The landfall probability of highwall slope’s geometry in PT. Mahakam Prima Akbar Sejati, East Borneo Province

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Abstract. PT. Mahakam Prima Akbar Sejati is a coal mining company that uses the open pit mining method which in its implementation will make slopes with certain geometries. This research was conducted in PIT ‘N’ section A-A ‘Highwall MPASGT-01 and section B-B’ Highwall MPAS GT-02, aimed to determine the value of safety factors that are safe and in accordance with the minimum safety factor values set by the company, namely ≥ 1.3. The safety factor value is determined by the Bishop method for overall slope, from the geometry of section A-A ’Highwall 01, an individual slope angle (α) of 65 °, bench width of 5 meters, height (h) of 10 meters, with a total of nine individual slopes formed slope, will produce an overall slope (Overall Slope) with 48 ° slope angle dimensions, 90 meters high, and has a safety factor value of 1.46 with a cumulative collapse of 13.48%. For the B-B ’Highwall MPAS GT-02 section, an individual slope angle (α) of 65 °, bench width of 5 meters, height (h) of 10 meters, with the number of individual slopes formed by eight slopes will produce an overall slope (Overall Slope) with a slope angle dimension of 48 °, a height of 80 meters, and has a safety factor value of 1.52 with a cumulative collapse of 8.90%.

1. Introduction

PT. Mahakam Prima Akbar Sejati itself is a mining company engaged in coal exploitation one of which located in PIT „N” sub-district Loakulu, Kutai Kartanegara district, East Borneo province and serves as the research area. In coal-mining activity, PT. Mahakam Prima Akbar Sejati applies the surface mining system with that of the open pit mining method. Open pit mining method is executed by digging the surface of the land in order to form mining slopes with certain elevation and gradient. The mining slopes created can be in the form of highwall slope. Highwall slopes are slopes intentionally dug up using mechanical equipment or blasting which tend to be made perpendicular to the direction of the rock layer or intersect with the direction (strike) where the surface layer forms a tiered bench and its position has a different elevation and forms an angle with a certain slope. In connection with coal production and mining operations in the work area of PT. Mahakam Prima Akbar Sejati, it is, therefore, necessary to analyze the safety factor of highwall slope geometry and determine the cumulative probability of slope failure. Slope geometry analysis was carried out in the area of the research site, the „N” pit. Especially in the area of MPASGT-01 and MPAS GT-02 drilling points.

2. Research methods

The method employed in this study is that of the direct method (primary data) and the indirect method (secondary data). The direct method consists of observation and retrieval of data directly in the field whereas the indirect method constituted mainly of retrieval of existing data (company data). The
The results of the field data are in the form of field observations and secondary data followed by the slope design planning by means of software technology. Secondary data acquired from the laboratory such as cohesion (c), content weight (γ) and deep shear angle (φ) are used as an index property analysis of the slope stability factor. The modeling the overall slope is created through Slide Rocscience software using the Bishop avalanche analysis (circular failure) method. The results of the analysis of the calculation of the value of safety factor from each cross section are then taken into consideration in designing a safe slope consistent with the safety factor of ≥ 1.3 according to the Mining Department provisions of PT. Mahakam Prima Akbar Sejati.

2.1. Bishop iteration

The Bishop method simplified [1] asserts that the forces acting on the sides of the slice have zero resultants in the vertical direction. The Bishop method is used to analyze circular slip surfaces. In this method, it is assumed that the circular collapse is the result of rotational motion in the mass of the earth and the normal force acting on the center of the slice in the vertical direction.

![Figure 1](source: Rock Slope Engineering [2].)

**Figure 1.** Forces working on the slice (Bishop Method).

From the figure 1. The equation to calculate the value of the security factor can be derived as follows Figure 2:
The equation to calculate the value of the security factor can be derived.

\[ F_K = \frac{1}{W \sin \alpha} \left( \frac{(c+b+(W-b)u)\tan \phi}{\tan \phi \tan \alpha} \right) \]

\[ F_K = \frac{1}{\sum W \sin \alpha} \left( \frac{1}{(1+\tan \phi \tan \alpha / F)} \right) \]

Legend:
- \( S \) = Effective shear force
- \( s \) = Existant shear force
- \( c \) = Effective cohesion
- \( P \) = Normal effective force on the basis of incision
- \( R \) = Circle radius of slip plane
- \( \phi \) = Effective inner sliding angle
- \( \mu \) = Pore water tension
- \( E_n, E_{n+1} \) = Horizontal forces on the slice
- \( X_n, X_{n+1} \) = Vertical forces on the slice
- \( F \) = Safety factor

2.2. Distribution of probability

The probability density function (PDF) provides the likelihood of a random variable to take a certain value. The typical density function is illustrated in the opposite manner. In this case the random variable is distributed in continuity (e.g., Can take all possible values). The area under the PDF is always united. An alternative way to present similar information is through a cumulative distribution function (CDF), which gives the probability that the variable will have a value less than or equal to the chosen value. CDF is an integral part of the corresponding probability density function, e.g., ordained at \( x \) in the cumulative distribution is the area under the probability density function to the left of \( x \). Take note that \( f_x (x) \) is used to ordain PDF while \( F_x (x) \) is used for CDF [3]. Probability value uses the value of the safety factor as a parameter of the random variable, which is then characterized by their respective values [4]. In this paper, the researcher uses the cumulative distribution function approach. The equation to determine CDF values is illustrated below:

\[ F_X (x) = \int_{-\infty}^{x} f_x (x) \, dx \]

3. Results and analysis

The results and discussion will be presented in the form of a calculation of the safety factor of a highwall slope, and an interpretation of the results of the calculations. This research was conducted in the plan to open a mining site at PIT "N" PT. Mahakam Prima Akbar Sejati.

3.1. Determining the value of the safety factor

Before conducting a safety factor analysis, a laboratory testing was first carried out aiming to find out the characteristics of the material in the location of PT. Mahakam Prima Akbar Sejati. Sample testing was implemented to determine the geotechnical parameters which would then be used in slope design modeling, the geotechnical parameters were in the form of physical properties and mechanical properties of materials (rocks). Rock mechanical properties such as the inside shear angle (\( \phi \)), cohesion (\( c \)), while physical properties of rock were fill weight (\( \gamma \)). From the two drilling hole points, the samples were then tested to determine the physical and mechanical properties. The test was carried out in the Tekmira Bandung laboratory. The following results of testing rock samples can be seen in Table 1 and Table 2.
Table 1. The testing results of physical properties of rock samples MPAS GT-01.

| Hole ID | ID Sample | Lithology | Classification | Specific Gravity | Cohesion (kPa) | Friction Angle (°) |
|---------|-----------|-----------|----------------|------------------|----------------|-------------------|
| MPAS GT 01 (UCS 01) | OB | Siltstone 1 | 20.23 | 54.06 | 30.76 |
| MPAS GT 01 (UCS 08) | OB | Siltstone 2 | 20.19 | 233.95 | 26.08 |
| MPAS GT 01 | Seam M | Coal | 12.74 | 280.00 | 25.00 |
| MPAS GT 01 (UCS 11) | Interburden 1 | Sandstone 1 | 20.49 | 273.14 | 20.50 |
| MPAS GT 01 | Interburden 2 | Claystone | 19.67 | 156.32 | 29.28 |
| MPAS GT 01 (UCS 12) | Seam NI | Coal | 12.74 | 280.00 | 25.00 |
| MPAS GT 01 | Interburden 3 | Sandstone 2 | 26.18 | 338.33 | 40.42 |
| MPAS GT 01 (UCS 13) | Seam N2 | Coal | 12.74 | 280.00 | 25.00 |
| MPAS GT 01 (UCS 13) | Interburden 3 | Sandstone 2 | 26.18 | 338.33 | 40.42 |

Source: Researcher’s calculation, 2019.

Data from the test results of physical properties of rock samples (soft rock) were then inputted and made into a model to obtain the value of the safety factor on the slopes of Highwall MPAS GT-01. With the slope dimension of 10 meters high, and an angle of 65°. The determination of the dimensions of the slope itself has been established by PT. Mahakam Prima Akbar, but if there is a mismatch, the slope dimensions can be changed to achieve the value of the safety factor set by the company. The results of the slicing design section and section AA rock correlation with the total length of the section 466.52 m using the 2007 AutoCAD software, produced the overall slope geometry design for Highwall 1 with a 110 m elevation namely a maximum height of the overall slope at PIT „N” Highwall 1 = 90 meters opening, seen from the results of the correlation of MPAS GT-01 geotechnical drilling points that the most dominant constituent rocks in the Highwall slope body were siltstone, coal, sandstone and claystone. These rocks are classified into several materials, namely Overburden, interbuden and Seam Coal. Figure 3.

Figure 3. Section A-A’ Highwall MPASGT-01.

The calculation of the slope safety factor section A-A’ Highwall MPASGT-01 was made in overall slope adjusted to the slope dimensions as planned by the company. From the results of the calculation of the overall safety slope factor, the safety factor value is 1.46 with an overall slope angle of 48° and a height of 90 meters, thus the slope section AA’ Highwall MPASGT-01 belongs to the safe category.
as described in Figure 4. It is shown from the factor value the security obtained is greater than the value of the security factor determined by the company.

![Image](image-url)

Source: Researcher’s calculation, 2019.

**Figure 4.** The slope form section A-A’ Highwall MPASGT-01.

The safety factor analysis was then carried out in section B-B 'Highwall MPAS GT-02, using the same method as in section A-A’ Highwall MPASGT-01. For the input of modeling section B-B 'Highwall MPAS GT-02 can be seen in Table 2.

**Table 2.** The testing results of physical properties of rock samples MPAS GT-02.

| Hole ID      | ID Sample    | Lithology | Classification | Specific Gravity (kN/m^3) | Cohesion (kPa) | Friction Angle (°) |
|--------------|--------------|-----------|----------------|---------------------------|----------------|-------------------|
| MPAS GT 02   | MPAS GT 02 (UCS 02) | OB        | Sandstone 1    | 18.54                     | 130.61         | 16.57             |
| MPAS GT 02   | MPAS GT 02 (UCS 04) | OB        | Claystone 1    | 18.46                     | 88.93          | 40.68             |
| MPAS GT 02   | Seam A       |           | Coal           | 12.74                     | 280.00         | 25.00             |
| MPAS GT 02   | Interburden 1 |           | Sandstone 2    | 19.95                     | 191.89         | 32.82             |
| MPAS GT 02   | Interburden 2 |           | Claystone 2    | 19.57                     | 322.26         | 32.55             |
| MPAS GT 02   | Seam N       |           | Coal           | 12.74                     | 280.00         | 25.00             |
| MPAS GT 02   | Interburden 3 |           | Sandstone 3    | 19.98                     | 338.33         | 40.42             |
| MPAS GT 02   | Seam B       |           | Coal           | 12.74                     | 280.00         | 25.00             |
| MPAS GT 02   | Interburden 2 |           | Claystone 2    | 19.57                     | 322.26         | 32.55             |

*Source: Researcher’s calculation, 2019.*
The section B-B of figure 5 has a section length of 466.52 m using AutoCAD 2007 software, interpretation results indicate the overall slope geometry design of Highwall from 2 up to 89 m elevation which is the maximum height of the overall slope at the PIT „N” Highwall 2 opening is 80 meters, the results of the rock correlation show that the most dominant constituent rocks on the Highwall 2 slope body are coal, sandstone and clay stone while other rocks are only the slope body inserts. The three dominant rocks above are classified into several materials, namely Overburden (see figure 6).

As for the calculation of the overall slope safety factor of Highwall 2 using Slide Rocsience Software, the recommended overall slope in total saturation is formed with an individual slope angle (α) of 65°, bench width 5 m, height (h) 10 m, and the number of individual slopes amounting to 8 slopes, will produce an overall slope with a slope angle dimension of 48°, a height of 80 meters, and has a safety factor value of 1.52 thus the calculation of the safety factor of Highwall 2 is included in the stable or safe category.
From the results of the analysis of safety factors, the failure probability analysis was then carried out on the slopes of section A-A' Highwall MPASGT-01 and section B-B' Highwall MPAS GT-02 to determine the cumulative probability of collapse. The probability analysis follows the KEPMEN RI No. 1827 K / 30 / MEM / 2018, with the minimum static safety factor being 1.3 and dynamic safety factor 1.00 for the overall slope. With probability criteria, it can be accepted by 10%. In this investigation, the researcher used the limit of safety factor of 1.00 as a dynamic security factor and static safety factor 1.30 which is adjusted to the stipulations of KEPMEN RI No. 1827 K / 30 / MEM / 2018 and to the needs of the company [5].

3.2. Collapse probability

3.2.1. Cumulative Collapse of the slope section A-A’ Highwall MPAS GT-01: From the results of the analysis of safety factors, an analysis was then made by the probabilistic methods to obtain the cumulative value of the collapse. As in Figure 7.

![Cumulative Probabilities of Collapse With dynamicSF](image)

**Figure 7.** The graphic of Cumulative slope section A-A’ Highwall MPAS GT-01 With dynamic security factor value (A) and static security factor value (B).
Based on the results of data processing of the slopes of section A-A 'Highwall MPAS GT-01, the cumulative collapse value of the dynamic safety factor of 13.48% means that the slope is categorized as unacceptable because 13.48% > 10%. As for the slope section AA 'Highwall MPAS GT-01 with static safety factors, the cumulative value of failure is 36.05%, where the results of the analysis show that the cumulative value of the static safety factor is greater than the Probability of failure (PoF) determined (36.05% > 20%), so the value of static safety factors in the category is not accepted.

3.2.2. **Cumulative Collapse of the slope section B-B’ Highwall MPAS GT-02**: From the results of the analysis of safety factors, an analysis was then made by the probabilistic methods to obtain the cumulative value of the collapse. As in Figure 8.

![Cumulative Probabilities of Collapse](image)

**Gambar 8.** The graphic of Cumulative slope section B-B’ Highwall MPAS GT-02 With dynamic security factor value (A) and static security factor value (B).
Based on the results of data processing on the Highwall section B-B 'MPAS GT-02' slope, the cumulative collapse value of the dynamic safety factor of 8.90% means that the slope is in the acceptable category, because 8.90% <10%. As for the slope section AA 'Highwall MPAS GT-01' with a static safety factor, the cumulative value of collapse is 25.67%, where the results of the analysis show that the cumulative value of the static safety factor is greater than the specified PoF (25.67% > 20%), so that the value of static safety factors is categorized as less accepted with low landslide severity.

4. Conclusion
Based on the results and data processing, the cumulative value of the collapse was then obtained on the slope of Highwall section AA 'MPAS GT-01' with a dynamic safety factor of 13.48% which means that the slope is in the category of unacceptable, because 13.48% > 10%, for the slope section AA' Highwall MPAS GT-01' with a static safety factor a cumulative collapse value of 36.05% was obtained where the results of the analysis show that the cumulative value with a static safety factor value is greater than the limit value of the specified probability of failure (36.05% > 20%), while the slope The BB highwall section MPAS GT-02 has a cumulative collapse value of 25.67%. where the results of the analysis show that the cumulative value of the static safety factor is greater than the specified PoF (25.67% > 20%), so the value of the static safety factor is in the less acceptable category, while the value of the dynamic safety factor slope of Highwall section BB 'MPAS GT-02' with a cumulative collapse value of 8.90% is considered safe because 8.90% <10%.

Acknowledgement
The gratitude of the researchers is addressed to the following:
- Mr. Ir. Rubendi Tarigan, as the Manager Explorasi PT. Indo Sejahtera Manunggal
- Mr. Nicodemus Riwu Lobo, ST, as the Deputy Project Manager PT. Mahakam Prima Akbar Sejati.
- Mr. Romy Parhusip, ST, as the Geology Supervisor of PT. Indo Sejahtera Manunggal who has helped the researcher
- Mr. Andrianus Kurniawa as well as all the team of the Exploration Department, Survey, Geology, Environment and Safety.

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