Illegal gold mining is extracting gold without a formal license from the government or competent authority. It presents a significant environmental and geological challenge in Bengkayang Regency, Indonesia. This practice, carried out without proper authorization or adherence to safety regulations, is recognized as a significant cause of slope instability in the area. This study analyzes slope stability from unlicensed gold mining in Kinande Village, Bengkayang Regency. It uses manual Fellenius calculations and Geo Studio/Geo Slope 2023 software to determine the Safety Factor (SF) for potential landslides, assuming circular landslide planes are unaffected by earthquakes. Laboratory tests revealed varying soil types and properties at these points, impacting shear strength and slope stability. Loamy soils exhibit high cohesion but low internal friction, making them susceptible to instability. Sandy soils lack cohesion and rely on particle friction. Shear strength parameters like cohesion (c) and internal friction angle (φ) are critical in assessing slope stability. The study employed the Fellenius method and Geo Studio 2023 software to analyze slope stability, with safety factor (SF) results indicating potential hazards. Mining in plain areas showed favorable SF values (>1.5), suggesting activity safety. Conversely, mining in mountainous and watercourse areas exhibited lower SF values (<1.5), indicating instability and safety risks. Recommendations include stratified mining practices to maintain stable slopes and ensure miner safety. This research contributes to understanding geohazards and proposes measures for enhanced safety, environmental sustainability, and regulatory governance in mining areas. Understanding and analyzing these factors are crucial for the stability and safety of geotechnical projects, ensuring balanced shear stress and shear strength for slope stability.

Keywords: Illegal gold mining, Environmental damage, Slope instability, Safety factor, Geotechnical analysis
1. Introduction

Illegal gold mining is extracting gold without a formal license from the government or competent authority (Rozo, 2020; Siqueira-Gay & Sánchez, 2021). It is generally conducted illegally and often involves harmful practices, including environmental damage and violations of the rights of local communities (Susanti et al., 2018). Illegal gold mining operates outside the legal framework (Saputra et al., 2023). Perpetrators often ignore environmental, licensing, and safety regulations that have been put in place to protect communities and ecosystems (Meutia & Gafur, 2023). Illegal gold mining can cause severe environmental damage. Practices such as deforestation, uncontrolled excavation, and using toxic chemicals such as mercury to separate gold from rock (amalgamation) can damage ecosystems and affect water quality and the lives of flora and fauna (Susanti et al., 2018; Siqueira-Gay & Sánchez, 2021).

Illegal gold mining poses a severe environmental and geological challenge (Mestanza-Ramón et al., 2018), including in Bengkayang Regency, West Kalimantan. These activities, conducted without proper permits or compliance with safety regulations, have been identified as essential contributors to slope instability in the region (Betancur-Corredor et al., 2018). Bengkayang Regency, situated in the province of West Kalimantan, is known for its rich mineral resources, notably gold deposits. However, the unregulated extraction of gold by illegal miners has altered landscape topography and disrupted natural drainage patterns (Mwakesi et al., 2021). This alteration and inadequate waste management practices increase the likelihood of slope failures and landslides (Macháček, 2019).

When viewed from the method and technique of mining, where mining activities are carried out by digging hills and digging the plains in a non-tiered manner, but just digging and it appears that the former opening of excavation of land is irregular and forms a straight and hanging wall so that it is very vulnerable to collapse (landslide) and can threaten and endanger the safety of the miners’ lives. The second type of soil damage is the loss of ground cover vegetation. Miners (panners) who excavate the land do not try to replant or reforest the area where they are digging or mining. Mining activities in an area show that miners leave the site alone, and it looks very arid. In addition, the miners’ deep excavation of the land can form ponds on a land surface of 6-8 meters. Third, land damage can cause erosion in the former mining area because the excavated land is left alone, so there is no vegetation on the ground. In addition, waterways have been closed due to the former excavation material that was lifted and diverted into the canals so that the waterways shrink and become murky so they cannot be consumed.

This study aims to analyze the slope stability due to unlicensed gold mining in Kinande Village, Lembah Bawang Sub-district, Bengkayang Regency, by determining the Safety Factor (Sf) of the potential landslide field using the Fellenius calculation method manually and Geo Studio or Geo Slope 2023 software. In this study, the landslide plane is assumed to be circular and unaffected by earthquakes. Thus, this research on slope stability due to unlicensed gold mining in Bengkayang Regency can provide various positive results and benefits, ranging from increasing understanding of geohazards to preparing recommendations that can be followed up to improve safety, environmental sustainability, and regulatory governance in mining areas.

2. Materials and Methods

2.1. Study Area

This study is more focused on applied study, a systematic and logical activity aimed at finding something new and applying theory to actual conditions in the field. The study was conducted in Kinande Village, Lembah Bawang Sub-district, Bengkayang Regency, at three points with different soil conditions to determine the soil conditions and which locations are prone to landslides. The locations were (a) mining in a mountainous area (point A), (b) mining in a plain area (point B), and (c) mining in a stream area (point C). At observation point A, the studied slope height (H) is 6 meters, and the slope length from the base to the top of the slope (L) is 8 meters. At observation point B, the slope height (H) measures 5 meters, and the slope length (L) is 7 meters. Similarly, at observation point C, the slope height (H) is 6 meters, and the slope length (L) is 8 meters.
Fig 1. Geometric Slope at Observation Points A, B, and C

Fig 2. Mining in mountainous areas (point A)

Fig 3. Mining in plain area (point B)

Fig 4. Mining in watercourse area (point C)
2.2. Data

The data used are secondary and primary. Secondary data includes location, topographic, geological, and soil mechanical properties. Primary data are slope geometry (slope height and angle), discontinuity data, physical data, and soil sample data from drilling conducted during field surveys at three points, as previously described: Points A, B, and C. The soil sample data was then tested at the Soil Mechanics Test Laboratory, Faculty of Engineering, Tanjungpura University, to obtain moisture content (\( w \)), soil volume weight (\( \gamma \)), and specific gravity (\( G_s \)). In addition, direct shear testing, sieve analysis, and soil classification were conducted.

The moisture content (\( w \)) is examined regarding SNI 1965:2008. Moisture content is a ratio between the weight of water contained in a soil sample or aggregate and the dry weight of the soil/aggregate. The moisture content value is usually expressed in percent (%). In this case, undisturbed soil samples are used due to drilling (Utami & Caroline, 2018). Like moisture content, the Volume Weight (\( \gamma \)) test is also conducted regarding SNI 1965:2008. In this case, undisturbed soil samples from drilling were also used. Volume weight, also known as unit weight or density, is a measure of the weight of a substance (such as soil, rock, or any material) per unit volume. It is typically expressed in units of force per unit volume, such as kilonewtons per cubic meter (kN/m\(^3\)) or pounds per cubic foot (lb/ft\(^3\)) (Higham & Boyes, 2003). The volume weight of a material depends on its mass and the volume it occupies, and it is an essential parameter in various engineering and scientific calculations, including those related to soil mechanics, construction, and materials science (Craig, 2013).

Specific Gravity (\( G_s \)) is the ratio between the weight of soil grain content and the weight of distilled water content at the same temperature and volume. This test aims to determine the specific gravity of soil using a pycnometer (Yu & Puppala, 2021). In this study, the reference for the Specific Gravity examination is SNI 1964:2008.

Soil shear strength is the shear resistance per unit area the soil can give to resist collapse and movement along the collapse line (Stefanow & Dudziński, 2021). In this study, soil shear strength was obtained by direct shear testing. This test aims to obtain the magnitude of cohesion (\( c \)) and soil shear angle (\( \theta \)) to obtain soil shear strength. The results of direct shear tests can be used for stability analysis in the geotechnical field, including foundation bearing capacity, slope stability analysis, retaining wall analysis, and others. In this study, the reference for the Specific Gravity examination is SNI 2813:2008.

2.3. Analysis Method

A slope is a surface where one end or side is at a higher elevation than another, characterized by a rising or falling surface. Specifically, an earth slope represents an unsupported, inclined surface composed of a soil mass. The soil failure beneath a slope is termed a “slide,” described by Salunkhe et al. (2017). This failure typically involves the entire soil mass’s downward and outward movement, contributing to the failure event. Understanding the dynamics of slope stability and soil mass movement is crucial for assessing and mitigating risks associated with slope failures, which can have significant implications for infrastructure, safety, and environmental management.

Suppose the stability of a slope in a mining operation is in doubt. In that case, its stability must be assessed based on the geological structure, groundwater conditions, and other controlled factors on a slope. Slope stability in rocks is influenced by slope geometry, rock structure, physical and mechanical properties of rocks, and external forces acting on the slope. To express/give weight (level), the stability of a slope is known as a safety factor. The safety factor (\( S_f \)) is needed to determine a slope’s stability in preventing future landslide hazards. This factor is the ratio between the retaining force that keeps the slope stable and the driving force that causes landslides.

\[
S_f = \frac{\sum \text{Retaining Force}}{\sum \text{Driving Force}} \tag{1}
\]

\( S_f > 1.5 \) : The slope is in stable condition.
\( S_f < 1.5 \) : Unstable slope
\( S_f = 1.5 \) : Slopes in critical condition
In this study, slope stability analysis was conducted using the Fellenius Method and Geo Studio or Geo Slope 2023 software. These two methods are some of the methods for slope stability analysis. The calculation with the Fellenius method uses as many as five (5) trials so that the five trial calculations obtain the average value of the safety factor on a slope, which will be compared with the results of the Geo Studio 2023 software calculation.

2.3.1. Fellenius Analysis Method

The Fellenius Swedish slip circle method is widely employed in geotechnical engineering to evaluate slope stability. This method encompasses multiple phases to assess a slope’s stability (Zolkepli et al., 2016; Alfat et al., 2017; Doan, 2023). The Fellenius method provides a systematic framework for assessing slope stability and is often used in combination with geotechnical field investigations and laboratory testing to obtain reliable results (Alnaim et al., 2022). The accuracy and reliability of the analysis depend on the quality and completeness of the input data and assumptions made during the analysis process.

According to Fellenius, 2023, the first stages of method analysis involve defining the slope stability problem and gathering relevant data. This includes information on the slope’s geometry, soil properties, groundwater conditions, and any external loading or environmental factors that may influence slope stability. Next, an assumed potential slip surface or failure plane is selected based on the slope geometry and soil properties.

Commonly assumed slip surfaces include circular, non-circular, or composite shapes, depending on the specific slope conditions. The next step involves calculating the shear forces and moments along the assumed slip surface. This includes determining the weight of the soil mass above the potential failure. A limit equilibrium analysis uses the calculated shear forces and moments to assess the slope’s stability.

The equilibrium equations (e.g., force and moment equilibrium) are applied to determine whether the slope is stable or susceptible to failure along the assumed slip surface. The factor of safety (FS) is calculated to quantify the slope’s stability. The safety factor is the ratio of the resisting forces (e.g., soil shear strength) to the driving forces (e.g., gravitational forces). A safety factor greater than 1 indicates slope stability, whereas a less than 1 indicates potential instability.

\[
Sf = \frac{\sum_{n=1}^{n=p} (c\Delta L_n + W_n \cos \alpha_n \tan \theta)}{\sum_{n=1}^{n=p} W_n \sin \alpha_n}
\]  
(2)

If there is water on the slope, then equation 1 becomes;

\[
Sf = \frac{\sum_{n=1}^{n=p} (c\Delta L_n + (W_n \cos \alpha_n - u\Delta L_n) \tan \theta)}{\sum_{n=1}^{n=p} W_n \sin \alpha_n}
\]  
(3)

Sf : Safety factor  
\(c\) : Cohesion (kN/m\(^2\))  
\(\theta\) : Inner shear angle (degree)  
\(\gamma\) : Soil volume weight (kN/m\(^3\))  
\(b_n\) : Slice width (m)  
\(\alpha\) : The angle of slip at each slope incision (degree)  
\(L_n\) : Length of slip at each incision (m)  
\(W_n\) : Area of each incision plane (m\(^2\)) X unit weight of soil content (\(\gamma\), kN/m\(^3\))  
\(\mu\) : Pore-water pressure (kN/m\(^2\))
Sensitivity analysis may be conducted to evaluate the influence of critical parameters (e.g., soil properties, slope geometry) on slope stability. This helps identify critical factors that significantly affect the stability of the slope and allows for informed decision-making. Based on the analysis results, recommendations and mitigation measures are proposed to enhance slope stability and reduce the risk of failure. This may include slope reinforcement techniques, surface water management, or altering slope geometry to improve stability.

2.3.2. Geo Studio 2023 Analysis Method

GeoStudio 2023 is geotechnical modeling software that offers various tools and modules for analyzing slope stability, groundwater flow, and other geotechnical problems (Malik & Karim, 2020). It is a powerful platform for conducting advanced geotechnical analyses, enabling engineers and researchers to assess slope stability and make informed decisions for engineering design, construction planning, and risk management (Kottama et al., 2023; Liu et al., 2023). The specific steps and procedures may vary depending on the complexity of the project and the specific analysis requirements (Tan et al., 2023).

The steps involved in performing slope stability analysis using GeoStudio 2023 typically include the following stages (Nanehkaran et al., 2023; Sharipov et al., 2023; Tan et al., 2023):

a. Project Setup
   Begin by setting up a new project in GeoStudio 2023. Define the project properties such as units, coordinate systems and other relevant settings.

b. Geometry and Material Definition:
   Define the slope's geometry by creating a 2D or 3D model using the GeoStudio interface. Input the slope dimensions, soil layers, material properties (e.g., soil type, density, and shear strength parameters), and any existing or proposed structures on the slope.

c. Boundary Conditions:
   Specify the boundary conditions for the slope model, including initial conditions (e.g., groundwater table, stress state) and external loads (e.g., surcharge loads, seismic forces).

d. Analysis Type Selection:
   Choose the appropriate analysis type for slope stability assessment within GeoStudio 2023. Joint analysis types include:
   - Slope Stability Analysis: Perform limit equilibrium analysis using methods like Bishop, Spencer, and Morgenstern-Price to assess the safety factor against slope failure.
   - Finite Element Analysis (FEA): FEA can model complex soil-structure interactions and analyze the slope's stress, deformation, and pore water pressure distribution.
   - Coupled Hydrogeological Analysis: Consider groundwater flow effects on slope stability by coupling hydrological and geotechnical analyses.

e. Model Setup and Mesh Generation:
   Set up the model parameters and generate a mesh for numerical analysis. Define the discretization of the model domain into finite elements or nodes, ensuring appropriate resolution for accurate results.

f. Analysis and Simulation:
   Run the analysis within GeoStudio 2023 to compute the stability analysis results. The software will calculate factors of safety, critical slip surfaces, stress distributions, and other relevant output parameters based on the selected analysis method.
g. Results Interpretation

Interpret the analysis results to assess the stability of the slope. Review safety factors, failure modes, displacement patterns, and other critical indicators to understand the behavior of the slope under different loading and boundary conditions.

h. Sensitivity Analysis and Optimization:

Conduct sensitivity analyses to evaluate the influence of critical parameters (e.g., soil properties and groundwater conditions) on slope stability. Optimize the model inputs to improve the accuracy and reliability of the analysis results.

i. Reporting and Recommendations:

Prepare comprehensive reports documenting the analysis methodology, input data, results, and conclusions. Based on the findings, provide recommendations for slope stabilization measures, risk mitigation strategies, or design modifications to ensure slope stability and safety.

3. Result and Discussion

3.1. Laboratory Test Results

Laboratory tests at each observation point show that the soil type is different. The soil type at point A is loamy soil; point B is sandy clay, and point C is sandy loam soil. Likewise, the soil's moisture content, volume weight, and specific gravity. Theoretically, Different soil types have varying shear strength parameters, which directly affect the stability of slopes (Li et al., 2014). Loamy soils usually have a high cohesion value but a low angle of internal friction, making them prone to stability problems such as slumping or sliding. It has more sand content for sandy loam soil than clay, which can affect cohesion and frictional resistance. Sandy soils have low cohesion and rely primarily on friction between particles for stability. Sandy loam soils have low cohesion and rely primarily on friction between particles for stability. Shear strength affects slope stability.

The shear strength of soil is influenced by critical parameters, specifically cohesion (c) and the angle of internal friction (φ). These factors are crucial in calculating soil shear strength under varying loading conditions and are essential for assessing slope stability. Changes in cohesion and friction angle directly impact the slope safety factor, as reported by Harabinová (2020). Additionally, the stability of slopes is significantly affected by the slope angle. As Chen et al. (2021) emphasize, increasing slope angles result in a higher component of gravitational force acting parallel to the slope surface, which can surpass the soil's shear strength, leading to slope failure. Understanding and analyzing these factors are essential for ensuring the safety and stability of geotechnical projects. Thus, it can be said that the balance of shear stress and shear strength determines stability. A slope is considered stable if the forces available to resist movement are more significant than the forces driving the slope.

<table>
<thead>
<tr>
<th>Laboratory Test</th>
<th>Point</th>
<th>Shear stress (kg/cm²)</th>
<th>Cohesion (c) (kg/cm²)</th>
<th>Shear angle (φ) (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct shear test</td>
<td>A</td>
<td>0.261 0.415 0.754</td>
<td>0.1098</td>
<td>43.3085</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>0.296 0.451 0.765</td>
<td>0.1395</td>
<td>42.6978</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>0.276 0.498 0.623</td>
<td>0.2167</td>
<td>32.4166</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Soil sample</th>
<th>Soil classification</th>
<th>USDA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point</td>
<td>Sand</td>
<td>Silt</td>
</tr>
<tr>
<td>A</td>
<td>39</td>
<td>29</td>
</tr>
<tr>
<td>B</td>
<td>47</td>
<td>29</td>
</tr>
<tr>
<td>C</td>
<td>63</td>
<td>25</td>
</tr>
</tbody>
</table>

Table 1. Laboratory test results
3.2. Slope Stability Analysis Results

Slope stability analysis determines the safety factor of a potential landslide field by calculating the amount of shear strength needed to maintain slope stability and the shear strength that causes landslides (Pangemanan et al., 2014).

The slope stability analysis in this study, done at points mining in mountainous areas (A), mining in plain areas (B), and mining in watercourse areas (C), is divided into five analysis experiments with the same soil data, but the difference is the height value under review (Y) and the distance under review (X).

Fig 5. Example of Geometric Sketch of Mining Slope for Analysis Using Fellenius Method

The geometric sketch of the mining slope for analysis using the Fellenius Method, shown in Figure 5 above, will be used in each experiment, except that the dimensions of parameters such as R, W, and bn, as well as H and L, are different.

Table 2. X and Y values of mining at Points A, B, and C

<table>
<thead>
<tr>
<th>No</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>X</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Y</td>
<td>9</td>
<td>8</td>
<td>10</td>
</tr>
</tbody>
</table>

Table 3. Radius (R) values of mining at Points A, B, and C

<table>
<thead>
<tr>
<th>No</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>1</td>
<td>8,934</td>
<td>8,845</td>
<td>9,346</td>
</tr>
<tr>
<td>2</td>
<td>8,933</td>
<td>8,834</td>
<td>9,346</td>
</tr>
<tr>
<td>3</td>
<td>8,906</td>
<td>8,844</td>
<td>9,346</td>
</tr>
<tr>
<td>4</td>
<td>8,862</td>
<td>8,850</td>
<td>9,346</td>
</tr>
<tr>
<td>5</td>
<td>8,809</td>
<td>8,841</td>
<td>9,346</td>
</tr>
<tr>
<td>6</td>
<td>8,749</td>
<td>8,842</td>
<td>9,346</td>
</tr>
</tbody>
</table>
Table 4. Area

<table>
<thead>
<tr>
<th>Trial Number</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.794</td>
<td>0.895</td>
<td>0.592</td>
</tr>
<tr>
<td>2</td>
<td>1.659</td>
<td>1.879</td>
<td>1.256</td>
</tr>
<tr>
<td>3</td>
<td>2.002</td>
<td>2.245</td>
<td>1.549</td>
</tr>
<tr>
<td>4</td>
<td>1.834</td>
<td>2.060</td>
<td>1.377</td>
</tr>
<tr>
<td>5</td>
<td>1.265</td>
<td>1.439</td>
<td>0.863</td>
</tr>
<tr>
<td>6</td>
<td>0.781</td>
<td>0.912</td>
<td>0.303</td>
</tr>
</tbody>
</table>

Table 5. Angle values of mining at Points A, B, and C

<table>
<thead>
<tr>
<th>Trial Number</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>62</td>
<td>58</td>
<td>57</td>
</tr>
<tr>
<td>2</td>
<td>50</td>
<td>47</td>
<td>38</td>
</tr>
<tr>
<td>3</td>
<td>40</td>
<td>38</td>
<td>39</td>
</tr>
<tr>
<td>4</td>
<td>31</td>
<td>29</td>
<td>31</td>
</tr>
<tr>
<td>5</td>
<td>24</td>
<td>22</td>
<td>25</td>
</tr>
<tr>
<td>6</td>
<td>16</td>
<td>17</td>
<td>18</td>
</tr>
</tbody>
</table>

Table 6. Slice width

<table>
<thead>
<tr>
<th>Trial Number</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
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<td>1</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
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<tr>
<td>4</td>
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<td>1</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

By entering the values in tables 2 to 6 into equation 2, the factor of safety for sites A and B is obtained, while by entering the values in tables 2 to 6 into equation 3, the factor of safety for site C is obtained, the values of which can be seen in Table 7.

Table 7. Safe Factor Analysis Results

<table>
<thead>
<tr>
<th>Location</th>
<th>SF with Fellenius Method</th>
<th>SF with Geo Slope 2023</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trial Number</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>1,333 1,279 1,408 1,416 1,719 1,431</td>
<td>1,321</td>
</tr>
<tr>
<td>B</td>
<td>1,515 1,754 1,473 1,867 1,524 1,627</td>
<td>1,559</td>
</tr>
<tr>
<td>C</td>
<td>1,107 1,142 0,833 1,340 1,072 1,099</td>
<td>1,325</td>
</tr>
</tbody>
</table>

The analysis results shown in Table 7 show that each mining slope safety factor was analyzed manually with the Fellenius Method and Geo Studio or Geo Slope 2023 application software. From the results of the analysis, it can be seen that among the three locations reviewed, the results of the SF analysis for Location B, namely mining in plain area, gave good results; because of the five trials carried out manually, the SF value > 1.5, as well as for the average value and the results of the analysis with Geo Slope 2023, which gave SF > 1.5. Thus, mining activities with a depth of 5 meters in the plain area at the study site are not dangerous and are safe for miners to carry out.

For mining in mountainous areas, the analysis showed that SF values > 1.5 were generated in the fifth trial, while those for trials 1 to 4 were < 1.5. Likewise, for the average SF value and the results of the analysis using Geo Slope 2023 application software, the SF result is < 1.5. Thus, mining in
mountainous areas cannot be carried out at a height of 6 meters because it can cause landslides on the slope and endanger miners' safety when conducting mining activities there.

The analysis results on mining in watercourse areas, including experiments 1 to 5, average values, and analysis using Geo Slope 2023 application software, are all < 1.5. Thus, mining in watercourse activities is unstable because the safety factor is < 1.5; this is due to the presence of water flow in the area; it can easily cause slope collapse and endanger the safety of miners carrying out mining activities.

Therefore, for stable slopes to remain stable and unstable ones to be stable for mining, mining activities should be stratified so that the slopes do not collapse easily and remain safe for miners.

4. Conclusion

Laboratory tests conducted at different observation points indicated varying soil types. Point A consists of loamy soil; point B contains sandy clay; point C comprises sandy loam soil. The soil's moisture content, volume weight, and specific gravity also differ. Different soil types possess distinct shear strength parameters crucial for slope stability. For instance, loamy soils have high cohesion but low internal friction angles, making them susceptible to issues like slumping or sliding. The proportion of sand in sandy loam soil affects cohesion and frictional resistance. Sandy soils lack cohesion and rely primarily on particle friction for stability. Shear strength parameters like cohesion (c) and internal friction angle (φ) significantly influence slope stability and safety. Slope angles further impact slope stability; steeper slopes can exceed soil shear strength, causing failures. Understanding and analyzing these factors are critical for ensuring geotechnical project stability. Slope stability analysis determines the safety factor against landslides, considering shear strength needs and thresholds. The study evaluates slope stability in mining areas, identifying safe conditions based on safety factor (SF) analyses. Mining in plain areas shows favorable SF results, indicating safety for activities. Conversely, mining in mountainous or watercourse areas poses risks due to lower SF values, indicating potential slope instability and dangers for miners. Strategic mining practices are recommended to maintain stable slopes and ensure miner safety.

5. Acknowledgement

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6. Author's Note

The author now declares that this article is an original work and does not plagiarize any research, as it has successfully passed the examination to obtain a Magister degree in engineering at the Faculty of Engineering, Tanjungpura University.

7. References


