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Analysis of Slope Stability on the Katapop II Hills During Rainfall, Sorong Regency

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ABSTRACT

Majaran Village, Salawati District (Katapop II), is a hilly area characterized by high rainfall intensity, making it susceptible to slope instability. Rainfall infiltration increases soil saturation and pore water pressure, leading to a reduction in effective stress and soil shear strength, which in turn decreases the slope safety factor (SF). This study aims to evaluate and compare slope stability under saturated and unsaturated soil conditions, both with and without external loading, using a combined manual and numerical approach. Slope stability analysis was conducted using the Bishop method, applied through manual calculations and validated using GeoSlope/SLOPE-W software. The safety factor values obtained from each condition were compared to assess the influence of soil saturation and loading on slope stability. The results indicate that under unsaturated conditions, the average safety factor exceeds 2.0, whereas under saturated conditions, the safety factor decreases to an average of approximately 1.5. Although both conditions remain within the stable classification range ($1.7 < SF \leq 2.0$), the observed reduction in safety factor under saturated conditions highlights the significant impact of rainfall infiltration on slope stability. Prolonged or high-intensity rainfall events may further increase instability risks. Therefore, continuous hydrogeological monitoring and appropriate slope management measures are essential to mitigate potential landslide hazards in the study area

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INTRODUCTION

Majaran Village, Majaran Village, Salawati Subdistrict, Sorong Regency, Southwest Papua, is a hilly area with high rainfall that is prone to landslides. Data from the Sorong Regency BMKG over the past five years shows that this area often experiences rainfall exceeding 100 mm/month, particularly during the rainy season. A report from the Sorong Regency Disaster Management Agency (BPBD) (2024) noted several landslides in the Katapop II area that caused damage to road infrastructure and disrupted community activities. This high level of vulnerability is influenced by geomorphological conditions, soil characteristics, and anthropogenic activities such as land clearing for agriculture (Jafaruddin et al., 2025).

Intense rainfall increases rainwater infiltration into the soil, leading to elevated pore water pressure and reduced effective stress, which consequently decreases soil shear strength and slope safety factor (SF). Recent studies have shown that rainfall-induced changes in pore water pressure play a dominant role in triggering slope instability in tropical regions (Rochmawati & Tonggiroh, 2019; Harijan, 2022; Hidayat, 2020). Research by Heriansyah Putra (2015) demonstrates that infiltration alters soil conditions from unsaturated to saturated, eliminating matric suction and reducing shear resistance. Similar findings were also reported in recent experimental and numerical studies focusing on rainfall-triggered landslides (Rokhman et al., 2024; 2025).

However, most previous studies primarily rely on numerical simulations or qualitative rainfall analysis, with limited validation using manual limit equilibrium calculations and limited consideration of additional surface loads. Therefore, this study addresses this research gap by systematically comparing saturated and unsaturated soil conditions using both manual Bishop calculations and GeoSlope/SLOPE-W simulations, with and without external loading, in a rainfall-prone slope in Southwest Papua.

LITERATURE REVIEW

Slopes

A slope is an inclined surface of land with a certain angle to the horizontal plane, which is part of the topography of an area (Hardiyatmo, 2012). Slope stability is strongly governed by the interaction between soil shear strength, pore water pressure, and external loading conditions. Recent geotechnical studies emphasize the importance of evaluating unsaturated–saturated transitions in slope materials, especially in tropical regions with high rainfall intensity.

The novelty of this study lies in the integrated evaluation of slope stability using manual Bishop calculations and GeoSlope/SLOPE-W numerical modeling, allowing cross-validation of results. Additionally, the explicit comparison between saturated and unsaturated conditions under loading provides practical insights for infrastructure planning on rainfall-prone slopes, particularly in eastern Indonesia, where published case studies remain limited.

Pore Water Pressure

Pore water pressure is the pressure generated by water trapped in soil pores. This pressure affects the mechanical properties of soil, including shear strength and slope stability. Pore water pressure is calculated based on the law of hydrostatics. It is expressed in equation 1.

$$u = \gamma w.h \quad (1)$$

Explanation:

u = pore water pressure (kPa)
γw = water density (9.81 kN/m³)
h = depth below the groundwater table (m)

Soil Shear Strength

The shear strength of soil is its ability to resist shear forces, influenced by cohesion and internal friction angle. In cohesive soils such as clay, cohesion plays a major role, while in non-cohesive soils such as sand, internal friction angle is the main determinant of shear strength (Rokhman et al., 2024, 2025).

Geoslope Software

GeoSlope is geotechnical software used for slope stability analysis, groundwater flow, pore water pressure, soil deformation, and various other geotechnical engineering problems. This software also supports various methods for analyzing slope stability, such as the Bishop, Janbu, Spencer, Limit Equilibrium, and other methods. In this study, slope stability analysis was performed using GeoSlope software with the Bishop method to calculate the slope safety factor (SF) under saturated and unsaturated soil conditions, considering pore water pressure (u), cohesion (c), and angle of internal friction (φ) .

Slope Stability Analysis

Slope stability analysis aims to determine the safety factor (SF) of a slope against the possibility of landslides. In this study, the method used to analyze slope stability is the Bishop method. Alan Wilfred Bishop, 1955 developed the Bishop method with a *circular slip surface* approach. This method takes into account the weight of the slip surface, the slip angle, the normal force, the shear stress of the soil, and the pore water pressure, which can be seen in equation 2.

$$FK = \frac{\sum \left[c' bi + (Wi - ui\ bi) tan\ \varphi'\right] \frac{1}{\cos\theta i((1+\mathrm{tg}\theta i\ \mathrm{tg}\varphi')/F)}}{\sum (Wi\ sin\theta i)} \quad (2)$$

Explanation:

F = Safety factor
c′ = Effective soil cohesion (kN/m²)
φ′ = Effective internal friction angle (degrees)
bi = Width of the i-th slice (m)
Wi = Weight of the i-th soil slice (kN)
μi = Pore water pressure of the i-th slice (kN/m²)
θi = Defined angle (degrees)

This study uses a simplified version of Bishop's iterative formula. After understanding the original form of Bishop's formula, it can be seen that calculating Bishop's formula involves many calculations, including angles and forces that must be calculated repeatedly. This formula is very accurate, but quite difficult to calculate manually. To simplify the manual analysis process, the formula for the Bishop method safety factor (SF) obtained by Anderson and Richards, 1987, (Arif Setia Wibowo, 2022) can be seen in the following equation. Equation 3 is used to calculate the Safety Factor (SF) for saturated soil conditions.

$$FK = \frac{(c'.l+(P-u.l)tan\emptyset')}{Wsin\,\alpha} \quad (3)$$

Equation 4 is used to calculate the Safety Factor (SF) for unsaturated soil conditions.

$$FK = \frac{(c'.l+(P.tan\emptyset')}{Wsin\,\alpha} \quad (4)$$

For the Safety Factor (SF) calculation formula with load, Equation 5 is used.

$$FK = \frac{(c'.l+(P.tan\emptyset')}{Wtot\,sin\,\alpha} \quad (5)$$

Explanation:
FK = slope safety factor
c' = effective soil cohesion (kN/m^2)
l = width of soil section (m)
P = total normal force on the section (kPa)
$\emptyset'$ = effective internal friction angle of soil (°)
u = Pore water pressure (kN/m^2)
W = Total weight of soil slice (kN)
Wtot = total weight of the soil slice with load (kN)
α = angle of inclination of the soil slice (°)

From the above formula, several equations can be derived, as follows:
The formula for the weight of wet soil slices (W_{sat}) can be seen in Equation 6.

$$W = \gamma sat.A \quad (6)$$

Explanation:
W = Weight of the i-th soil slice (Kn)
γsat = Wet soil weight (kN/m^3)
A = Cross-sectional area of the i-th slice (m^2)

The formula for soil section weight (W) can be seen in Equation 7.

$$W = \gamma.A \quad (7)$$

Explanation:
W = Weight of the i-th soil slice (kN)
γ = Soil weight (kN/m^3)
A = Cross-sectional area of the i-th slice (m^2)

The formula for finding the angle of the cut (α) can be seen in Equation 8.

$$\alpha = \alpha rc\ sin\ (\frac{xi}{R}) \quad (8)$$

Explanation:
α = Intersection angle i (°)
xi = Distance from the center of the segment to the center of rotation (m)
R = Radius of the sliding circle (m)
The formula for finding the Resultant Normal Force (P) can be seen in Equation 9.

P = W x cosα ....(9)

Explanation:
P = Normal Force (kN)
W = Weight of the i-th soil slice (kN)
α = Angle of the i-th slice (°)

The formula for finding the resultant shear force (T) can be seen in Equation 10.

T = W x sinα ....(10)

Explanation:
T = Thrust Force (kN)
W = Weight of the i-th soil slice (kN)
α = Angle of the i-th slice (°)

Formula for calculating the load or weight of the tower

To calculate the load or weight of the tower, the volume and mass of the tower must be known, which are described in the following equations:
The formula for finding the volume of the tower pole can be seen in Equation 11.

V = L × W × H..(11)

Explanation:
L = Length of the Pole
W = Pole width
H = Tower Height
The formula for calculating the mass of the tower can be seen in Equation 12.

Tower mass = Vtot × steel density ....(12)

Explanation:
Tower mass = mass of the tower in kg
$Vtot$ = Total Volume
ρsteel = density of steel (7850 kg/m³).
The formula for calculating the weight of the tower can be found in Equation 13.

W_{Tower} = mTower × g ....(13)

Explanation:
mTower= Mass of the Tower
g = Gravitational Constant (9.81 m/s²)

The formula for finding the weight of a slice with a load can be seen in Equation 14

$$P_{Irisan} = \frac{Wmenara}{Total\ Jarak} \times Jarak\ Ke\ Irisan \quad (14)$$

Explanation:
P_{Slice} = Load received on each slice

W_{Tower} = Total weight of the tower
Total Distance = Distance from the center point of the tower to the farthest slice
Distance to Slice = Horizontal distance from the tower to each slice.

The formula for finding the total weight of the intersection with the load can be seen in Equation 15

$W_{tot} = W + P_{Segment}$ .... (15)

Explanation:
W_{tot} = Weight of soil slice i with additional load (Kn)
W = Weight of soil slice i

To determine the stability level of a slope, the safety factor (SF) value is used as the main indicator. The slope stability classification can be seen in Table 1 below.

Table 1. Classification of Stability

Safety Factor	**Stability Classification Slope**	**Description**
FK > 1.5	Stable	Only major disturbances can cause instability
1.25 < FK < 1.5	Moderate stability	Moderate instability disturbances can cause instability
1 < FK < 1.25	Somewhat stable	Minor instability disturbances can disrupt stability
FK < 1	Unstable	Requires slope stability improvement

Source: SNI 13-7124, 2018

METHODOLOGY

The research conducted was a field-based experimental and analytical study involving direct field investigation and laboratory testing. Field investigations included slope geometry measurements and soil sampling using hand boring at the peak, middle, and foot of the slope. Two soil layers were identified at each sampling point.

Laboratory testing consisted of moisture content, specific gravity, bulk density, particle size distribution (hydrometer analysis), and direct shear tests, conducted at the Soil Mechanics Laboratory, Department of Civil Engineering, Muhammadiyah University of Sorong.

Slope stability analysis was carried out using two complementary approaches:

1. Manual calculations using the simplified Bishop method, and
2. Numerical simulations using GeoSlope/SLOPE-W software.

Analyses were performed under four scenarios:

- Unsaturated soil without load
- Unsaturated soil with load
- Saturated soil without load

- Saturated soil with load

This dual-method approach enhances the reliability and robustness of the stability assessment.

RESULTS AND DISCUSSION

Slope Measurement Data Results

Slope measurement data was obtained by conducting a slope mapping or topography survey using a theodolite, tripod, measuring rod, tape measure, compass, and writing instruments. Meanwhile, data processing was carried out using *Microsoft Excel* and *Civil3D software.* After obtaining the calculation results, the results were then illustrated using *Civil3D* to obtain a longitudinal section *(Long section)* image of the slope from the slope contour, as shown in Figure 1.

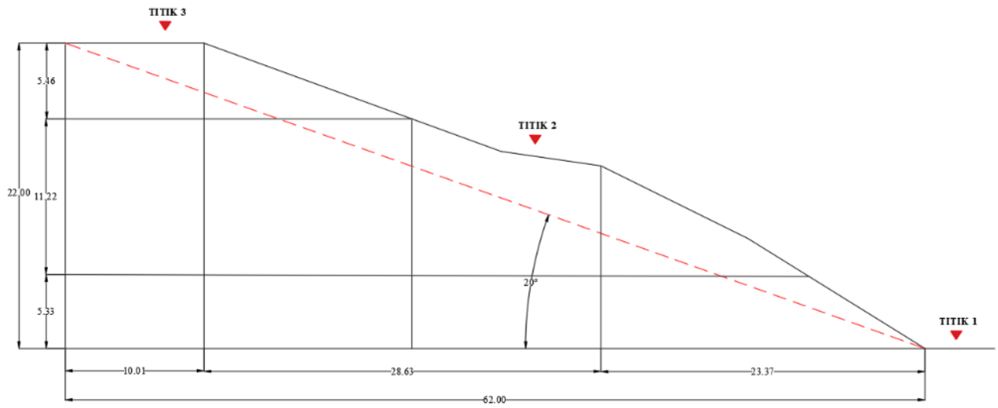

Figure 1. Geometry of the Slope
Source: AutoCAD, 2021

Laboratory Test Results

To support slope stability analysis, a series of soil tests were conducted in the laboratory to obtain the physical and mechanical parameters of the soil. The tests conducted included moisture content, bulk density, specific gravity, particle size analysis, and direct shear. The results of these tests were used as parameters in slope stability analysis, both manually and using GeoSlope software. The laboratory test results can be seen in Tables 2 to 5.

Table 2. Results of Moisture Content & Bulk Density Testing

Sample	Saturated		Unsaturated	
	Specific Gravity	Moisture Content	Weight	Moisture Content
	(grams/cm3)	(%)	(grams/cm3)	(%)
Peak	1.33	33.50	1.29	30.67
Middle	1.33	33.66	1.30	31.51
Foot	1.36	36.57	1.32	32.60

Source: Laboratory Testing, 2025

Table 3. Specific Gravity Test Results

Sample	Peak	Middle	Foot
Specific Gravity	2.57	2.73	2.74

Source: Laboratory Testing, 2025

Table 4. Particle Analysis Test Results

No.	Sample	Particle Analysis Test			Unit
		Sand	Silt	Clay	
1	Peak	15	32	53	%
2	Middle	50	10	40	%
3	Leg	50	5	45	%

Source: Laboratory Testing, 2025

Table 5. Direct Shear Test Results

Sample	Saturated		Unsaturated	
	Cohesion	Shear Angle	Cohesion	Angle of repose
	kg/cm2	(°)	kg/cm2	(°)
Peak	0.13	27.99	0.15	32.45
Middle	0.09	31.01	0.11	34.84
Foot	0.08	34.71	0.10	35.68

Source: Laboratory Testing, 2025

Software Analysis

In addition to manual analysis, GeoSlope (Slope/W) software was used to perform numerical simulations of slope stability. Modeling was carried out using the Bishop method, as in the manual approach, to ensure consistency of results. In this analysis, soil conditions were modeled in two scenarios: unsaturated and saturated conditions. The simulation results provided a visualization of the landslide-prone zone and more detailed FK values. In analyzing the stability of *existing* slopes with saturated and unsaturated conditions, initial data is required in the form of *a long section* of the slope (Figure 1) and soil material data including unit weight (γ), cohesion (c), and internal angle of friction (φ) in saturated and unsaturated conditions. The unit weight and cohesion values shown in Table 6 have been converted to kN/m^3 for unit weight and kN/m^2 for cohesion, in accordance with international standard units in geotechnical analysis.

Table 6. Soil Parameter Data

Samp le	Saturated			Unsaturated		
	Bulk Density	Cohesi on	Angle of repose	Specific Gravity	Cohesi on	Angle of repose
	kN/m^3	kN/m^2	(°)	kN/m^3	kN/m^2	(°)
Peak	13.00	12.26	27.99	12.61	14.71	32.45
Midd le	13.05	8.34	31.01	12.75	10.79	34.84
Foot	13.34	7.85	34.71	12.95	9.32	35.68

Source: Laboratory Testing, 2025

The software analysis process begins with slope geometry modeling based on previously created slope longitudinal sections, including slope height, length, and slope angle. Next, soil parameter data from laboratory tests is entered, converted to units based on Table 6, such as soil unit weight (γ), cohesion (c), and internal friction angle (φ) for each soil layer. After all material and geometry data have been entered, modeling is carried out in *SLOPE/W* assuming saturated and unsaturated soil conditions with and without loads. From the modeling results, the critical slip plane and FK value are obtained, which indicate the slope stability level. The visualization results are in the form of slip plane contours and FK values shown in Figures 2 to 5.

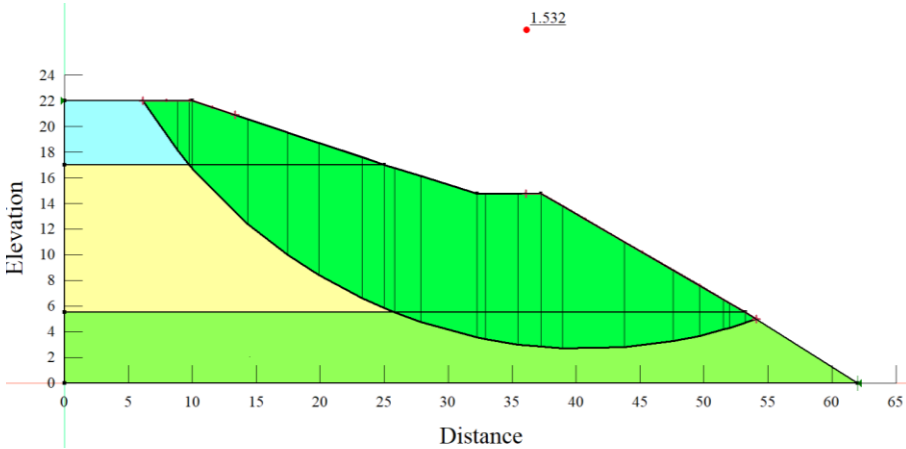

Figure 2. Saturated Soil Analysis Results
Source: GeoSlope Software, 2024

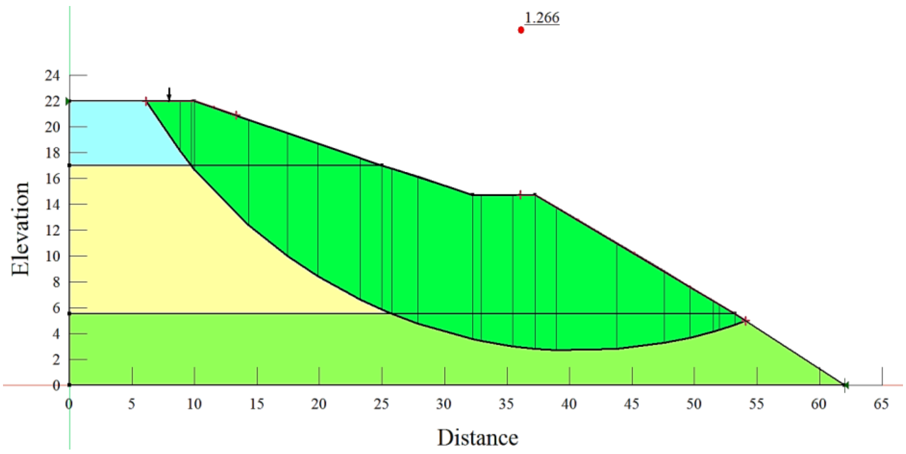

Figure 3. Results of Saturated Soil Analysis with Load
Source: GeoSlope Software, 2024

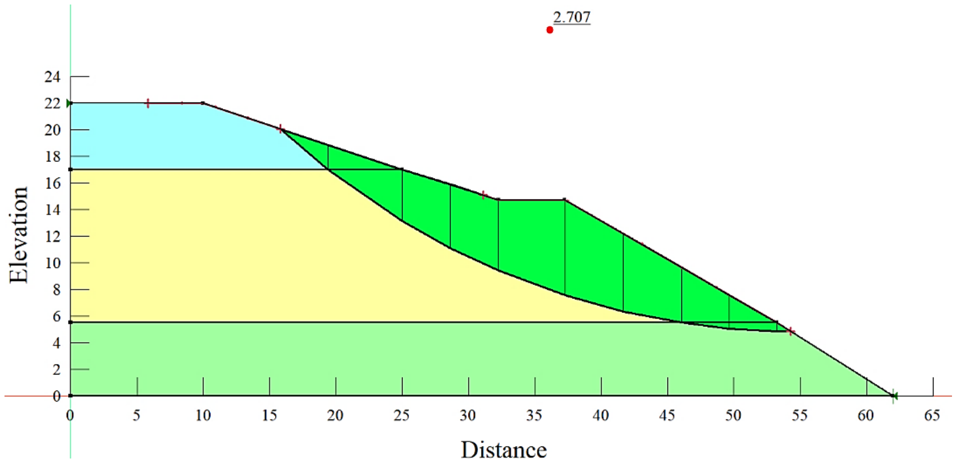

Figure 4. Results of Unsaturated Soil Analysis
Source: GeoSlope Software, 2024

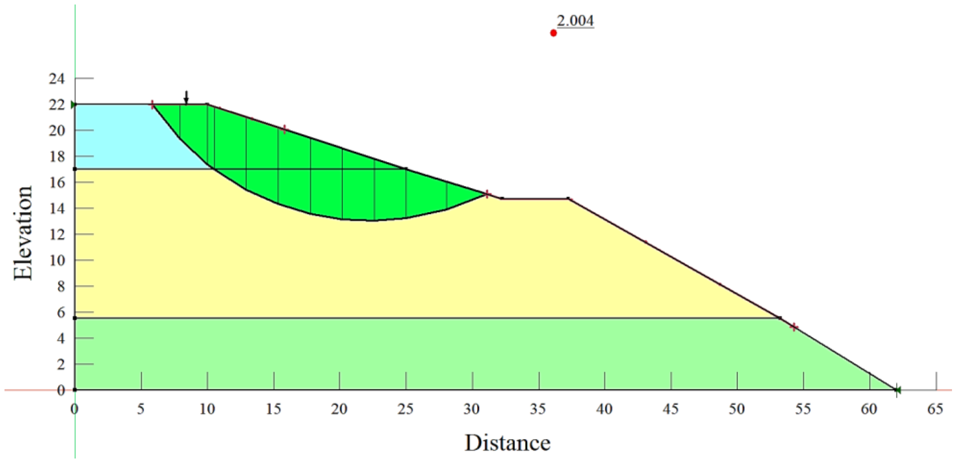

Figure 5. Image Results of Unsaturated Soil Analysis
Source: GeoSlope Software, 2024

Manual Analysis

The Bishop manual method analysis begins with an analysis of the landslide area using GeoSlope software. After obtaining the coordinates of the landslide area, the next step is to redraw the slope geometry using Autocad software and divide the sections to form sections with dimensions that can be used for further analysis. This manual analysis calculates the Safety Factor (SF) value in two main conditions, namely saturated soil due to rain and unsaturated soil.

Table 7. Recap of Calculations for Saturated Soil Conditions

No. Section	Section Width (m)	Section Height (m)	Section Area (m²)	Distance from 1/2 Slice to Point O (m)	Slice Weight (kN)	Slice Angle (a)	Normal Force (P)	Shear Force (T)	Pore Water Pressure (μ)
1	6,16	4,21	18,33	26,70	238,52	62,07	111,72	210,73	41,30
2	4,71	8,65	26,80	21,28	349,17	44,76	247,93	245,88	84,86
3	4,71	10,30	45,10	16,59	588,18	33,30	491,62	322,89	101,04
4	4,71	11,07	51,03	11,92	665,85	23,23	611,87	262,64	108,60
5	4,71	11,14	52,65	7,25	687,49	13,88	667,41	164,93	109,28
6	4,68	10,59	45,05	2,41	589,08	4,57	587,20	46,98	103,89
7	4,71	10,24	46,02	2,31	601,97	4,38	600,20	46,01	100,45
8	4,71	8,19	37,66	6,91	494,01	13,22	480,92	112,96	80,34
9	4,71	5,31	20,23	11,56	264,77	22,49	244,63	101,28	52,09
10	4,07	2,08	7,45	15,79	97,86	31,50	83,44	51,13	20,40
∑							4126,94	1565,44	802,26

Source: Calculation Results, 2025

Table 8. Summary of Calculations for Saturated Soil Conditions with Load

No. Cross-section	Section Width (m)	Section Height (m)	Cross-Section Area (m²)	Distance from 1/2 Slice to Point O (m)	Slice Weight (kN)	Slice Angle (a)	Normal Force (P)	Shear Force (T)	Pore Water Pressure (μ)
1	6.16	4.21	18.33	26.70	4747.89	62.07	59.96	-57.20	41.30
2	4.71	8.65	26.80	21.28	1088.19	44.76	772.65	850.15	84.86
3	4.71	10.30	45.10	16.59	1019.54	33.30	852.17	559.70	101.04
4	4.71	11.07	51.03	11.92	970.23	23.23	891.57	382.70	108.60
5	4.71	11.14	52.65	7.25	922.87	13.88	895.92	221.40	109.28
∑							3,472.28	1956.76	445.08

Source: Calculation Results, 2025

Table 9. Summary of Unsaturated Soil Condition Calculations

No. Section	Section Width (m)	Slice Height (m)	Slice Area (m²)	Distance from 1/2 Section to Point O (m)	Slice Weight (kN)	Slice Angle (a)	Normal Force (P)	Shear Force (T)
1	4,84	1,62	8,88	15,94	112,56	52,03	69,26	88,74
2	3,38	3,57	13,96	11,83	177,98	35,81	144,34	104,13
3	3,38	4,57	35,46	8,45	211,60	24,70	192,23	88,43
4	3,38	5,16	39,78	5,07	240,47	14,52	232,79	60,30
5	3,38	5,93	39,61	1,69	266,76	4,79	265,82	22,30
6	3,38	5,91	33,97	1,69	238,32	4,79	237,48	19,92
7	3,38	5,06	26,23	5,07	194,79	14,52	188,57	48,84
8	3,38	3,88	19,67	8,45	139,63	24,70	126,85	58,35
9	5,38	1,67	8,72	12,78	111,12	39,20	86,11	70,24
∑							1543,45	561,23

Source: Calculation Results, 2025

Table 10. Summary of Calculations for Unsaturated Soil Conditions with Load

No. Section	Section Width (m)	e Section Height (m)	Slice Area (m²)	Distance from 1/2 Slice to Point O (m)	Slice Weight (kN)	Slice Angle (a)	Normal Force (P)	Shear Force (T)
1	4.84	1.62	8.88	15.94	112.56	52.03	69.26	88.74
2	3.38	3.57	13.96	11.83	177.98	35.81	144.34	104.13
3	3.38	4.57	35.46	8.45	211.60	24.70	192.23	88.43
4	3.38	5.16	39.78	5.07	240.47	14.52	232.79	60.30
5	3.38	5.93	39.61	1.69	266.76	4.79	265.82	22.30
6	3.38	5.91	33.97	1.69	238.32	4.79	237.48	19.92
7	3.38	5.06	26.23	5.07	194.79	14.52	188.57	48.84
∑							1330.49	751.80

Source: Calculation Results, 2025

To calculate the slope safety factor, the Bishop method can be analyzed by first summarizing the calculations of the length of the slope, the weight of the soil volume, the area of the cut, the weight of the soil cut, the angle of each soil cut, the m value, the l value, and the μ value. The results of the manual analysis using the Bishop method are shown in Tables 7 to 10. Based on Equation 3, the safety factor (FK) value obtained for saturated soil conditions without load is 1.577 and with load is 1.261. Referring to Table 1 on slope stability classification, these values still meet the safety number ($1.7 < FK \leq 2.0$), which means that the slope is stable, even with and without load. Meanwhile, in unsaturated soil conditions without load, calculations using Equation 4 produce an FK value of 2.717 and with load of 2.028. This value is also included in the stable category based on Table 1, so it can be concluded that although soil saturation reduces stability, the additional load is not sufficient to cause slope failure.

CONCLUSIONS AND RECOMMENDATIONS

The results of this study demonstrate that rainfall-induced soil saturation significantly influences slope stability by increasing pore water pressure and reducing effective stress and soil shear strength. Analysis using the Bishop method, both through manual calculations and GeoSlope/SLOPE-W simulations, consistently shows that safety factor values under saturated conditions are lower than those under unsaturated conditions, regardless of the presence of external loading.

Despite the reduction in safety factor, the analyzed slopes remain within the stable classification range under existing conditions. The close agreement between manual and numerical results confirms the reliability of the adopted analytical approach. However, the decrease in stability under saturated conditions indicates that prolonged or intense rainfall may increase the likelihood of slope failure if additional triggering factors are present.

Based on these findings, it is recommended that slopes in rainfall-prone areas such as Katapop II be subject to continuous monitoring, particularly with respect to groundwater levels and pore water pressure. Preventive measures, including surface and subsurface drainage systems, controlled loading near slope crests, and periodic slope stability evaluations, should be implemented to reduce potential landslide risks and enhance long-term slope safety.

FURTHER STUDY

This study has several limitations. The slope stability analysis was conducted using a two-dimensional limit equilibrium approach and assumed homogeneous soil properties within each layer. Transient rainfall infiltration and time-dependent pore water pressure variations were not explicitly modeled. Future research is recommended to incorporate transient seepage analysis, three-dimensional slope stability modeling, and long-term field monitoring to better capture rainfall-induced slope behavior.

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REFERENCES

Amri, N., Dharmawansyah, D., & Hermansyah, H. (2021). Comparison of the Bishop and Janbu Methods in Slope Stability Analysis on the Labu Sawo Sumbawa Bridge Approach. Journal of Civil Engineering and Planning (JCEP), 2(1), 20-33. Yogaswara, D. (2023). Analysis of slope stability against landslides (case study on the Bandung-Garut highway in Cihareng Village, Nareg District).

Bishop, A. W. (1955). The use of the slip circle in the stability analysis of slopes. Geotechnique, 5(1), 7-17.

Bowles, J. E., Hainim, K. J. 1991. Physical and Geotechnical Properties of Soil (Soil Mechanics). Second edition. Jakarta: Erlangga Publishers.

Christady, H. (2003). Soil Mechanics II. Third edition. Yogyakarta: Gadjah Mada University Press.

Hafidz, A., Fauzan, M., Putra, H., & Daniswara, A. (2019). Analysis of Changes in Slope Safety Factors Due to Rainfall. Journal of Civil and Environmental Engineering, 4(3), 169-176. Ahmad Januar & R. Rokhman (2025). The Effect of Clay Soil Stability with Lime Additives on Shear Strength

Harijan, H. (2022). Slope Stability Analysis Reviewed from the Influence of Rainwater Infiltration and Slope Geometric Reinforcement Case Study: Slope Landslide in Kondoruba Hamlet (Km. 25+ 575-26+ 100) Preservation of the Kalukku-Salubatu-Mambi-Malabo Road, West Sulawesi (Doctoral dissertation, Sepuluh Nopember Institute of Technology). Parluhutan, O. C., & R. T. (2014). Slope stability analysis using the Bishop method (Case study: Citraland area, 1000m station).

Hidayat, R. (2020). Analysis of the effect of rain infiltration on slope stability in Pangkalan, West Sumatra. Journal of Hydraulic Engineering, 11(1), 25–36.

Putra, H., Rifa'i, A., & Sujono, J. (2014). The Effect of Infiltration on Partially Saturated Soil Parameters in Slope Stability Analysis. Department of Civil and Environmental Engineering. Gadjah Mada University. Yogyakarta. Putra, P. A., Sutiono, W., & Rokhman, R. (2019). Experimental Testing of Clay Soil Stabilization Using Sand and Lime. Journal of Civil Engineering: Design and Construction, 5(2), 53-60.

Rochmawati, R., & Tonggiroh, M. (2019). THE EFFECT OF INFILTRATION ON SLOPE STABILITY ANALYSIS.

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). Spinger. 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

Sitepu, F., Selintung, M., & Harianto, T. (2017). The effect of rainfall intensity and slope gradient on erosion that has the potential to cause landslides. Journal of Engineering Research, 21(1), 23-27.

Wibowo, A. S. (2022). Safety Factor Analysis of Sedayu Mountainous Area Using Limit Equilibrium Method 2D. Bulletin of Geology, 6(2), 968-977. Aisah, E. (2022). Study of the effect of rainfall on slope stability using the Perisi program. Palembang: Department of Civil Engineering, Faculty of Engineering, Andalas University (Unand)