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GEOTECHNICAL ANALYSIS FOR SLIDE DUMP GEOMETRY OPTIMIZATION AT PT ALAMJAYA BARA PRATAMA MINE DISPOSAL AREA IN PIT 4B, KUTAI KARTANEGARA REGENCY

Yoga Apri Disetia, Prasetyo Wibowo, Pratama Gilang Kusuma, Faraz Sya'bana, M. Tegar Rizqullah
PT Antareja Mahada Makmur, Indonesia
Email: yoga.disetia@abpenergy.co.id prasetyo@abpenergy.co.id pratama.gilangkusuma@amm.id faraz.syabana@amm.id tegar.rizqullah@amm.id

Abstract
The management of open-pit mines is one of the challenges that often arises in the management of mine disposal areas, especially in supporting the efficiency of transporting mining materials. In this context, it is important to design a safe and efficient slide dump geometry to reduce the risk of slope failure and operational costs. The study involved the collection of geotechnical data, such as lithological and stratigraphic data obtained from exploratory drilling activities, as well as material property data, including cohesion and deep shear angle (). The collected data was then input into slope stability analysis software with the limit equilibrium method, which ultimately informed safe design recommendations for the disposal slide dump area. The results of this study not only provide an understanding of slope stability, but also highlight the importance of design optimization in supporting operational efficiency. Overall, this study confirms that the design of the disposal slides at the high wall of Pit 4B is stated to be feasible according to the calculations, simulations, and risk analysis that have been carried out, with the hope of meeting the aspects of safety, efficiency, and environmental sustainability.

Keywords: slope stability, disposal slide dump, open pit mine, geotechnical analysis, safety factors

INTRODUCTION

The mining industry is one of the strategic sectors in the Indonesian economy, contributing significantly to state revenue through the export of mining materials such as coal. Coal accounts for around 38% of Indonesia's total mineral exports, making it a key commodity in supporting national development (Garnaut, 2015; Islam et al., 2024; Soelistijo, 2015; Warburton, 2019; Wollff, 2023). However, mining activities are often faced with major challenges, such as the complexity of geotechnical conditions in the field, the need for operational efficiency, and the importance of maintaining occupational safety (Colas et al., 2023; Firoozi et al., 2024; Qian & Lin, 2016; Simser, 2019; Tubis et al., 2020). One of the challenges that often arises is the adequate management of mine disposal areas, especially in supporting the efficiency of transporting mining materials.

PT. Alamjaya Bara Pratama, located in Kutai Kartanegara Regency, East Kalimantan, carries out coal mining activities using the open-pit mining method. This method involves removing large quantities of overburden material before extracting the desired coal seam (Altiti et al., 2021; Elbeblawi et al., 2022; Gupta & Paul, 2015; Khaboushan et al., 2020; Ngwenyama et al., 2017). At the Pit 4 jobsite, the dumping pad area is currently on the side of the low wall, which is farther than the planned disposal location. This distance not only increases the cost of material transportation but also poses a challenge in terms of slope stability in the disposal area. Therefore, it is important to design a safe and efficient slide dump geometry to reduce the risk of slope failure and operational costs.

The stability of the slope in the disposal area is one of the key factors in determining the sustainability of mine operations. Unstable slopes have the potential to cause landslides,

which not only hampers operational activities but also increases the risk of work accidents (Ho et al., 2017; Sim et al., 2022). Geotechnical studies are an important approach to ensure slope stability, taking into account various parameters such as physical and mechanical properties of materials, groundwater table conditions, and slope geometry configurations. Previous research have shown that the limit equilibrium method is effectively used in slope stability analysis, especially for open-pit mines (Bednarczyk, 2017; Chiwaye & Stacey, 2010; Su et al., 2022).

In this study, the researchers would like to analyze the slope stability in the slide dump disposal area in Pit 4B. The study involved the collection of geotechnical data, such as lithological and stratigraphic data obtained from exploratory drilling activities, as well as material property data, including cohesion and deep shear angle (φ). The data was analyzed using Slide 6.0 software, which allows for the simulation of slope geometry and the calculation of safety factors (FK) based on material parameters.

In addition to slope stability, operational efficiency is also the main focus in this study. Reducing the distance to transport overburden materials can have a significant economic impact, both in the form of operational cost savings and increased productivity (Ghisellini et al., 2018). With shorter transport distances, fuel consumption and heavy equipment cycle time can be minimized, thus supporting the optimization of production unit utilization (de Jong et al., 2017). In this context, the design of the disposal slide dump area is not only aimed at ensuring the stability of the slope, but also to improve the efficiency of material transportation.

This research adopts a systematic approach to answer these challenges. The stages carried out include literature studies to understand geotechnical conditions in the mining area, primary data collection through direct observation in the field, and laboratory analysis to identify the mechanical properties of materials. The collected data is then used to model the slope geometry and calculate the value of the safety factor. A FK value greater than 1.2 is considered stable, while a value below that indicates the risk of failure. With this approach, the research is expected to provide relevant technical recommendations to support safer and more efficient mine operations.

The urgency of this research lies not only in the importance of maintaining work safety, but also in its contribution to the efficiency of mine operational costs. With guaranteed slope stability, the risk of failure can be minimized, thus supporting the smooth running of production activities. In addition, the efficient design of disposal areas can increase mine productivity, which ultimately has an impact on increasing state revenue through taxes and royalties.

This study has two main objectives. First, it provides a recommendation on the geometry of a safe slide dump based on geotechnical analysis. Second, optimizing the use of means of transportation to reduce the cost of transporting overburden materials. The results of this study are expected to make a real contribution to the management of open-pit mining in Indonesia, especially in supporting aspects of safety, efficiency, and operational sustainability.

The study is designed to provide technical solutions that are not only relevant in the context of operational efficiency, but also in line with regulations and sustainability principles. By combining geotechnical analysis and design simulation approaches, this research is expected to be able to answer the increasingly complex operational needs of open-pit mines, especially in facing geotechnical and operational challenges in the disposal slide dump area.

RESEARCH METHOD

The technical study on dumping activities in the slide dump disposal area was conducted by a team of five experts specializing in mine engineering and safety. Their objective was to analyze technical aspects related to slope stability and operational efficiency. The study commenced on October 23, 2024, and concluded on October 30, 2024. It included various activities such as literature reviews, data collection, modeling of slope geometry, stability analysis, and the preparation of a final report.

The research utilized both primary and secondary data to enhance the accuracy and relevance of its findings. Primary data was gathered through direct observations in the slide dump area, which involved measuring ground vibration acceleration to evaluate the effects of blasting on slope stability. Additionally, the team collected information on the design of the dump slide and the condition of the disposal area, alongside examining the properties of slope-forming materials to ascertain important geotechnical parameters. Secondary data were sourced from existing internal reports, including lithological and stratigraphic information, exploration drilling reports, and Life of Mine (LOM) design maps, which served as valuable references for modeling slope geometry and conducting stability analyses.

The analysis was conducted using a geotechnical approach grounded in the limit equilibrium method, specifically employing the Mohr-Coulomb principle. This approach enabled the calculation of slope safety factors by considering both the holding and pushing forces of the materials involved. The analysis process began with literature reviews and the collection of geotechnical data, followed by modeling the slope geometry using parameters such as cohesion and deep shear angle. The collected data was then input into slope stability analysis software to determine the safety factor value, which ultimately informed safe design recommendations for the slide dump area.

RESULT AND DISCUSSION

Data Processing

Correlation of Lithology and Formation of Transverse Incisions in the Disposal Slide Dump Area

The data used at this stage are lithology and stratigraphic data obtained from exploration drill data. Exploratory drill data from several drill points is the basis for determining the distribution of the lithology that constitutes the slope area of the dump slide. Then from the data it was correlated with material property data obtained from the geotechnical report of PT. ABP.

Technical Calculations

Slope stability analysis uses a combination of transverse incision data made at the data processing stage with material property data. The process of elaborating these data is assisted by Slide 6.0 slope stability analysis software. The following is attached to the material property data used in the analysis.

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface	Hu Type
Clay		21.29	Mohr-Coulomb	150.16	36.83	Water Surface	Constant
Sand		20.9	Mohr-Coulomb	190.21	41.91	Water Surface	Constant
Coal		12.6	Mohr-Coulomb	120	34.13	Water Surface	Constant
Residual		16.9	Mohr-Coulomb	50	19.2	Water Surface	Constant

Figure 1. The material property data used in the analysis

The geotechnical analysis was carried out using the boundary equilibrium method, with the type of circular slip plane, and the condition of water influence using the assumption of the saturated groundwater table.

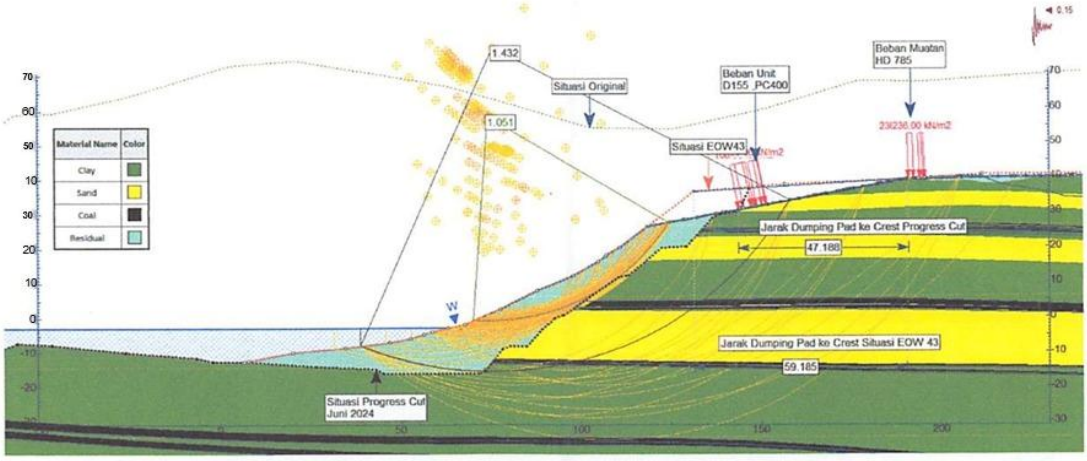

Figure 2. The result of geotechnical analysis

The analysis for the slide dump slope is based on the data and information sources listed in the geotechnical laboratory analysis report that has been carried out by tekMIRA and the drilling results carried out by PT. ABP with hole ID GT-08. The representative incision is incision A. At the high wall location, there is inpit dump material from the old disposal and will be used as analysis data at the location. For the condition of the pile, it is not known exactly the distribution and condition of the material that is piled up in the area and there is a possibility that each detail is different so that it is necessary to carry out a more detailed mapping if there is an anomaly and affects the stability of the slope. The results of the slide dump slope analysis show that the design made by the technical study team is still in a stable condition with a Safety Factor above 1.2 so there is no need to redesign. However, in the stockpile area there is a Safety Factor value below 1.2 which states that the condition is geotechnically unsafe.

The above study shows that the slope stability in the disposal slide dump area has been analyzed using Slide 6.0 software with the limit equilibrium method. Based on calculations, the disposal area of the slide dump has a Safety Factor (FK) of more than 1.2, which indicates a stable and safe condition for operations. However, in the backfill area, the FK was found to be less than 1.2, indicating a potential risk of slope failure that requires mitigation measures. Analysis using lithological and stratigraphic data from exploratory drilling as well as material

property data shows that slope geometry planning based on incision A can still be applied with additional evaluation in the deposit area.

The results of this study not only provide an understanding of slope stability, but also highlight the importance of design optimization in supporting operational efficiency. An increase in coal production of up to 46,000 mT by the end of 2024 has the potential to increase non-tax state revenue (PNPB) by ±Rp3,000,000,000.00. In addition, the reduction of the overburden transportation distance by 700 meters can save operational costs of up to ±Rp5,940,000,000.00. The estimated cost of establishing a disposal area of IDR 60,000,000.00 is an efficient investment to support the sustainability of mine operations.

The main risks identified included a height difference of ±15 meters in the disposal area and a slope leading to the void. This condition has the potential to trigger landslides if not overcome with the right mitigation measures. Therefore, mitigation measures are implemented, such as the installation of dumping limiters, the establishment of stoppers, the maintenance of heavy equipment maneuver areas (HD), and strict supervision during dumping activities. These measures aim to reduce operational risks while improving occupational safety.

The implementation plan for the formation of a slide dump disposal area involves excavating as much as ±10,000 BCM using a D155 dozer, followed by the formation of a stopper with a PC400 excavator. Supervision by an experienced workforce is a key element to ensure that dumping activities run according to safety and efficiency standards. The provision of the HD785 hauler unit is also an integral part of efforts to optimize mine operations.

Discussion

The results of the analysis show that the design of the disposal slide dump area has been designed with adequate safety factors in mind. FK above 1.2 in the main area of the disposal slide dump shows that the geometric design is appropriate to ensure the stability of the slope. However, a FK of less than 1.2 in the stockpile area is an indication of the need for additional evaluation. One of the factors affecting stability in this area is the condition of residual materials with low deep shear angles (19.2°) and small cohesion (50 kN/m²). With these conditions, technical interventions, such as strengthening the slope structure, are needed to improve stability.

Operational efficiency is one of the main benefits of the implementation of this study. The reduction of the overburden transportation distance of up to 700 meters provides significant operational cost savings, reaching nearly IDR 6 billion. This efficiency not only reduces operational costs, but also increases the productivity of production units, which has a positive impact on the overall operation of the mine. Design optimization also shows that the right geotechnical solutions can support mine sustainability without sacrificing safety aspects.

The risk mitigation measures implemented reflect the company's commitment to the implementation of good mining engineering principles. The installation of dumping limiters and the formation of stoppers are strategic efforts to prevent potential landslide hazards. In addition, the maintenance of an HD maneuver area with a width of at least 35 meters and strict supervision during dumping activities ensure that risks can be minimized. This supervision is carried out by an experienced workforce, who has a deep understanding of field conditions and potential risks.

The importance of supervision in the implementation of activities in the disposal area cannot be ignored. By involving supervisors who have at least two years of experience, each process is carried out in accordance with the safety and efficiency standards that have been set. The use of heavy equipment such as the D155 dozer and the PC400 excavator also emphasizes the importance of proper resource allocation to support the successful

implementation of the design. Strict monitoring ensures that each stage of implementation runs according to plan and produces optimal output.

Overall, this study confirms that the design of the disposal slide dump area can be implemented with appropriate risk mitigation measures. The stability of the slope that is guaranteed through the calculation of FK above 1.2 provides a guarantee of safety for mine operations. However, stockpile areas that have a FK below 1.2 require more attention to reduce the risk of failure. In addition, the resulting economic benefits, such as operational cost savings and increased productivity, show that design optimization is not only relevant in the context of safety, but also has a significant financial impact.

This research makes an important contribution to supporting the sustainability of open-pit mine operations. With a combination of careful technical planning and strict monitoring, it is hoped that the implementation of this design can provide optimal results in supporting efficiency, safety, and operational sustainability at PT. Alamjaya Bara Pratama.

CONCLUSION

The technical study by the ABP AMM Technical Study team developed strategic steps for the safe and efficient implementation of the slide dump design in the Pit 4B disposal area, including the installation of design reference tape, standardizing the dumping pad width to at least 35 meters, and incorporating safety features like a 2-meter high roadside embankment and a 1-meter high stopper. Experienced production supervisors oversee operations to ensure adherence to safety standards, with additional measures such as a dumping limiter and specialized equipment like dozers and excavators allocated to support the area. The design has been deemed feasible based on thorough calculations, simulations, and risk analysis, aiming to ensure safety, operational efficiency, and environmental sustainability. Future research could focus on long-term monitoring of the design's effectiveness, exploring advanced monitoring technologies, evaluating different materials and construction techniques, and assessing the training of supervisors to enhance safety and operational strategies in slide dump management.

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