

# Analysis of Slope Stability Due to Variations in Slope and Soil Characteristics Using the Slope Mass Rating (SMR) Method in Sorong Regency

Rokhman<sup>1</sup>, Jeanne Akerina<sup>2</sup>, Ahmad Januar Jafaruddin<sup>3</sup>, Retno Puspa Rini<sup>4</sup>  
Civil Engineering, Muhammadiyah University of Sorong, Pendidikan Street, Sorong, Papua Barat Daya

---

## Article Info

**Keywords:**  
slope stability,  
Soil Characteristics,  
Slope Mass Rating (SMR)

## ABSTRACT

Sorong Regency experiences high rainfall in certain months, especially in the Katapop area, so slope stability is one of the important factors related to soil characteristics and slopes that cause landslides. Previously, it was known that there are many models for analyzing slope stability, one of which is Slope Mass Rating (SMR), which is usually used on rocky slopes. However, this study will analyze the level of slope stability on soil slopes with modified parameters. The purpose of this study is to analyze slope stability in the Katapop area through an analysis of the influence of slope inclination and soil characteristics using the Slope Mass Rating (SMR) approach and comparing the results with the Safety Factor (SF) values from the Bishop method in GeoSlope to assess the feasibility of using modified SMR as an alternative method. The data collection technique used a handboring tool. The results of the study show that the potential for landslides in Katapop is influenced by slope inclination, soil composition, and water content, which affect the SMR value and slope stability. Validation using the Bishop method in GeoSlope is in line with the SMR classification results.

---

This is an open access article  
under the [CC BY-NC](https://creativecommons.org/licenses/by-nc/4.0/) license



## Corresponding Author:

Rokhman  
Muhammadiyah University of Sorong  
Sorong City  
[rokhman@um-sorong.ac.id](mailto:rokhman@um-sorong.ac.id)

---

## INTRODUCTION

The Katapop II Majaran area, located in Salawati District, Sorong Regency, has varied slope conditions and is prone to landslides, especially during the rainy season. Based on records from the Sorong Regency Regional Disaster Management Agency (BPBD) (2024), several landslides in this area have caused damage to road infrastructure and disrupted community transportation access. This high level of vulnerability is influenced by a combination of geomorphological factors, soil characteristics, and human activities such as land clearing for agriculture (Jafaruddin et al., 2025).

Studies on slope stability are increasingly developing, particularly with the application of the *Slope Mass Rating* (SMR) method, which is considered effective in assessing slope stability based on geotechnical parameters. Several studies in Indonesia support the effectiveness of this method, for example, research by (Yudha et al, 2020) which analyzed the potential for landslides in Patuk District, Gunung Kidul, through an SMR approach that linked variations in slope and soil conditions to the level of stability. Another study by (Putra and

Widodo, 2021) shows that SMR values can be integrated with *Factor of Safety* analysis using the Bishop method to provide more accurate validation of slope stability levels.

Given the geological conditions of Katapop II Majaran, which has the potential for soil cavities and is dominated by sandy clay soil with high water content, slope stability analysis using the SMR method is very important to provide mitigation recommendations. (Rokhman et al., 2024, 2025)

The objective of this study is to analyze the influence of slope inclination and soil characteristics on slope stability in Katapop II Majaran using the SMR method and to validate it with the Bishop method's Safety Factor (SF) values in the *GeoSlope* application to assess the feasibility of the modified SMR method as an alternative approach to slope stability analysis.

## Literature Review

### Slope Stability

Slope stability is a condition of equilibrium in the mass of soil or rock that forms a slope, whether natural or artificial.

**Table 1.** Classification of Safety Factors

FK	Slope Stability	Failure Type
> 2.0	Very Stable	Landslides Very Rarely Occur
1.7 < SF ≤ 2.0	Good Stability	Landslides Occur Rarely
1.2 < SF ≤ 1.7	Moderately stable	Potential Landslide
≤1.2	Unstable	Landslide Occurred

Source: Ward. R, 1987 in SNI 13-7124-2005

### Slope Geometry

Slope geometry refers to the shape, slope, and dimensions of the slope, including height, slope angle, and length. Slope geometry includes:

- The higher the slope, the greater the potential for instability. This is due to the increase in gravitational force acting on the mass of soil on the slope. Steep slopes tend to have more pressure on the lower part, which can cause landslides if there is insufficient support.
- Slope angle: The angle of the slope affects the magnitude of the force driving soil mass. Steeper slopes have greater gravitational forces acting to push the soil downward, thereby increasing the risk of landslides. The safe slope angle usually depends on the type of soil and geological conditions.
- Overall slope angle is the total angle of the slope that affects overall stability. A larger angle can increase the risk of landslides, especially when combined with other factors such as rainfall or human activity.

**Table 2.** Slope Classification

Slope Angle (°)	Slope Category	SMR Value	Stability Classification	Type of Failure
0-15	Flat	>75	Very Good Stability	No Movement
15	Moderate	50	Good stability	Small Cracks
30-45	Steep	30-50	Moderately stable	Small collapse

Slope Angle (°)	Slope Category	SMR Value	Stability Classification	Type of Failure
45	Very Steep	20	Poor	Potential for Local Landslides
>60	Nearly Vertical	<20	Unstable	Total collapse

Source: Hudson & Harrison, 1997

### Soil Characteristics

Soil characteristics include the physical and mechanical properties of soil that affect its behavior. Physical properties include moisture content, specific gravity, bulk density, and soil particles, while mechanical properties include direct shear properties such as cohesion and angle of repose. These characteristics are important in determining the suitability of soil for agriculture, construction, or geotechnical engineering.

### Slope Mass Rating (SMR)

The *Slope Mass Rating (SMR) method* is an extension of the *Rock Mass Rating (RMR)* method used specifically to assess the stability of rock slopes. This method was introduced by (Romana et al., 1985) as a way to modify the RMR value to better suit the geotechnical conditions of slopes. SMR is a classification system that adapts RMR from (Bieniawski, 1979) by considering the orientation of discontinuity planes relative to slope inclination. The calculation involves correction factors based on the relationship between weakness planes and slope inclination, as well as the influence of the support method used.

**Table 3.** SMR Classification Based on FK Values

SMR	FK	Slope Stability	Failure Type
> 75	> 2.0	Very Stable	Landslides are very rare
50-75	1.7 < SF ≤ 2.0	Good Stability	Landslides Occur Rarely
30	1.2 < SF ≤ 1.7	Moderately stable	Potential Landslides
< 30	≤ 1.2	Unstable	Landslide Occurred

Source: SMR, Romana (1985) and FK, Ward. R, 1987 in SNI 13-7124-2005

### Soil Characteristics

Soil characteristics include the physical and mechanical properties of soil that affect its behavior. Physical properties include moisture content, specific gravity, bulk density, and soil particles, while mechanical properties include direct shear properties such as cohesion and angle of repose. These characteristics are important in determining the suitability of soil for agriculture, construction, or geotechnical engineering.

### Slope Mass Rating (SMR)

The *Slope Mass Rating (SMR) method* is an extension of the *Rock Mass Rating (RMR)* method used specifically to assess the stability of rock slopes. This method was introduced by (Romana et al., 1985) as a way to modify the RMR value to better suit the geotechnical conditions of slopes. SMR is a classification system that adapts RMR from (Bieniawski, 1979) by considering the orientation of discontinuity planes relative to slope inclination. The calculation involves correction factors based on the relationship between weakness planes and slope inclination, as well as the influence of the support method used.

**Table 4.** SMR Classification Based on FK Values

SMR	FK	Slope Stability	Failure Type
> 75	> 2.0	Very Stable	Landslides are very rare
50-75	$1.7 < SF \leq 2.0$	Good Stability	Landslides Occur Rarely
30	$1.2 < SF \leq 1.7$	Moderately stable	Potential Landslides
< 30	$\leq 1.2$	Unstable	Landslide Occurred

*Source :* SMR, Romana (1985) and FK, Ward. R, 1987 in SNI 13-7124-2005

### SMR Parameter Classification

To determine the SMR value, the SMR calculation is based on the classification of parameters F1-F5 as follows:

#### Correction factor based on $\phi$ value (F1)

For soil slopes, F1 can be modified based on direct shear tests, as shear parameters (cohesion and internal friction angle) determine the weakness of the soil against the inclined plane.

**Table 5.** F1 Values

Internal Friction Angle ( $\phi$ )	Category	F1
$\phi \geq 35^\circ$	Very Stable	1.0
$30^\circ \leq \phi < 35^\circ$	Stable	0.8
$25^\circ \leq \phi < 30^\circ$	Less stable	0.6
$\phi < 25^\circ$	Unstable	0.4

*Source:* Hudson & Harrison, 1997

#### Soil type factor (F2)

In soil, it can be modified with particle analysis data and moisture content tests to see the tendency of soil to weaken against slope inclination.

**Table 6.** F2 Value

Soil Type	F2
Coarse sand/gravel (stable)	1
Medium-fine sand (fairly stable)	0.9
Silt/clay slightly plastic	0.7
Highly plastic clay (prone to landslides)	0.5
Organic soil/expansive clay (highly prone)	0.3

*Source:* Hudson & Harrison, 1997

#### Variation in slope gradient (F3)

In the original SMR, F3 is used to classify landslide types based on morphology and collapse mechanisms. If you want to replace it with slope inclination, the scale can be based on slope inclination categories from geotechnical references such as USGS Landslide Classification or Geotechnical Standards (Eurocode 7, SNI 8460:2017, etc.).

**Table 7.** F3 Values

Slope Inclination Degree ( $^\circ$ )	Slope Category	F3
0-15	Gentle (Stable)	1
15	Moderate (Low Landslide Potential)	0.85

Slope Inclination Degree (°)	Slope Category	F3
30	Steep (Moderate Landslide Potential)	0.7
45	Very Steep (High Landslide Potential)	0.5
>60	Nearly Vertical (Very Unstable)	0.3

Source: Hudson & Harrison, 1997

#### Correction factor based on soil saturation level (F4)

In soil slopes, it can be associated with water content, degree of saturation, and plasticity to represent changes in mechanical properties due to water.

Table 8. F4 Value

Soil Conditions & Water Content	F4
Dry & compact soil (very stable)	0
Moist soil with moisture content < 15%	-
Water-saturated soil with moisture content 15-30%	-
Highly water-saturated soil (high plasticity)	-8

Source: Hudson & Harrison, 1997

#### Additional Correction Factor Due to External Activity (F5)

Can be determined from direct field observations, for example, additional loads on slopes, vegetation cover, or the occurrence of erosion.

Table 9. F5 Value

External Factors	F5
No human activity, no additional burden	0
There is slope-stabilizing vegetation	2
There is light erosion or minor vibrations (footpaths, wind)	-1
There is additional load from buildings or heavy vehicles	-3
There is exploitation activity (mining, drilling)	-5

Source: Hudson & Harrison, 1997

#### SMR equation

$$SMR = RMRb + (F1 \times F2 \times F3) + F4 \dots \dots \dots (1)$$

with

RMRb = Basic RMR before orientation correction (without discontinuity plane correction factor)

F1 = Factor related to the parallelism of the discontinuity plane to the slope

F2 = Factor representing the angle relationship between the discontinuity plane and the slope

F3 = Factors related to the type of rock mass movement

F4 = Correction factor based on slope support or stabilization methods

#### Modified SMR Equation

$$SMR_{MOD} = RMRb + (F1 \times F2 \times F3) + F4 + F5 \dots \dots \dots (2)$$

with

$$RMRb = (a \times c) + (b \times \phi)$$

Explanation:

Cohesion (c) in kPa

Internal friction angle ( $\phi$ ) in degrees

(a and b are constants. In this case, a = 0.5 and b = 1.5)

F1 = Correction factor based on the value of  $\phi$  (the larger  $\phi$ , the more stable)

F2 = Soil type factor (clay, sand, silt) and suitability for slope inclination

F3<sub>0</sub> = Slope gradient variation

F4 = Correction factor based on soil saturation level

F5 = Additional correction factor due to external activity

RMR<sub>b</sub> is calculated using a linear combination where Cohesion (c) has units of kPa (kiloPascal) and Internal Friction Angle ( $\phi$ ) has units of degrees ( $^{\circ}$ ). When combined with regression-based constants, the result is a dimensionless scale value. F1, F2, F3, F4, and F5 are ratio or scale correction factors, so they have no units. Therefore, SMR is a *dimensionless value*.

## METHOD

The research conducted was experimental in nature with field research in the form of handboring tests at the peak, middle, and foot points, followed by laboratory tests in the form of moisture content, specific gravity, bulk density, hydrometer analysis, and direct shear tests with 18 test samples for 3 slopes. Each test point had 2 soil layers. The test results will be processed for further analysis.

### Preparation

Conducting a literature study to understand the theories and concepts related to landslides, slope inclination, and soil characteristics. Developing a research plan and determining the data collection location.

### Data Collection

Conduct slope inclination measurements, soil sampling, and geological observations in the field. Collect secondary data from various sources.

#### a. Slope Measurement

Measurements were taken on three slopes in Kapatopo II, Sorong Regency, using a theodolite.

#### b. Soil Sampling

Sampling was carried out by hand boring at the peak, middle, and foot of each slope, with 2 tubes of samples taken at each point.

#### c. Laboratory Testing

Laboratory testing was conducted on the collected samples, including moisture content testing, specific gravity testing, bulk density testing, hydrometer analysis, and direct shear testing to determine soil characteristics. These tests were performed at the Soil Mechanics Laboratory of the Civil Engineering Department at Muhammadiyah University Sorong.

### Data Analysis

#### a. Manual Analysis

Performing calculations using the *Slope Mass Rating* (SMR) method that has been modified to soil parameters

b. *Software Analysis*

Safety factor analysis using *Geoslope software* with the Bishop method to validate the *Slope Mass Rating (SMR)* value.

**Interpretation of Results**

Interpretation of results is interpreting the analysis results to determine the potential for landslides in the study area, namely comparing the results of data analysis between manual SMR calculations and *Geoslope software* using the Bishop method.

**RESULTS AND DISCUSSION**

**Slope Measurement Results**

The results of slope measurements using a theodolite obtained field data which was then processed in Civil3D software to obtain slope contours. From these slope contours, the geometry of each slope was obtained, as shown in Table 10.

**Table 10.** Slope Geometry Measurement Results

Slope	Height (m)	Bottom Width (m)	Slope (°)
I	17	20	40
II	6.45	16.90	21
III	17.50	38	25

*Source:* Theodolite Data Processing Results

**Soil Characteristics Test Results**

The following are the results of testing the soil characteristics on slopes I, II, and III. These can be seen in Tables 10 to 12.

**Table 11.** Slope I Test Results

Slope Sample Lab Testing	Peak	Middle	Base
Specific Gravity	2.56	2.64	2.74
Moisture Content	32.84	38.38	34.67
Net Weight	1.35	1.36	1.33
Cohesion	0.15	0.14	0.10
Angle of repose	29.11	31.01	35.80
Hydrometer Analysis	49% (Clay)	44% (Clay)	30% (Clay)
	5% (Silt)	16% (Silt)	15% (Silt)
	46% (Sand)	40% (Sand)	55% (Sand)

*Source:* Laboratory Test Data Processing

**Table 12.** Results of Slope II Testing

SLOPE SAMPLE Lab Testing	Peak	Middle	Foot
Specific Gravity	2.57	2.73	2.74
Moisture Content	33.50	33.66	36.57

SLOPE SAMPLE	Peak	Middle	Foot
Lab Testing			
Net Weight	1.33	1.33	1.36
Cohesion	0.13	0.09	0.08
Angle of repose	27.99	31.01	34.71
Hydrometer Analysis	53% (Clay)	40% (Clay)	45% (clay)
	32% (Silt)	10% (Silt)	5% (Silt)
	15% (Sand)	50% (Sand)	50+++ (Sand)

Source: Laboratory Test Data Processing

**Table 13.** Slope III Test Results

SLOPE SAMPLE	Peak	Middle	Base
Lab Testing			
Specific Gravity	2.60	2.59	2.58
Moisture Content	30.38	33.81	35.29
Net Weight	1.32	1.30	1.33
Cohesion	0.14	0.13	0.12
Angle of repose	15.56	18.54	24.49
Hydrometer Analysis	15% (Clay)	12% (Clay)	12.5% (Clay)
	61.5% (Silt)	52% (Silt)	64.50% (Silt)
	16% (Sand)	36% (Sand)	23% (Sand)

Source: Laboratory Test Data Processing

### Manual and Software Calculation Results

The following are the results of manual calculations using the Slope Mass Rating method and Geoslope software using the Bishop method. In the manual calculations, the analysis was carried out on slope I with a steep slope category and slope III with a gentle slope category, the results of which can be seen in Table 13.

#### Manual

Manual analysis using the SMR method with Equation (2). The results of the manual analysis can be seen in Table 13.

**Table 14.** SMR Analysis Results

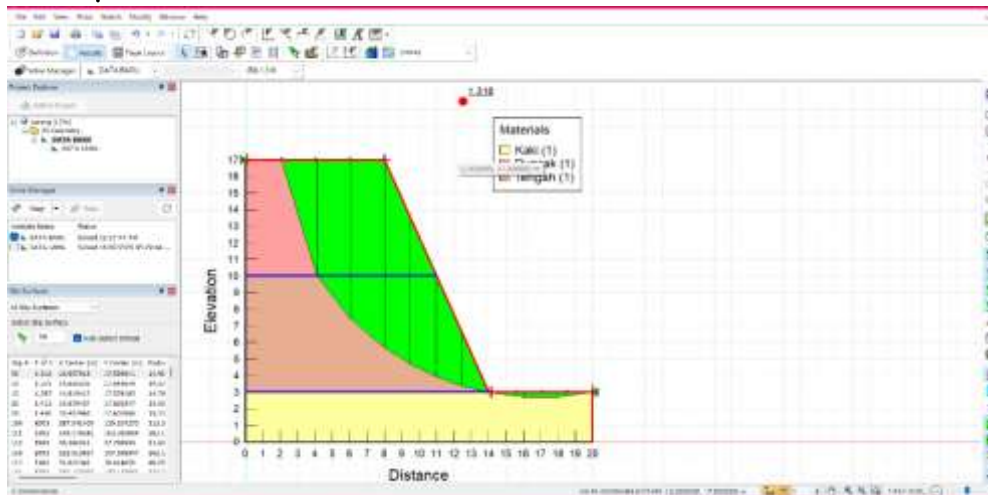
Slope	Slope (°)	Sample Point			Average
		Peak	Middle	Foot	
I	40	36.02	38.87	46.11	40.33
III	25	18.67	23.13	32.05	24.62

Source: Manual Calculation

#### Software

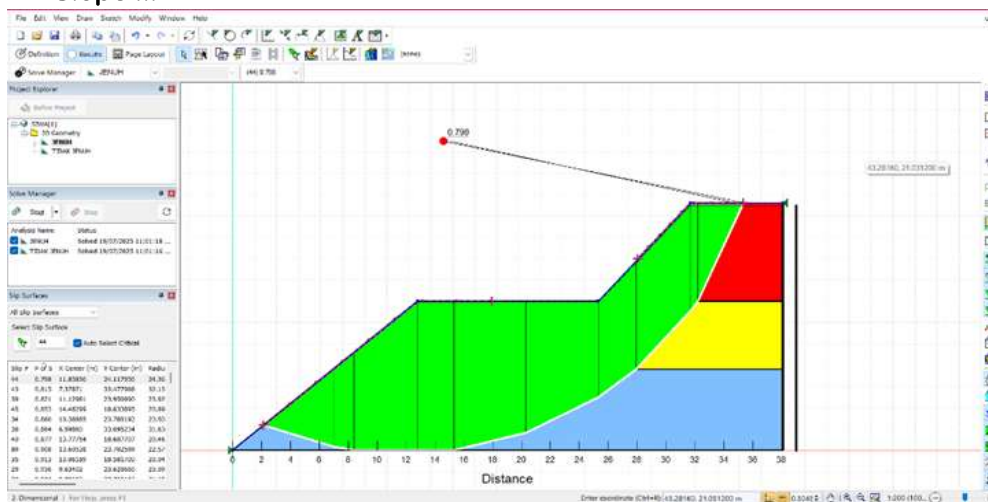
Software analysis was performed using the Geoslope application with the Bishop method as follows:

### Slope I



**Figure 1.** Analysis of Fk Value for Slope I  
 Source: Geoslope Software

### Slope III



**Figure 2.** Analysis of Fk Value for Slope III  
 Source: Geoslope Software

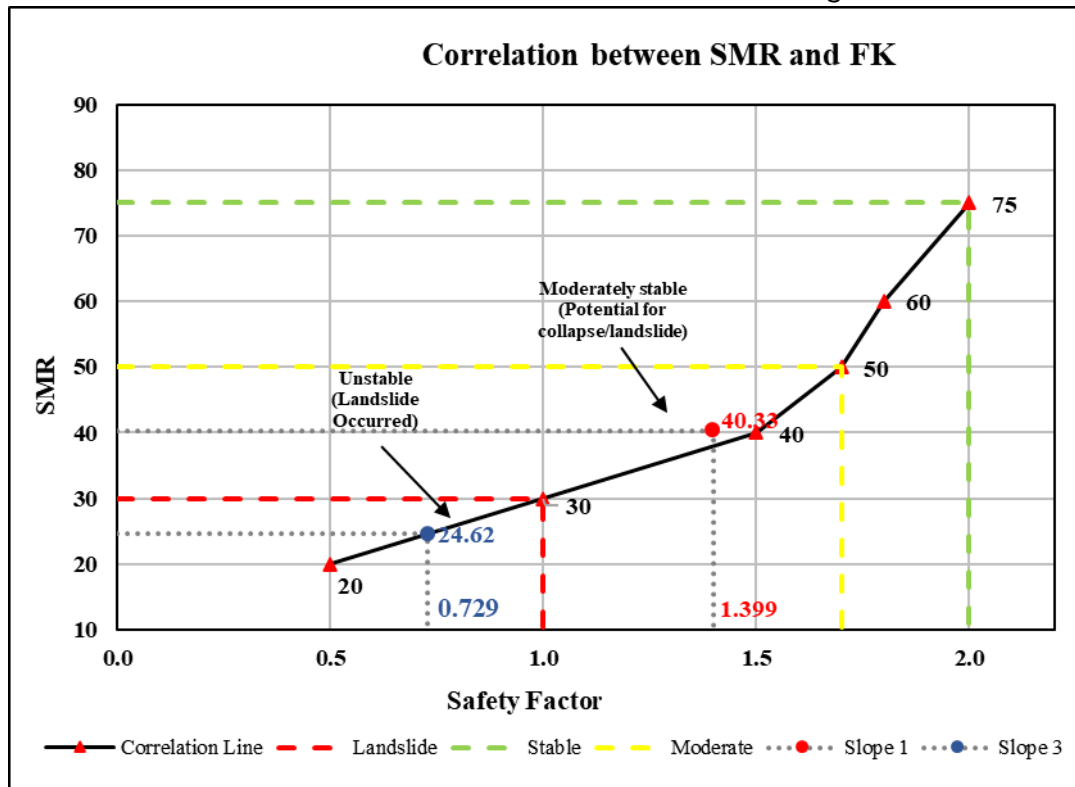
**Table 15.** Manual and Software Analysis Results

Slope	Slope (°)	Stability Value	Sample Point			Average	Failure Type
			Peak	Middle	Foot		
I	40	SMR	36.02	38.87	46.11	40.33	Small Debris
		FK	1.316				
III	25	SMR	18.67	23.13	32.05	24.62	Landslide
		FK	0.798				

Source: Manual Calculations and Software

### Validation and Correlation of the SMR Method with the Bishop Method

Statistical analysis shows a correlation between SMR and FK values, indicating that the lower the SMR value, the lower the FK value. In this study, it was found that the slope of SMR value I was in the range of 30-50, namely 40.33, which falls within the moderate stability zone. This is synchronous with an FK value >1. Meanwhile, slope I is in the range of 20-30, namely 24.62. On the graph, it is in the landslide zone, which is in accordance with a safety factor of <1. The correlation between SMR and FK can be seen in Figure 3.

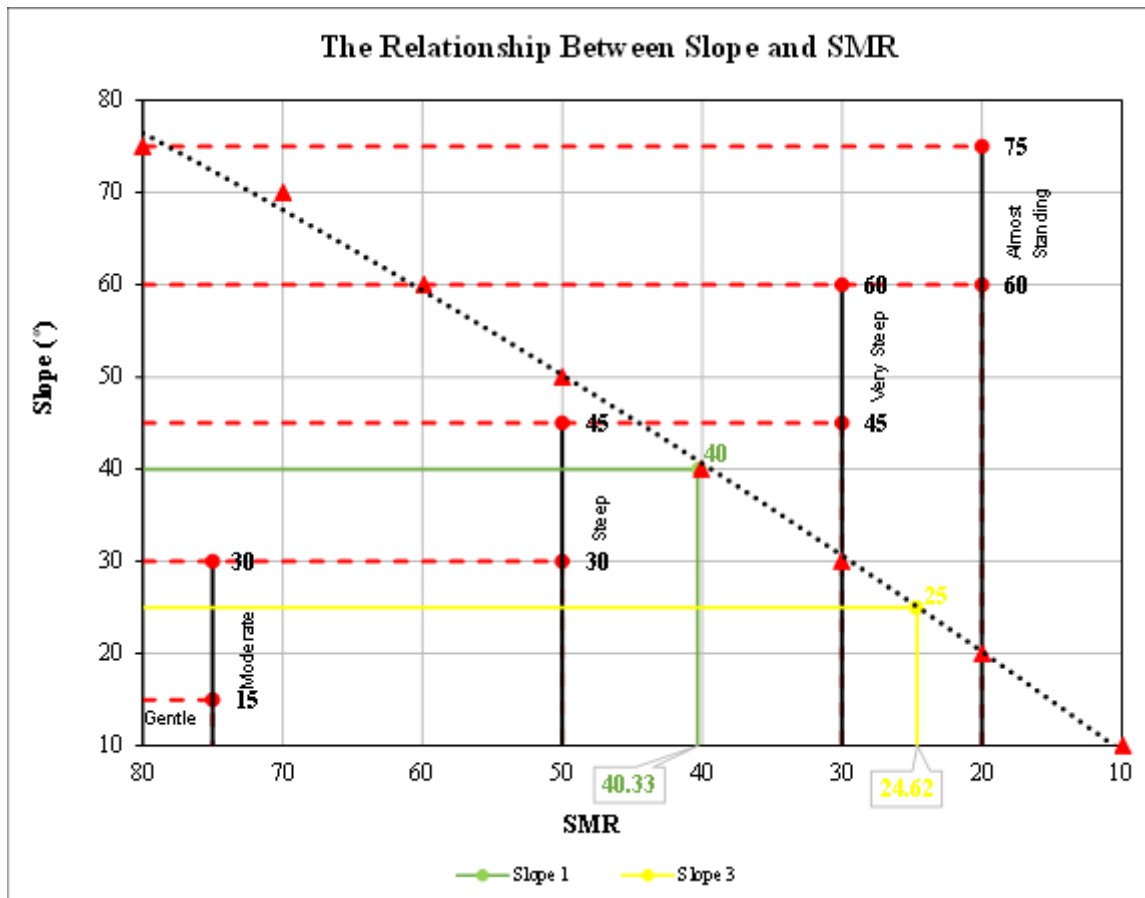


**Figure 3.** Correlation Graph of SMR and FK Values

*Source:* Results of SMR Classification and Safety Factor Processing

### Analysis of the Relationship between Slope Variation and Landslide Potential

The regression analysis results show a negative correlation between slope inclination and SMR values. Under normal soil conditions, slopes with an angle of >30° tend to have SMR values ≤30-40, which increases the potential for landslides. Meanwhile, slopes with an angle of <30° have SMR values >30, which reduces the potential for landslides. However, if the soil is in the worst condition or saturated, the SMR value may show the opposite even though the slope is in the gentle category. This is due to soil conditions and differences in slope soil characteristics, as found in slopes I and III. The correlation between slope and SMR can be seen in Figure 4 and compared with Table 2.



**Figure 4.** Graph of the Relationship between Slope and SMR

*Source:* Results of SMR and Slope Classification Processing

The slope angle and SMR value of slope I indicate that the slope is classified as steep with a fairly high SMR value, meaning that even with a large slope angle, the potential for landslides is only small. This is influenced by the soil characteristics, as slope I has clay soil, which is more cohesive, thereby reducing the potential for landslides. Meanwhile, the results of the graph for slope III show that it is in the gentle zone, but the SMR value is small, indicating that landslides can occur on this slope. This is also influenced by the soil characteristics, which are sandy loam, weaker than clay loam, and in the worst or saturated condition.

## CONCLUSION

Based on the analysis results, slope inclination and soil characteristics were found to have a significant effect on landslide potential. Slopes with an angle of  $>30^\circ$  tend to have a low Slope Mass Rating (SMR) value, making them more prone to landslides, while gentler slopes have a higher SMR value and are more stable. However, this is also influenced by soil conditions and characteristics. As shown in this study, the slope is gentle, but the SMR value is also relatively small, so landslides still occur. In addition, variations in soil composition, especially particle size distribution and moisture content, affect the mechanical properties of soil such

as cohesion and angle of repose, where zones with high clay content and moisture content tend to be more prone to landslides. Validation of the results between the Bishop method safety factor (SF) in GeoSlope and the SMR classification shows consistency in determining stable and unstable zones, so that a combination of slope analysis and soil characteristics is key to landslide mitigation efforts in this region.

## REFERENCES

- Abdillah, M., et al. (2017). Modification of Rock Mass Rating (RMR) system for slope stability assessment in soil slopes.
- Agustian, W., Wardana, N. K., & Putra, B. P. (2023). Rock mass classification analysis using the Slope Mass Rating (SMR) method in the Gosowong Pit gold mine, North Maluku.
- Ahmad Januar & R. Rokhman (2025). Pengaruh Stabilitas Tanah Lempung Dengan Bahan Tambah Kapur Terhadap Kuat Geser
- Albar, A., & Mohd-Nordin, M. M. (2022). Slope stability classification using the Slope Mass Rating (SMR) method and geological hazard vulnerability assessment.
- Bieniawski, Z. T. (1989). Engineering rock mass classifications: A complete manual for engineers and geologists in mining, civil, and petroleum engineering. Wiley.
- Faradibah, N., et al. (2016). Analisis kestabilan lereng menggunakan metode Slope Mass Rating (SMR) dan software Geoslope/W 2007 pada Tambang Air Laya Selatan lokasi Suban di PT Bukit Asam (Persero) Tbk.
- Hamzeh, M. A. S. (2019). Application of fuzzy logic in slope stability evaluation using the SMR method in the Khoy open-pit mine, Iran.
- Hudson, J. A., & Harrison, J. P. (1997). Engineering rock mechanics: An introduction to the principles. Elsevier.
- Hussin, H. (2023). Rock mass quality and rockfall hazard assessment in tropical regions using the Slope Mass Rating (SMR) method.
- Maulida, S. (2023). Slope stability assessment in Sampoiniet District, Aceh Jaya, using the Slope Mass Rating
- Pantelidis, L. (2009). Rock slope stability assessment through rock mass classification systems.
- Pastor, J. L. (2019). Enhancing Slope Mass Rating (SMR) accuracy and efficiency using the SMR Tool software.
- Rokhman, Harianto, T., Muhiddin, A. B., & Arsyad, A. (2024). Characteristics of Soft Soil Stabilization with *Bacillus subtilis* Bacteria on Unconfined Compression Strength and Shear Stress of Soils. In *Select Proceedings of CREST 2023* (Vol. 448, pp. 365–373). Springer. [https://doi.org/10.1007/978-981-99-9227-0\\_34](https://doi.org/10.1007/978-981-99-9227-0_34)
- Rokhman, Harianto, T., Muhiddin, A. B., & Arsyad, A. (2025). Bearing Capacity and Strength of Bacterial Soil Columns Full-Scale Tests. *Civil Engineering Journal (Iran)*, 11(4), 1353–1370. <https://doi.org/10.28991/CEJ-2025-011-04-06>
- Romana, M. (1985). New adjustment ratings for application of Bieniawski classification to slopes.
- Runtutahu, R. C., et al. (2020). Alternatif penanganan lereng di Desa Hatalai, Kota Ambon.

- Sesa, H. M. (2024). Open-pit mine slope stability analysis using the Slope Mass Rating (SMR) method.
- Triana, K. (2020). Rockfall hazard assessment along roadways using the Slope Mass Rating (SMR) method.
- Wildani, E. (2022). Slope stability evaluation in PT Karya Sumber Alam Perkasa mining area, West Kalimantan, using the Slope Mass Rating (SMR) method.