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Slope Stability Analysis of Mining Activities Using Slope Mass Rating of the Poboya Region, Palu City, Central Sulawesi Province

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ABSTRACTS

This study analyzed the level of stability and types of slope avalanches that could potentially occur in mining activities at PIT in the Poboya area of Mantikulore District, Palu City, Central Sulawesi Province, using the SMR method and modeling the mining area. The analysis was conducted by taking large rock samples and discontinuity data using the scanline method in the field. The rock samples were then tested using a point load test to obtain the compressive strength value of the rock, which is included in the 5 parameters of the RMR value and the other 4 are RQD, spacing of the fault plane, condition of the fault plane and groundwater condition of the slope plane. The final SMR result is obtained by combining the RMR value and the correction factor. Based on the RMR calculation results at the location point of the research area, the rock mass class on Slope-1 and Slope-3 is included in class III (medium rock), while the rock mass class on Slope-2 and Slope-4 is included in class II (good rock) with the analysis of the safety factor on the four slopes of the study area is still classified as a relatively stable slope, namely F above 1.25. Then in the stereographic analysis, the point that shows the type of landslide is Slope-3 and Slope-4, with the calculation of the SMR method these two slopes are still classified in class II with stable slope conditions.

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INTRODUCTION

Slope is one of the problems that often occur in open pit mining. Changes in slope geometry can pose a risk to slope stability. Slope stability itself is an important factor in the design and operational planning process in mining. Therefore, it is necessary to review the strength of the rock mass on the slope (Rai et al., 2013) by conducting a special geotechnical study at the research location so that we can find out the stability of the slope by estimating the possibility of the slope experiencing landslides and the value of the safety factor at the research location and maybe the currently stable slope can be optimized again.

Gold is a resource that has long-term investment potential and is also a non-renewable natural resource, therefore gold mining must be planned very carefully. Prior to the occurrence of landslides in mining activities, mitigation efforts are needed to prevent or reduce the risk of landslides, the SMR method can be used in this condition. Slope mass rating classification is one of the rock avalanche potential assessment systems that combines qualitative and quantitative analysis based on the rock mass rating method by involving its parameters and adjusting the orientation direction of the bridle so as to produce a good slope stability assessment. Metode ini telah diterapkan pada berbagai penelitian kestabilan lereng sebelumnya di Indonesia (Wulandari dkk., 2016; Amin dkk., 2018; Hasria dkk., 2019).

METHODS

Administratively, the research area is included in the PT Citra Palu Minerals area. Mantikulore sub-district, Palu city, Central Sulawesi. Astronomically located at 119º 56' 54.9“ East longitude and 00º 51' 43.9” South latitude. The location of the study area can be accessed by air by using an airplane with the route Makassar-Palu.

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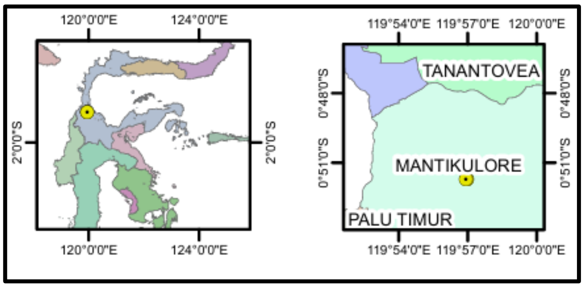

Figure 1 Location map of the study area

Figure 2 PIT location of the study area

The research method was carried out by taking field data including fresh rock samples and slope discontinuity orientation data using the scanline method at 4 points of the research site slope. The rock samples were then tested using the point load test and triaxial apparture tools to measure the compressive strength and shear angle of the rock.

Once tested, data analysis is required in analyzing slope stability for SMR value determination. The data processing includes Rock Mass Rating data processing which is analyzed to classify the rock mass at each research point. Stereographic data analysis and processing to determine the type of avalanche that occurs on the rock slope of the research location using Dips 6.0 software, as well as analysis of the slope safety factor using software assistance in the form of Slide 6.0.

RESULTS AND DISCUSSION

Slope Geometry

Slope geometry measurements were carried out using a compass, Global Positioning System (GPS) and roll meter to determine the slope height, slope length, strike, dip direction and slope angle (dip). From the field measurements, geometry data were obtained:

Table 1. Geometry of the Study Slope

Field	Slope orientation			Slope height	Slope length
	slope gradient	slope angle	slope direction		
L-1	97º	43º	187º	9,6 m	115 m
L-2	147º	47º	237º	3,5 m	56 m
L-3	125º	43º	215º	5 m	28 m
L-4	95º	55º	185º	9,5 m	115 m

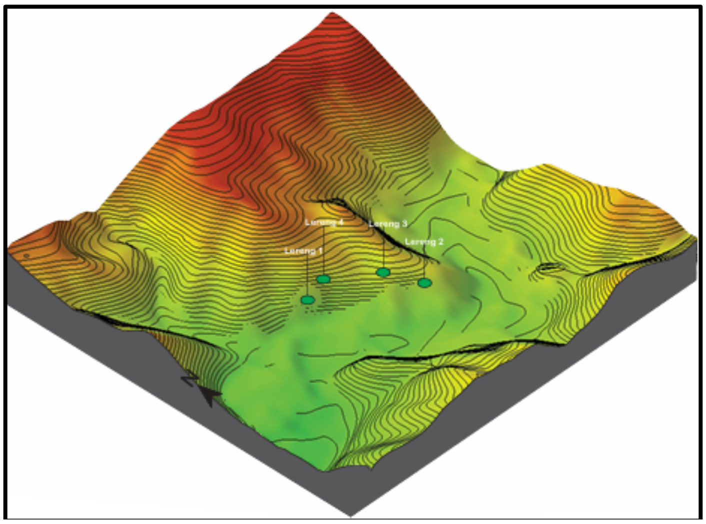

Figure 3 3D location of the study area

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Rock Mass Characterization by Rock Mass Rating Method

The Rock Mass Rating (RMR) method, or commonly known as Geomechanics Classification (Bieniawski, 1989), is one of the empirical methods used to determine the weighting of rock mass from five measured and observed parameters, namely rock compressive strength, bridle spacing, Rock Quality Designation (RQD), bridle condition and groundwater condition.

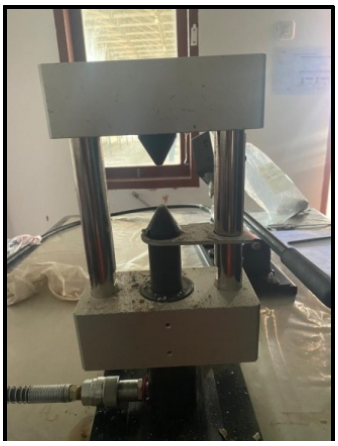

Figure 4 Point Load Test

1. Rock compressive strength

Rock compressive strength is obtained by direct testing in the laboratory using the Point Load Index tool (Broch & Franklin, 1972), and the resulting strength values are classified following Deere & Miller (1966). Calculation of rock compressive strength values obtained on Slope-1 of 1.98 Mpa with a weight value of 4, Slope-2 of 2.51Mpa with a weight value of 7, Slope-3 of 0.56 Mpa with a weight value of 1, and Slope4 of 2.09 Mpa with a weight value of 7.

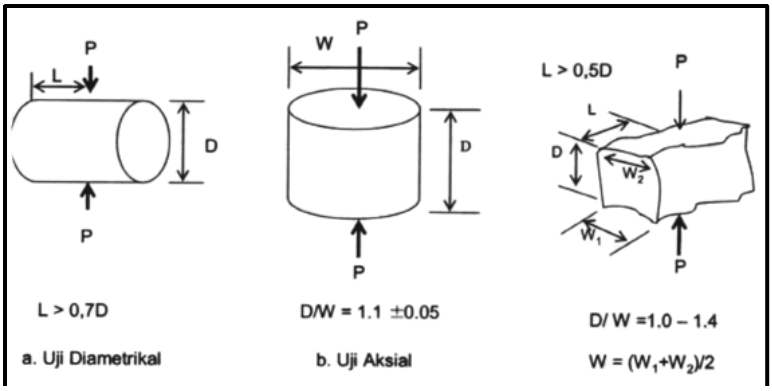

Figure 5 PLI test rock sample type (ISRM, 1985)

2. Brittle Spacing

In the scanline method, discontinuity spacing is the distance between two adjacent discontinuities in one scanline. The spacing distance between bridle planes obtained from field measurements was then corrected using the equation proposed by Kramadibrata (1996) to obtain the average spacing distance between the actual bridle planes. The average spacing of the bridle planes on Slope-1 is 76.3 mm with a weight value of 8. Slope-2 is 64.92 mm with a weight value of 8, Slope-3 is 66.18 mm with a weight value of 8, and Slope-4 is 71.10 mm with a weight value of 8.

3. Rock Quality Designation (RQD)

From the corrected brittle spacing distance, the RQD value can be calculated using the equation proposed by Priest and Hudson (1976).

$$\mathrm{RQD} = 100\mathrm{e}^{-0.1\lambda}.(0.1\lambda + 1) \quad (1)$$

Based on the calculation of the RQD value on Slope-1, a value of 62% is obtained with a weight value of 13, Slope-2 a value of 53.68% with a weight value of 13, Slope-3 55.16% with a weight value of 13, and Slope-4 58.70% with a weight value of 13.

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4. Brittle Condition

The results of the observation of brittle conditions at the research site based on the observed parameters, namely brittle persistence, brittle aperture width, brittle roughness, infilling material and weathering. Based on the observation of the bridle condition on Slope-1, the average weight of the bridle persistence is 4.63, the average bridle aperture is 3, the roughness of the bridle is 4.03, the infilling material is 4.1 and the weathering level is 3.26. From the observation of the condition of the bridle on Slope-1, a weighted value of 20 is obtained. On Slope-2, the average weight of the bridle continuity is 3.96, the average bridle opening is 3.35, the roughness of the bridle is 3.23, the filler material is 4.23 and the level of weathering is 2.72, so a weighted value of 18 is obtained. Slope-3, obtained the average weight of bridle continuity is 4.58 average bridle opening is 3.09 bridle roughness is 3.10 fill material is 3.56 and the weathering rate is 1.94, then obtained a weighted value of 16. Slope-4, obtained the average weight of bridle continuity is 4.58 average bridle opening is 4.03 bridle roughness is 2.93 fill material is 4.70 and the weathering rate is 3.41, then obtained a weighted value of 18.

Figure 6 (a) Brittle openings >5mm (b) Brittle continuity

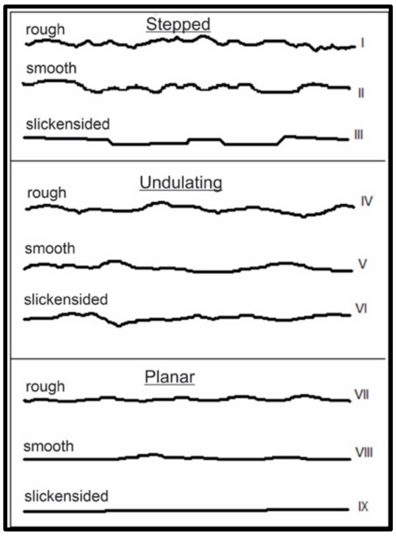

Figure 7 Roughness profile of jointing (ISRM, 1981)

Figure 8 Calcite vein as filler material

5. Groundwater Conditions

Observations of groundwater conditions with respect to general conditions on the PIT slopes were taken during sunny weather so as to represent groundwater conditions on the slopes, with categories of dry, damp, wet, dripping, and flowing. Observations of groundwater conditions on Slope-1, Slope-2, Slope-3, and Slope-4 are dry with a weighted value of 15 each.

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Parameter L1	Nilai Kondisi	Bobot
Kuat Tekan Batuan	1,98 Mpa	4
Spasi Kekar	76,3	8
RQD	62%	13
Kondisi Kekar	Kemenerusan Kekar 1-3 m, Bukaan Kekar 0,1-1 mm, Permukaan Kekar Kasar, Material Pengisi Keras < 5mm, Tingkat	20
Kondisi Air Tanah	Kering	15
Nilai RMR		60
Kelas Massa Batuan		III

Parameter L2	Nilai Kondisi	Bobot
Kuat Tekan Batuan	2,51 Mpa	7
Spasi Kekar	64,92	8
RQD	53,68%	13
Kondisi Kekar	Kemenerusan Kekar 1-3 m, Bukaan Kekar 0,1-1 mm, Permukaan Kekar Sedikit Kasar, Material Pengisi Keras < 5mm, Tingkat Pelapukan Lapuk Sedang	18
Kondisi Air Tanah	Kering	15
Nilai RMR		61
Kelas Massa Batuan		II

Parameter L3	Nilai Kondisi	Bobot
Kuat Tekan Batuan	0,56 Mpa	1
Spasi Kekar	66,18	8
RQD	55,16 %	13
Kondisi Kekar	Kemenerusan Kekar 1-3 m, Bukaan Kekar 0,1-1 mm, Permukaan Kekar Sedikit Kasar, Material Pengisi Keras < 5mm, Tingkat Pelapukan Sangat Lapuk	16
Kondisi Air Tanah	Kering	15
Nilai RMR		53
Kelas Massa Batuan		III

Parameter L4	Nilai Kondisi	Bobot
Kuat Tekan Batuan	2,09 Mpa	7
Spasi Kekar	71,10	8
RQD	58,70 %	13
Kondisi Kekar	Kemenerusan Kekar 1-3 m, Bukaan Kekar 0,1-1 mm, Permukaan Kekar Sedikit Kasar, Material Pengisi Keras < 5mm, Tingkat Pelapukan Lapuk Sedang	18
Kondisi Air Tanah	Kering	15
Nilai RMR		61
Kelas Massa Batuan		II

Figure 9 RMR calculation results on Slope-1, Slope-2, Slope-3, Slope-4

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Analysis of Avalanche Type by Stereographic Method

Stereographic analysis is used to identify the type of avalanche that occurs on a rock slope (Hoek & Bray, 1981). Based on the data of the dip direction of the slope, the dip of the slope, the strike/dip of the bridle and the magnitude of the inner shear angle, the type of avalanche potential will be known.

Stereographic Analysis and Factor of Safety of Slope-1

From the bridle grouping process, three sets of bridles were obtained on Slope-1, namely, the general position of JS1 is N 49ºE / 72º, the general position of JS2 is N 324ºE / 82º and the general position of JS3 is N 127ºE / 81º. Stereographic analysis on Slope-1 did not show any avalanche potential.

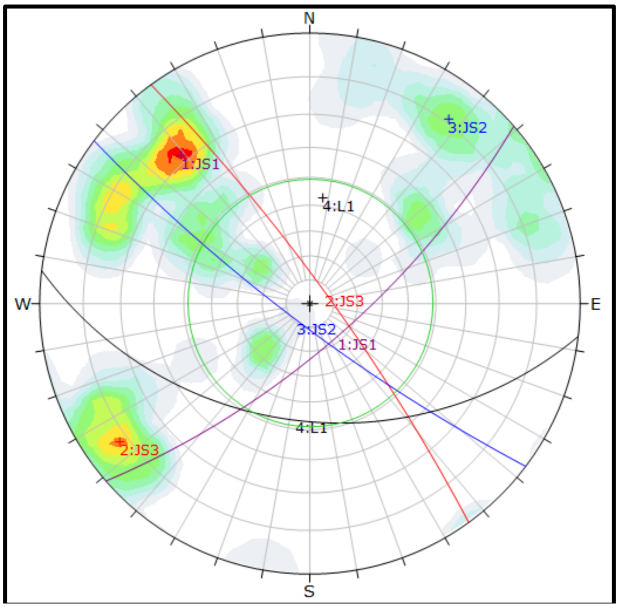

Figure 10 Interpretation of bridle set of Slope-1

And from the analysis of the safety factor obtained a value of 2.049 from the data of slope length, slope angle, inner shear angle, cohesion, unit weight, and UCS value. Based on the range of safety factors according to Bowles (1991), the safety factor on Slope-1 is included in the relatively stable slope.

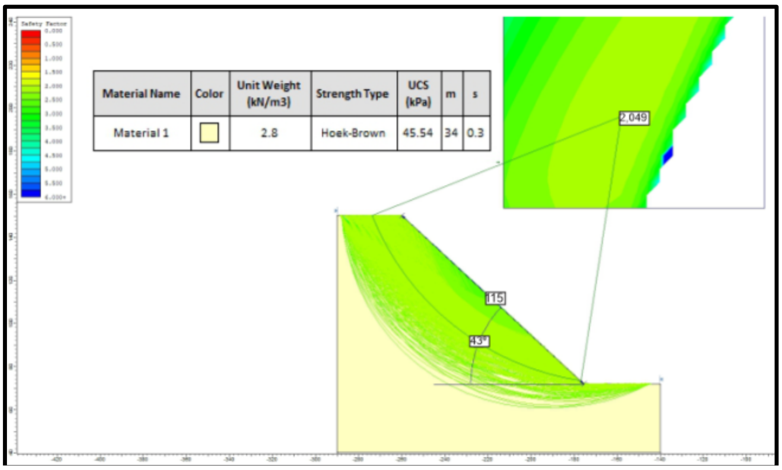

Figure 11 FK Analysis of Slope-1

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Stereographic Analysis and Factor of Safety of Slope-2

From the process of bridle grouping with three sets of bridles obtained on Slope-2, namely, the general position of JS1 is N 70ºE / 47º, the general position of JS2 is N 138ºE / 85º and the general position of JS3 is N 289ºE / 64º. Stereographic analysis on slope-2 did not show any avalanche potential.

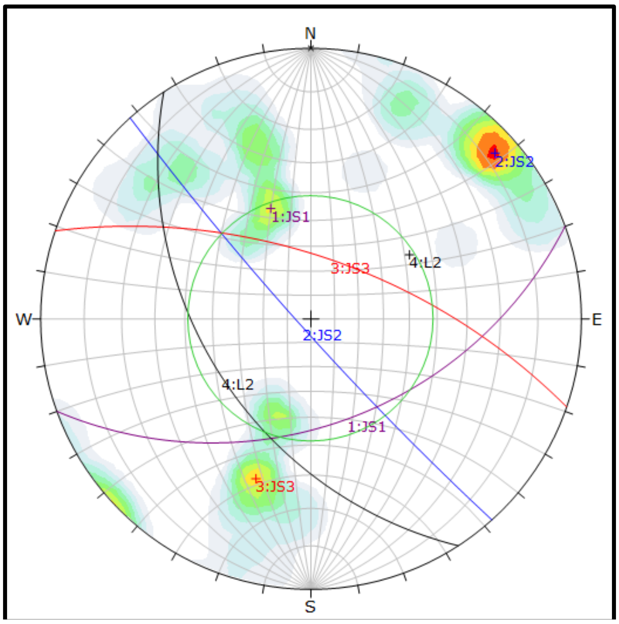

Figure 12 Interpretation of bridle set of Slope-2

From the analysis of the factor of safety obtained a value of 2.508, the factor of safety on Slope-2 is included in the relatively stable slope.

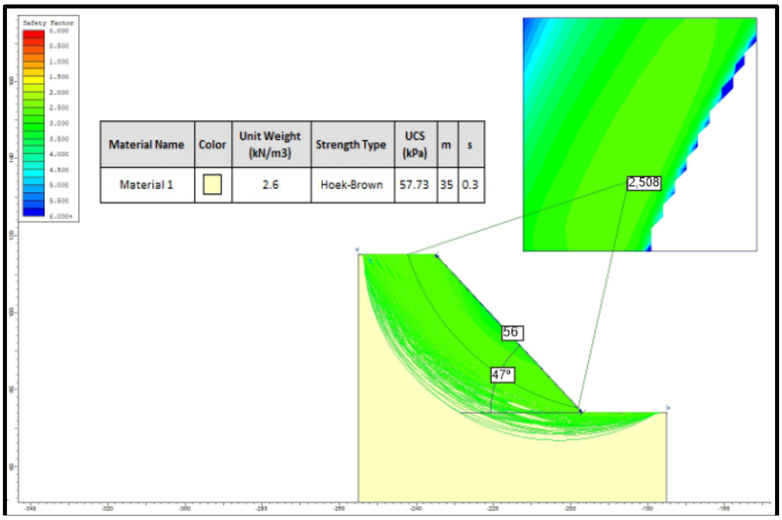

Figure 13 FK Analysis of Slope-2

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Stereographic Analysis and Safety Factor of Slope-3

From the bridle grouping process, four sets of bridles were obtained on Slope-3, namely, the general position of JS1 is N 77°E / 87°, the general position of JS2 is N 140°E / 88°, the general position of JS3 is N 254°E / 47° and the general position of JS4 is N 347°E / 46°.

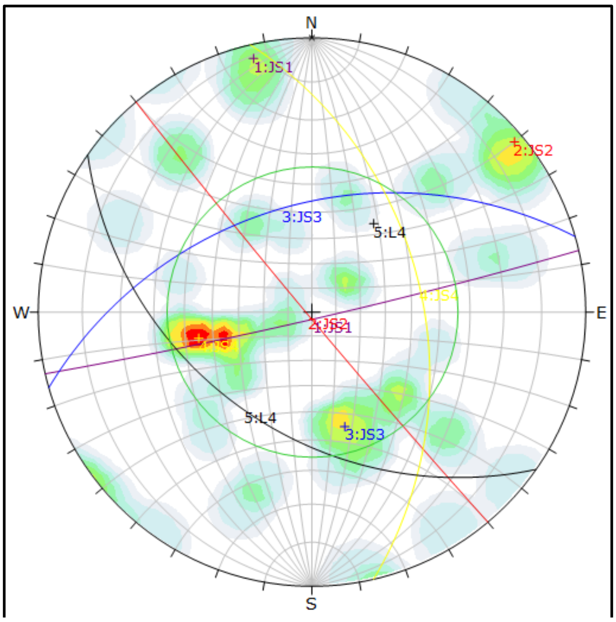

Figure 14 Interpretation of bridle set of Slope-3

Slope-3 shows oblique toppling as indicated by the intersection point formed by the JS1 and JS2 sets of braces within the critical zone of oblique toppling avalanches.

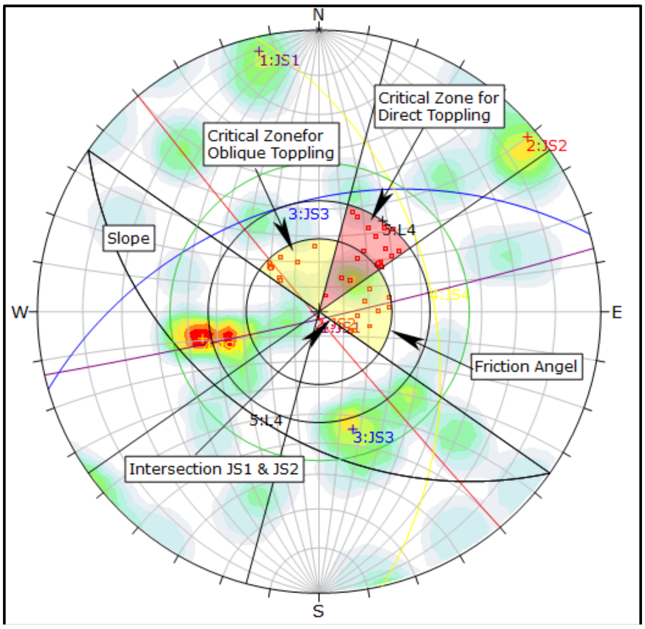

Figure 15 Stereographic analysis of Slope-3 shows oblique toppling avalanches.

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From the factor of safety analysis with a value of 1.993, the factor of safety on Slope-3 is included in the relatively stable slope.

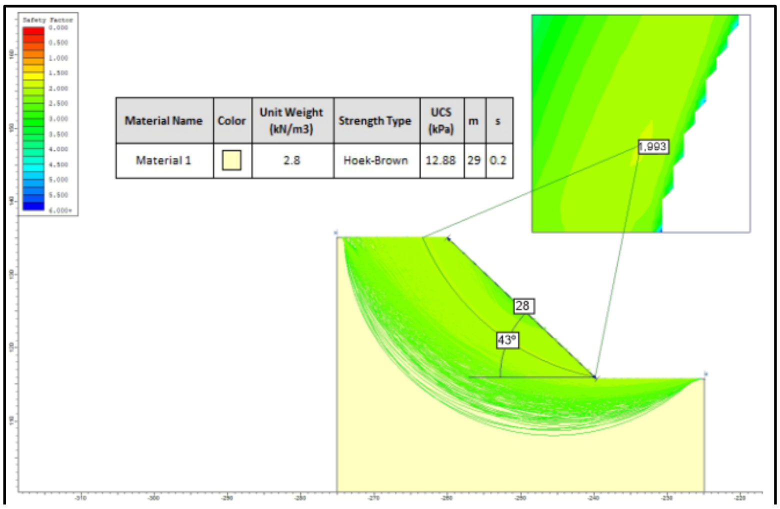

Figure 16 FK Analysis of Slope-3

Stereographic Analysis and Safety Factor of Slope-4

From the bridle grouping process, three sets of bridles were obtained on slope-4, namely, the general position of JS1 is N 69ºE / 75º, the general position of JS2 is N 146ºE / 39º and the general position of JS3 is N 322ºE / 41º. Slope-4 shows the presence of wedge failure and planar sliding failure. This is indicated by the point of intersection formed by the two sets of braces JS1 and JS2 being within the critical zone of wedge failure and then indicated by the general position of JS2 being within the critical zone of planar sliding failure.

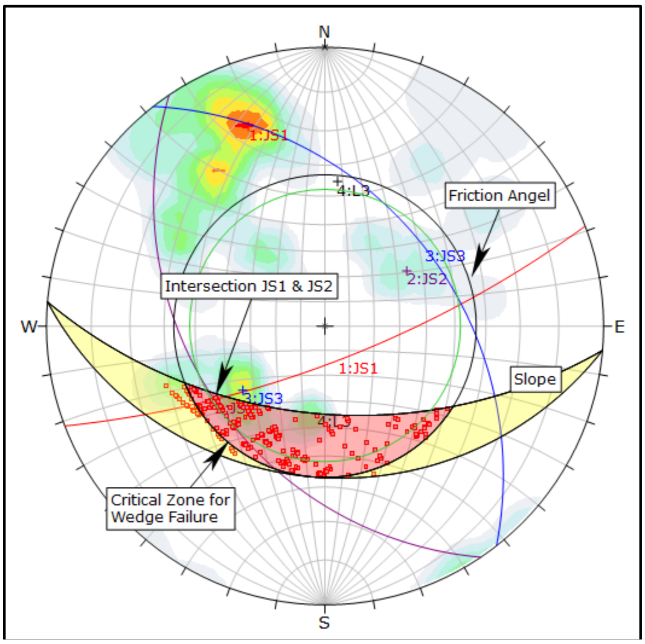

Figure 17 Stereographic analysis of Slope-4 showing wedge failure avalanche

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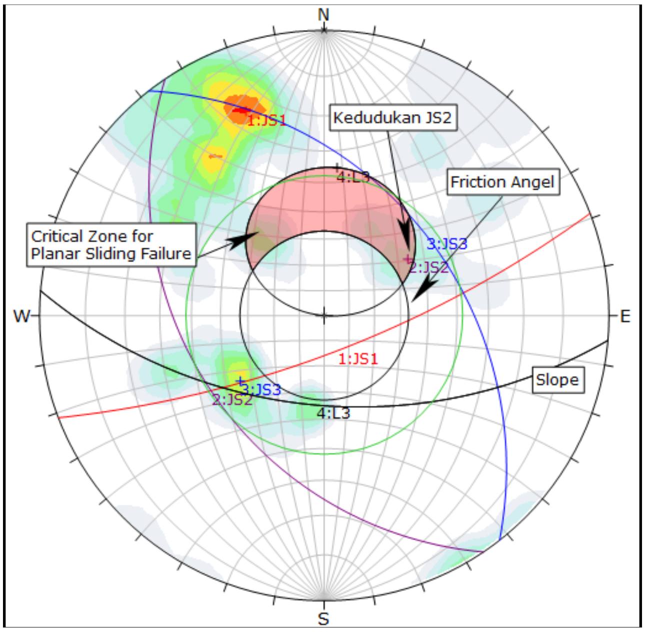

Figure 18 Stereographic analysis of Slope-4 showing planar sliding failure avalanche.

From the analysis of the factor of safety obtained a value of 1.550, the factor of safety on Slope-4 is included in the relatively stable slope.

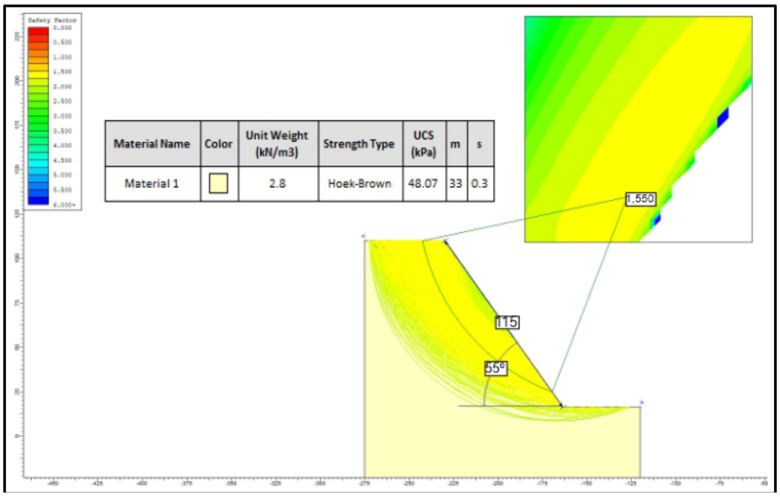

Figure 19 FK Analysis of Slope-4

Weighting of Slope Mass Rating (SMR) Parameters on Slope-3 and Slope4

Based on the results of the calculation of the slope mass rating of Slope-3, in the type of oblique toppling avalanche, the F1 value in the JS1 and JS2 brittle sets is 138° and 75° respectively, the F2 value in the JS1 and JS2 brittle sets is 87° and 88° respectively, and the F3 value in the JS1 and JS2 brittle sets is 130° and 131° respectively. Then the calculation on Slope-4 in the type of wedge failure obtained F1 value of 139°, F2 value of 42° and F3 value of -13°. In the type of planar sliding failure, the F1 value in the JS2 bridle set is 141°, the F2 value is 39°, and the F3 value is -16°.

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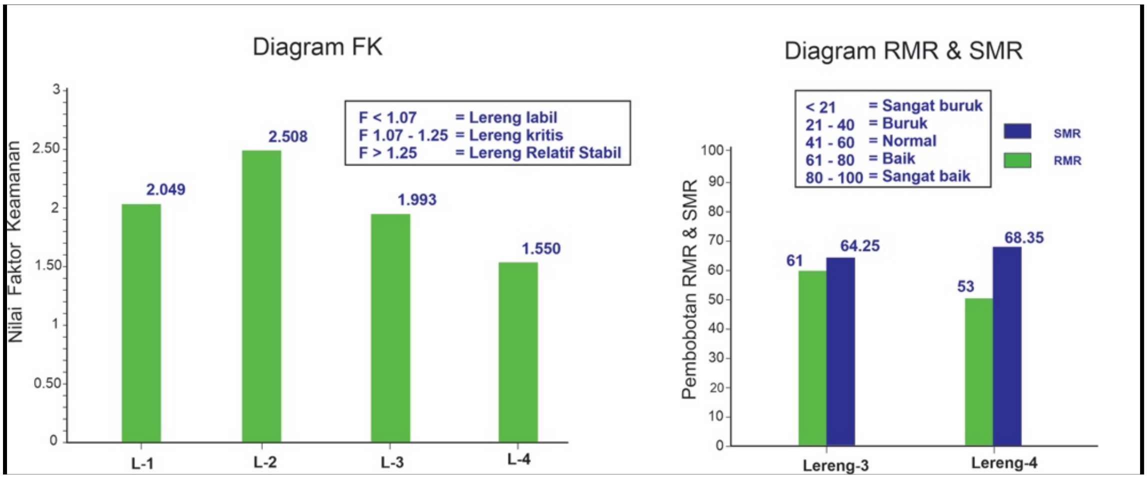

Figure 20 Diagram of research results

From the results of weighting the F1, F2, F3 and F4 slope mass rating values based on the equation proposed by Romana (1993), Slope-3 and Slope-4 are included in class II (Good) slopes with stable slope conditions.

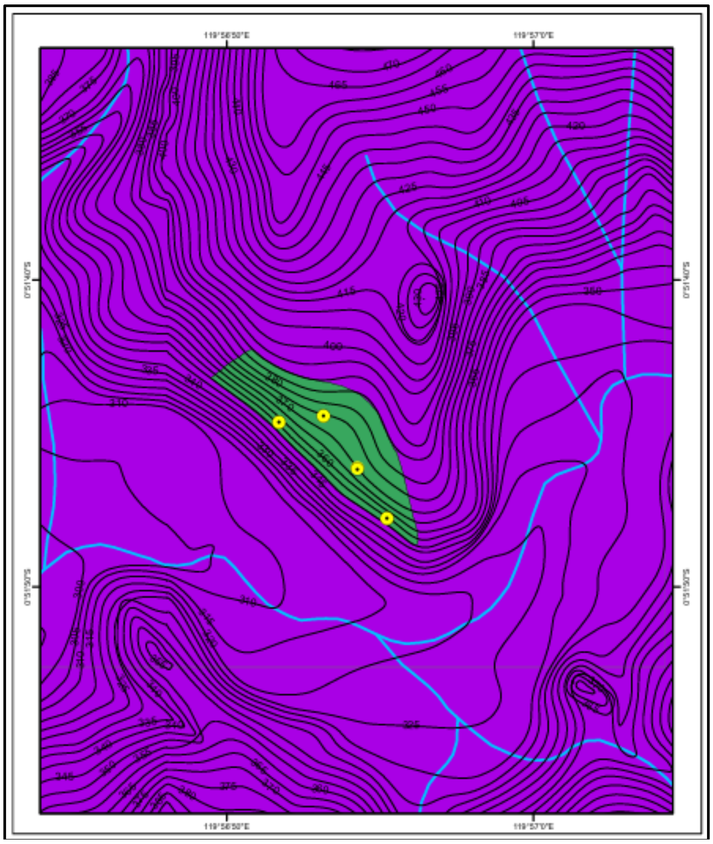

Figure 21 SMR map of the study area

CONCLUSION

Based on the results of the slope stability analysis research that at four points of the slope of the research area has rock mass in good condition where this condition is obtained based on field data which is then calculated and analyzed using the RMR method. From the stereographic analysis on Slope-3 and Slope-4 shows the existence of a potential avalanche type, based on the weighting results using the SMR method, Slope-3 and Slope-4 are still classified as slope class II, which is a good class with stable slope conditions. The weighting results of the SMR method use the equation proposed by Romana (1993).

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