indicated to be unstable. The simulation results show that the slope using the double bench has an FK value of 1.055 (**Figure 6.a**), and FK on the triple bench is 1.042 (**Figure 6.b**).

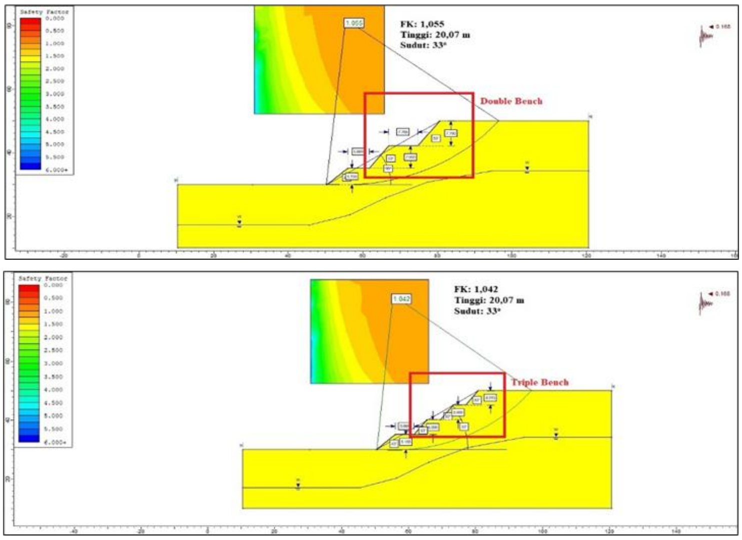

Figure 6. (a) *Double Bench* Slope (b) *Triple Bench* Slope

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Table 4.
Recapitulation of Actual Slope FK and After Changes

Model	Height (m)	Angle (°)	FK Value
Double Bench	20,07	33	1,055
Triple Bench	20,07	33	1,042

In addition to relying on changes in slope geometry, maintaining slope stability can also be done by keeping the groundwater level from exceeding the equilibrium limit. As shown in the modeling results, the groundwater level does not touch the landslide plane; when water touches the landslide plane, it will cause instability to the slope. Regular monitoring of the groundwater level will be very helpful in maintaining the stability of the slope. When the water table exceeds the landslide limit, pumping should be done immediately until the water table returns to the normal limit.

Moreover, deformation monitoring of slopes is crucial and needs to be planned to minimize the risk of landslides. Monitoring of slopes will also help in analyzing and reviewing the causes of slope instability so that countermeasures and preventive measures can be taken quickly through back analysis. Deformation monitoring can be done using tools such as crack meters, extensometers, total stations, and also radar (slope stability radar).

The results of this study have implications for the operational safety of open-pit mines. By considering seismic effects through pseudo-static methods, this approach can improve the predictability of landslide risks, especially in regions with earthquake activity. In the context of mining industry standards, the results emphasize the importance of complying with regulations to ensure mine slope stability.

There are several suggestions for future studies to improve the accuracy and application of the research results, including collecting more material samples to understand the variability of physical properties and mechanical properties of soil/rock; validating the model with field monitoring data, such as measurements of slope deformation and groundwater level; and developing simulations that consider complex geological structures to improve the representation of field conditions.

Conclusions

Slope stability analysis at PT J Resources Bolaang Mongondow was conducted at the Mine Ridge Pit area where a previous landslide had occurred. The landslide occurred at Pit Mine Ridge in the argillic domain. The actual slope has a height of 20,070 meters and a slope of 47°. Modeling results with the simplified Bishop's boundary equilibrium method obtained an FK of 0.942. Based on the classification of Kepmen ESDM No.1827 K/30/MEM/2018, the slope is classified as unstable, where the minimum FK for pseudo-static analysis of the overall slope is 1 (FK>1).

The slope geometry needs to be redesigned to obtain a safer geometry. The material properties of the slope, namely cohesion ( ) and deep shear angle ( ), affect stability. Weak materials, such as the argillic domain of the Mine Ridge Pit, require a gentler slope angle to improve stability. The redesign allows customization of the geometry according to the material characteristics. Simulations were conducted by trying appropriate heights and slopes until a stable FK was obtained. An FK of 1.035 was obtained for the slope with the slope geometry reduced to 33° (single bench). The slope can still be formed into double bench and triple bench with FKs of 1.055 and 1.042, respectively.

In addition to relying on the stability of the slope geometry, it is also possible to maintain stability by monitoring the groundwater table. If the water table exceeds the threshold, that is, if it reaches the argillic domain, or when the water touches the avalanche plane, it will destabilize the slope. Regular monitoring of the water table will help maintain slope stability. When the water table exceeds the landslide limit, pumping should be done immediately until the water table is back to normal. Monitoring of deformation is also important as an early measure to detect slope instability.

This research reinforces the applicability of the pseudo-static method in slope stability analysis, which considers the influence of earthquake-induced inertial forces. This contribution is important because conventional methods often neglect dynamic loads, resulting in less representative analysis results for seismic conditions. The findings can serve as a basis for further research, such as the integration of full dynamic (time-history) analysis or numerical approaches such as the finite element method (FEM) for more complex conditions.

References

5607-02, A. D. (2002). Code ASTM D 5607 - 02 Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force. Code Book, 04.

Ali, R. K., Winarno, T., & Jamalulail, M. A. (2020). Characteristics of Alteration and Epithermal-Type Mineralization of the Mount Budheg and Surrounding Areas, Tulungagung, East Java. Eksplorium,41 (1), 1. https://doi.org/10.17146/eksplorium.2020.41.1.5676

Arief, Irwandy. 2016. "Geotechnical Mining". Gramedia Pustaka Utama: Jakarta

Hardianto, A., & Heriyadi, B. (2019). Analysis of Pit D Disposal Area Slope Design at PT. Aman Tobilah Putra Lahat Regency, South Sumatra Province. Journal of Bina Tambang, 4(2), 21–30.

Hoek, E., Bray. (1981): Rock Slope Enginerring Revisde 3rd Edition, The Institution of Mining and Metallurgy, London, 341 - 351.

Hudson, J.A. and Harison, J.P. 1997. "Engineering Rock Mechanics an Introduction to the Principles". Elsevier Science Ltd: United Kingdom.

Iswandaru, I., & R., R. N. (2019). Analysis of the Effect of Structure Position on Avalanche Potential using Stereographic Projection. ETHOS (Journal of Research and Service),7 (2), 302-310. https://doi.org/10.29313/ethos.v7i2.4709

Minister of Energy and Mineral Resources Decree No. 1827 K/30/MEM Year 2018 concerning Guidelines for the Implementation of Good Mining Practices.

Kliche, Charles A. 1999, "Rock Slope Stability, Society for Mining", Metallurgical an Exploration (SME), Littleton, Colorado, pp. 2-5; 9-12; 41-43; 111-114.

Manullang, P. (2020). Analysis of Slope Failure Probability in Coal Mine Slope Design Using the Boundary Equilibrium Method. Perhapi XXIX TPT Proceedings, 1–12.

Muchtar, A. F., & Anaperta, Y. M. (2020) Prism to Know the Movement on Inpit and Expit Slopes of PT Sago Prima Pratama (J Resources) Site Seruyung, Sebuku District, Nunukan Bina Tambang, 1-10. http://ejournal.unp.ac.id/index.php/mining/article/view/107813

Ramadani, R. N., & Iswandaru, I. (2019). Coal Mine Slope Stability with a New Approach of Empirical Method of Rock Mass Classification. ETHOS (Journal of Research and Service),7 (2), 297-301. https://doi.org/10.29313/ethos.v7i2.4708

Rifandi P Anis, M. D., & Isjudarto, A. (2022). Analysis of Avalanche Potential Using the Slope Mass Rating Method at the East Access Pit Mine Ridge and Camp Site. Mining Insight, 03(01), 63–72.

Sudinda, T. W. (2021). Slope Stability Analysis of the Tanah Laut Coal Mine Site in South Kalimantan. ALAMI Journal: Journal of Disaster Risk Reduction Technology,4 (2), 96-104. https://doi.org/10.29122/alami.v4i2.4556

Terzaghi, K., & Peck, R. B. (1967). Soil Mechanics in Engineering Practice (2nd ed.). John Wiley & Sons, New York.

Usman, D. N. (2017). Good Mining Practice as a Support for Sustainable and Environmentally Sound Mining Management. ETHOS (Journal of Research and Service), 1. https://doi.org/10.29313/ethos.v0i0.2219

 DOI: https://doi.org/10.29313/ethos.v13i1.4437