Available online at:
Al-Fiziya: Journal of Materials Science, Geophysics,
Instrumentation and Theoretical Physics
Website: http://journal.uinjkt.ac.id/index.php/al-fiziya
Vol.7 No. II 2024, 14 - 21

DESIGN OF SAFETY FACTORS FOR LANDSLIDE POTENTIAL AND ANDESITE MATERIAL SLOPES GEOMETRY

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Submitted: October; Revised: November; Approved: December ; Available Online: December

Abstract. This study was carried out in order to maximise the material absorption capacity. To ensure that there is no risk of landslides in the research region, a mining slope geometry with an ideal safety factor value must be created. The Morgenstern pricing approach was selected because it takes into account the stability of forces and moments. The actual slope geometry that has not been tested for safety needs to be changed. The physical and mechanical properties data collection is processed to produce a geometric model with a safety factor in accordance with applicable regulations. The actual slope geometry of the Cijurey block is 20 m with a slope of 85°, 8 m with a slope of 88°, 5 m with a slope of 83° and 4 m with a slope of 85° with a safety factor value of 1.01. A geometric change was made with a slope height of 6 m and a ladder width of 3m which was made multi-level with an overall angle of 80o having a safety factor of 1.302 which means that it has met the slope safety criteria.

Keywords: *geometry, safety factor, slope.*
DOI : 10.15408/fiziya.v7i2.42160

INTRODUCTION

The need for andesite stone in Indonesia is increasing from year to year along with the increasing population, the development of technology and economic growth. This is supported by one of the government's priority programs to advance Indonesia's infrastructure. In order to advance the Mining Industry, especially in Industrial Mines, so that the material absorption capacity is maximized, it is necessary to conduct a study of the mining slope safety factor for employee safety, the surrounding environment, and also the smoothness of production activities. With that, optimal mining planning must be determined from the slope geometry design that can be applied in the field [1].

One of the mining activities carried out by the Andesite mining company is mining with the sidehill quarry method with mining levels [2]. Where at the mining level there are still many materials that are suitable for production. Therefore, this study was conducted to analyze the slope geometry to obtain the optimum safety factor value in order to minimize the potential for landslides that arise as a form of increasing the safety factor and andesite material production can be increased and the profits obtained by the company can be maximized again [3].

Thus, the planning of Mining Slope Geometry for Safety Factors in the Cijurey block, Neglasari Village, Sukabumi can help and provide recommendations for mining slope geometry with a safe safety factor value and maximize the andesite mining material that can be taken.

RESEARCH METHODOLOGY

Time and Location of the Research

This research was conducted in the Cijurey Block, Neglasari Village, Nyalindung District, Sukabumi Regency, West Java Province. The research area is geographically located at coordinates 106°57'11.95" – 106°57'36.40" East Longitude (BT) and 6°58'34.25" – 6°58'49.87" South Latitude (LS). The specific location of the research is at the mining site owned by PT Gunung Bumi Perkasa, with coordinates (x,y) 82.83956683075046, 120.72301718730303.

Data Collection Techniques

This study uses quantitative analysis preceded by primary data collection through rock sampling in the field, as well as secondary data obtained from the Head of Mining Engineering. These data are used in the analysis process to determine the safety factor value which is the basis for designing the stability of andesite mine slopes in the Cijurey Block, Neglasari Village. Primary data were collected through direct measurements of the actual slope geometry in the field, including the slope width measured using a meter, the slope height measured using an altimeter, and the slope slope measured using a geological compass. Meanwhile, the secondary data used include the safety factor value and the probability of mine slope landslides in accordance with the provisions of KEPMEN No. 1827, as well as the physical and mechanical properties of rocks obtained from PT Gunung Bumi Perkasa. Data collection on the physical and mechanical properties of rocks was carried out by taking two rock samples at the research location, where each sample represents a certain layer in the research area. One sample can be used to determine both properties. Physical tests are carried out non-destructively to obtain the dry and wet weight of the rock, while mechanical tests are destructive to determine the strength of the rock through the Unconfined Compressive Strength (UCS) test, so that the rock structure is destroyed. This data is needed to calculate the RMR (Rock Mass Rating) value, which is then used to determine the GSI (Geological Strength Index) value as an important parameter in calculating the safety factor. In addition, the orientation of the discontinuity plane such as the strike direction and the slope of the exposed fracture on each bench is also measured and used in the RMR analysis. Other parameters used in this analysis include the UCS value from laboratory tests, the distance between discontinuity planes measured perpendicularly, and the Average Fracture Frequency (AFF), which is then converted into the RQD (Rock Quality Designation) value using the Priest and Hudson method.

Data Processing Techniques

Vol.7 No. II 2024, 14-21
P-ISSN: 2621-0215, E-ISSN: 2621-489X

This study uses quantitative This data processing is done using quantitative methods. The first stage is analyzing the type of landslide using the slope direction data from the fracture that has been measured in the field using the Geological Compass at each level of the mining slope.

Analyze the safety factor using the Mogenstern Price method which takes into account the equilibrium of various forces, such as vertical force, horizontal force, and moment force or rotational force[12]. Where this method uses the same assumption as the limit equilibrium, namely the relationship between the shear force between slices, and the normal force between slices so that the value of the slope safety factor is obtained, using the parameters of the Generalized Hoek & Brown collapse criteria. So that the value of the safety factor is obtained from the actual slope and the slope that has been optimized [13].

Calculations are made by comparing the actual geometry with the optimized geometry to obtain the volume that can be extracted or maximized, so that the volume obtained is calculated with the selling price of andesite material processing to obtain the profit that can be achieved.

RESULT AND DISCUSSION

Slope Forming Materials

This research was conducted in the Cijurey block, Sukabumi. Observations were made directly so that the material forming the slope could be identified. The slope-forming material that all has the same type and color can be classified into a homogeneous structure type material [2]. The material forming the slope in the field is Andesite Lava Rock [3]. The stability of the slope itself may be affected by the occurrence of cracks or discontinuous planes brought on by the earth's movement [20].

Actual Slope Geometry

The geometry of this slope is created by modeling the actual conditions through a straight section in the northwest-southeast (NW-SE) direction to make it easier to determine the slope conditions, landslide slip planes, and so that the display becomes 2-dimensional [15]. Based on the results of the section that has been made, the highest point is at coordinates (x,y) 82.83956683075046, 120.72301718730303 this point is on the section and the lowest point is at coordinates (x,y) 82.83989375450317, 120.727776427703.

Table 1. Actual Slope Geometry

Bench	Height (m)	Bench Terrace Width (m)	Slope Angle of Incline (°)
1	4	14.9	85
2	5	6	88
3	8	7	83
4	20	24.8	85

In this study, actual slope geometry data collection has also been carried out, which can be seen in **Table 1**. So that actual slope modeling can be carried out.

Section A-A' with an overall slope of 50° and has a length of 55.999 m and an overall height of 37 meters, there are 4 benches in this section with the toe position parallel to the lower end of the slope.

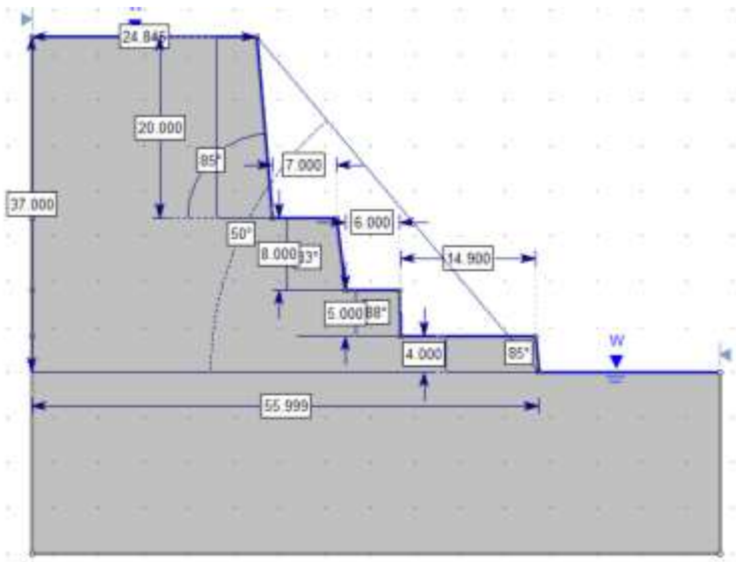

Figure. 1 Actual Slope Model

Slope Geometry Changes

The discussion in this study is in the form of an analysis of the types of landslides that have the potential to occur in the field, so that this study can determine the types of landslides that occur, then the actual geometry is made to determine the value of the safety factor of the slope by entering the parameters that have been explained above[11]. After the safety factor value of the actual geometry has been obtained, optimization is carried out by designing two types of mining slope geometry designs to maximize the value of the safety factor according to what has been determined and maximize the material that can be taken [8].

Actual Safety Factor

The fracture data that has been processed to determine the type of landslide from the Cijurey block slope shows that the potential landslide type is the wedge landslide type which will then determine the safety factor analysis of the mining slope. It was also found that the slope geometry of the Cijurey block has four slopes, where the slope geometry of each section is different.

The analysis conducted to determine the safety factor of the actual geometry is divided into two sections due to differences in geometry, especially in the width of the slope terrace (berm width) of each level [4]. Based on the generalized Hoek and Brown parameters, processing and analyzing slope stability have been carried out, so the safety factor is obtained with the Morgenstern Price slope stability calculation method, namely 1.010.

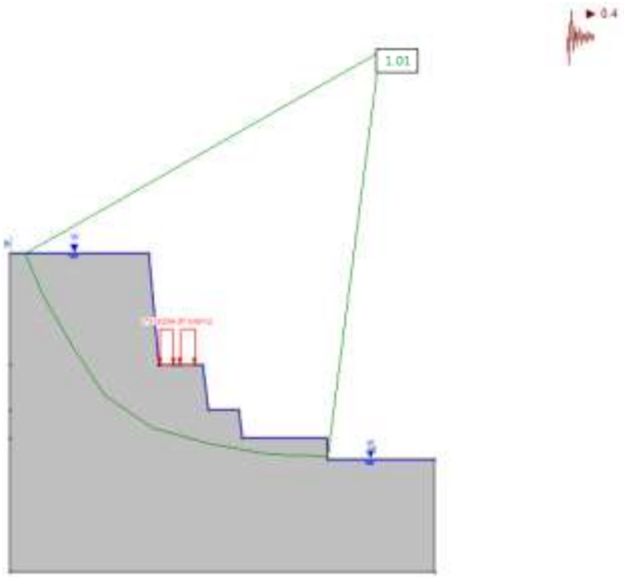

Figure. 2 Actual Slope Geometry Safety Factor

The minimum safety factor value that has been set in KEPMEN 1827 is ≥ 1.1 for dynamic slopes and FK ≥ 1.2 for static slopes. So based on KEPMEN 1827, the slope condition is very safe so that it needs to be optimized again so that the material absorbed is more than its actual geometry.

Safety Factor Optimization

In the Cijurey block, the actual mining slope geometry has different geometries[10]. So that the mining slope needs to be optimized so that more material is obtained by reducing the FK value of each cross-section that has been adjusted by KEPMEN 1827 [9].

This optimization is done by changing the geometry of the mining slope, the first change made is to the slope of the slope which is equalized at each level by increasing the slope and reducing the width of the level so that more material can be obtained [5]. Changes are also made to the first level which is changed to three levels (benching) so that the material taken can be maximized, then changes are also made to the third level as stipulated by KEPMEN 1827 [7].

Simulations to optimize the slope were carried out 3 times with changes in the width of the steps and the slope gradient, with the slope height set at 6 meters. The first dynamic slope simulation was carried out by changing the geometry of the slope with a height of 6 meters, a width of 3 meters with a slope of 83°. The second simulation was by changing the geometry with a height of 6 meters, a width of 3 meters and a slope of 81°. The last simulation was by changing the width to 3 meters, a height of 6 meters, and a slope of 80°. On the static slope, a geometry change was carried out where the geometry was the same as the dynamic slope, because the dynamic slope was approaching the safety factor value set by KEPMEN 1827. The three simulations of geometric changes in dynamic and static slopes can be seen in **Table 2**.

Table 2. Actual Slope Geometry

Simulation	Height (m)	Width (m)	Slope (°)	Ramp Width (m)	*Overall Slope*(°)	FK Value

1	6	3	82	9	55	1.20
2	6	3	80	9	54	1,302
3	6	3	83	9	53	1.02

After conducting 3 simulations with different slope geometries, the optimal slope geometry was obtained, namely in the second simulation. In this study, the slope geometry recommendations are divided into two, namely mining slopes with ramps (interramps) and slope geometry without using ramps.

Slope Geometry Recommendations

Geotechnical modeling by changing the geometry of the mining slope which is 6 meters high, 3 meters wide, and 80° slope or can be seen in the geometry can be applied to mining slopes with 6 levels. The value of the dynamic slope safety factor without a ramp is 1.302 without any distributed load or vertical loading from the hauler heavy equipment. This value is greater than what has been decided by the Decree of the Minister of Energy and Mineral Resources 1827K of 2018 Dynamic Overall Slope, which is ≥ 1.1. With the same FK value as that which has been determined, modeling with slope geometry.

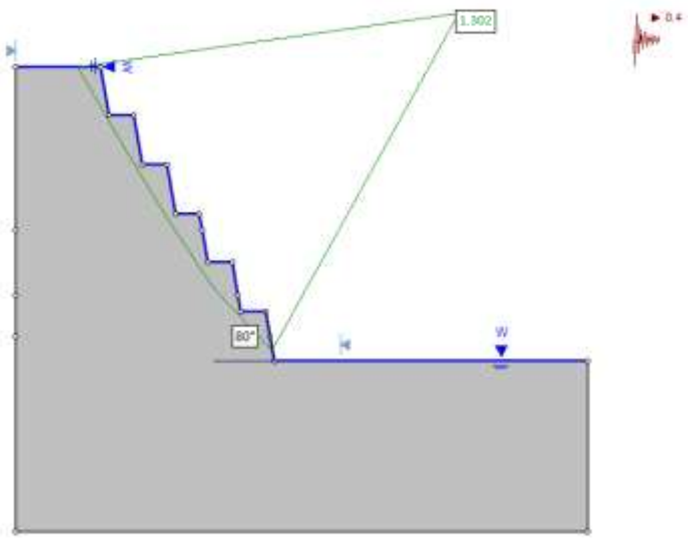

Figure. 2 Slope Geometry Recommendation Modeling

CONCLUSION

Geotechnical modeling on actual slopes that have various slopes and differences in height of the steps with a safety factor of 1.01 which is declared unsafe, geometric changes are made according to the Morgenstern price analysis, resulting in a slope geometry that has a height of 6 meters, a width of 3 meters and a slope of 80°. This slope geometry can be applied to slopes with a total number of steps of 6 steps in the cross section. The slope has a geometry that is 6 meters high, a bench width of 3 meters and a slope of 80°. The dynamic slope safety factor value is 1.302. The slope resulting from this geotechnical modeling has exceeded the minimum safety factor value set by the Decree of the Minister of Energy and Mineral Resources Number 1827 K of 2018 for static slopes.

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