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STABILITY ANALYSIS OF SLOPE ON TRANS SULAWESI ROAD, PONTOLO VILLAGE, MANANGGU SUB-DISTRICT, BOALEMO DISTRICT, GORONTALO PROVINCE

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Abstract

The research location is in Pontolo Village, Mananggu Sub-district, Boalemo District, Gorontalo Province. The research location has rock slopes that have a discontinuity area in the form of fractures in the rock body which is a factor causing landslides. The purpose of the research is to determine geological conditions, rock mass quality, types of potential landslides, and recommendations for slope stability. The methods used are direct field observation, Scanline Mapping, Rock mass Rating (RMR), kinematics analysis, and Slope Mass Rating (SMR). The results of the geomorphological research of the research area are units of lava flow plains, and units of intrusive hills. The lithology of the research area is in the form of granodiorite units, and porphyry dacite units, while the geological structure is in the form of joints. Scanline mapping is carried out on 4 segments, that is: segment 1, segment 2, segment 3 and segment 4. The rock mass class consists of 2 classes, good class and fair class. Types of landslides consist of wedge sliding and toppling sliding. SMR consists of 2 classes stable and unstable, the results of observations that unstable slopes need to be handled in slope reinforcement.

Keywords: Landslide, Rock Mass Rating (RMR), Kinematics Analysis, Slope Mass Rating (SMR)

A. Introduction

Indonesia has a problem with slope stability that often occurs when the ground is not invariably horizontal, and elevation are different from one place to another. Unstable soil or rock will experience material movement on the slopes which causes landslides (Karnawati, 2011). Landslides are one of the geological disasters that often occur in several places that can claim lives, while the causes of landslides are by several factors such as rainfaall, slope, loose and water – permeable soil conditions, and very weathered rock conditions making up the slopes (Pratama,2021)

Gorontalo is located in the northern of Sulawesi is a magmatic pathway formed by the subduction of the Sulawesi sea plate. Sulawesi, which is located in the microplate tectonic plate area, is very disturbed to the movement and collision of the three earth plates which will cause geological phenomena that can harm humans (Kaharuddin, 2011).

The formation of local faults that affect rock weathering and form steep topographical grooves so that the rock experiences fragmentation and landslides occur (usman, 2018). Factors that cause landslides are: geological activity, lithology, rainfall, and slope (Robot, 2021). Tektonic processed lead to the formation of fractures in rock outcrops, fractures are formed intensiverly in rock outcrops so the landslides are easy to occur (Usman,2020). The landslide factor is related to slope stability conditions where unstable slopes be on a slope steep until very steep (Asiki, 2019).

Slope stability analysis is very be required in geotechnical studies to countermeasure the movement of rocks on a slope. Landslides can be studied based on geological and geomorphological mapping data, geotechnical and geodesic studies and geophysical investigations (Zainuri, 2018). Kinematics analysis and Rock Mass Rating are needed to determine the condition of slope stability. Rock slopes have good strength and resistance, but if the rock has a geological structure (fracture) and intense weathering, it will experience instability on the slope (Nani,2022).

The research location is in Pontolo Village, Mananggu Sub-district, Boalemo District there are rock slopes along the road. The slope has a discontinuity area which is a factor causing landslides. Before an avalanche occurs, it is necessary to make efforts to prevent the risk of avalanches that can endanger road users, so that a slope stability analysis is carried out based on the Slope mass rating value. This method is a landslide potential assessment that combines the RMR value and the direction of the fracture orientation so as to produce a better assessment of slope stability.

B. Methodology

1. Research Design

The method used is direct field observation in the form of geomorphology, lithology, structure and slope geometry observations. The scanline method by stretching a meter with a length of 15 meters for each slope segment is used to measure fractures in the form of strike and dip, fracture spacing, fracture aperture, persintence, and observation of fracture conditions in the form of fill, roughness, groundwater conditions and weathering.

2. Instruments

Tools and materials used in this research are geological compass, hammer, meter, loop, laptop for data processing equipped with ArcMap 10.8 and Dips 7.0 applications, topographic maps, and RMR observation tables.

3 . Technique of Data Analysis

The data obtained in the field are in the form of geomorphological data, lithology, geological structures and then processed to obtain geomorphological maps and geological maps of the research area. RMR processing is based on 5 parameters on the slope including rock strength, RQD, fracture spacing, fracture conditions and groundwater conditions (Bieniawski, 1981). The results obtained are the weighting of rock mass classes. To determine the type of landslide that occurs in each slope segment, kinematics analysis is carried out using dips 7.0 software. The data used are strike and fracture dips, slope direction and slope, internal shear angle values obtained from RMR weighting.

The SMR weighting developed by Romana (1985) is determined by the formula SMR = RMR- value (F1x F2x F3) + F4. For F1, F2, F3 obtained from the kinematics analysis adjusted for the type of avalanche, while the value of F4 was obtained from the stripping method. After obtaining the SMR value, it can be seen that the slope is stable and unstable. Unstable slopes will be treated based on the SMR class.

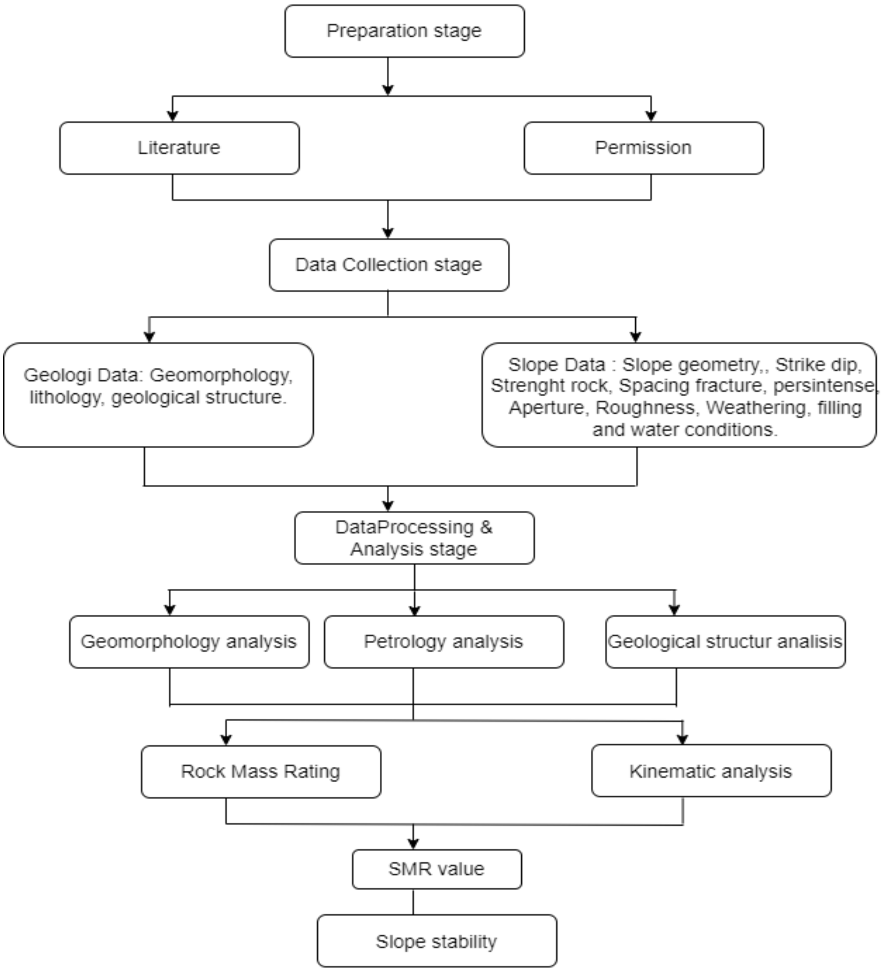

Figure 1. Research Flowchart

C. Findings and Discussion

1. Findings

1.1. Lithology

The lithology of the research area is divided into two units, namely: granodiorite units and porphyry dacite units.

a. Granodiorite unit

This unit consists of granodiorite rocks scattered on the hills. Megascopically, granodiorite has a light gray color and has a faneritic, hypocrystalline, equigranular texture, still composed of quartz, plagioclase, and biotite minerals.

Figure 2. Granodiorite Rock Outcrop at Station St.15

b. Porphyry Dacite Unit

This unit consists of porphyry dacite rocks scattered in the lowlands. Megascopically, dacite porphyry is characterized by greenish-gray color, massive structure, porphyritic granularity, hypocrystalline, inequigranular, and has phenocrysts measuring 2 mm-5 mm.

phenocryst minerals in the form of plagioclase, power and biotite.

Figure 3. Porphyry Dasite Rock Outcrop at Station St.17

1.2. Rock Mass rating (RMR)

a. Segment 1

Segment 1 slope geometry N10°E/73°, composed of granodiorite and andesite contact rock. Granodiorite has the characteristics of gray, brownish black weathered color, massive, has a faneritic texture, hypocrystalline, equigranular, composed of minerals plagioclase, quartz, biotite and orthoclase. While andesite has characteristics of dark gray, massive, aphanitic, hypocrystalline, equigranular. Composed of minerals plagioclase, biotite, horonblend and quartz. The RMR weighting shows a value of 68 which is included in class II with good rock mass (Table 1.)

Table 1. RMR weighting segment 1

No	Parameter		Results	Weight
1	Rock Power		100-250 Mpa	12
2	*Rock Quality Design* (RQD)		92.60%	20
3	Fracture Spacing		0.22	10
4	Fracture Condition	*Persistence (m)*	3-10	2
		Rudeness	*Smooth*	1
		Aperture (mm)	3.16	1
		Filling Material	-	6
		Weathering Rate	Very Weathered	1
5	Water Condition		Dry	15
Amount				68
Rock Class (II): Good				

b. Segment 2

Segment 2 slope geometry N110°E/79°, composed of granodiorite rock. Granodiorite ha characteristics of ligh gray, massive, faneritic texture, hypocrystalline, equigranular, composed of minerals plagioclase, quartz, biotite, and orthoclase. The RMR weighting shows a value of 72 which is included in class II with good rock mass (Table 2.)

Table 2. RMR weighting segment 2

No	Parameter		Results	Weight
1	Rock Power		100-250 Mpa	12
2	*Rock Quality Design* (RQD)		91%	20
3	Fracture Spacing		0.21	10
4	Fracture Condition	*Persistence (m)*	3-10	2
		Rudeness	*Smooth*	1
		Aperture (mm)	3.86	1
		Filling Material	-	6
		Weathering Rate	Slightly Weathered	5
5	Water Condition		Dry	15
Amount				72

Rock Class (II): Good

c. Segment 3

Segment 3 slope geometry N310°E/75°, composed of granodiorite and andesite rock. Granodiorite characteristics of dark gray, massive, faneritic texture, hypocrystalline, equigranular. Composed of the mineral plagioclase, quartz, biotite, and horonblend. Andesite with characteristics of dark gray, massive, aphanitic texture, holocrystalline. Composed of the mineral quartz, horoblend, and biotite. The RMR weighting shows a value of 58 which is included in class III with medium rock mass (Table 3.)

Table 3. RMR weighting segment 3

No	Parameter		Results	Weight
1	Rock Power		50-100 Mpa	7
2	*Rock Quality Design* (RQD)		79.5%	17
3	Fracture Spacing		0.11	8
4	Fracture Condition	*Persistence (m)*	3-10	2
		Rudeness	*Smooth*	1
		Aperture (mm)	2.71	1
		Filling Material	-	6
		Weathering Rate	Very Weathered	1
5	Water Condition		Dry	15
Amount				58
Rock Class (III): Medium				

d. Segment 4

Segment 4 slope geometry N80°E/70°, composed of granodiorite rock. Granodiorite has the characteristics light gray color, masive, phaneritic texture, hypocrystalline, equigranular. Composed of minerals plagioclase, quartz, biotite, and orthoclase. The RMR weighting shows a value of 70 which is included in class II with good rock mass (Table 4.)

Table 4. RMR weighting segment 4

No	Parameter		Results	Weight
1	Rock Power		100-250 Mpa	12
2	*Rock Quality Design* (RQD)		90.49%	20
3	Fracture Spacing		0.19	8
4	Fracture Condition	*Persistence (m)*	3-10	4
		Rudeness	*Smooth*	1
		Aperture (mm)	2.68	1
		Filling Material	-	6
		Weathering Rate	weathered	5
5	Water Condition		Dry	15
Amount				70
Rock Class (II): Good				

1.3. Kinematics analysis

Kinematics analysis was carried out by doing stereographic modeling to determine the types of landslides based on Hoek & Bray (1981) that can occur on slopes and also as data used to determine the value of the *Slope Mass Rating* (SMR). Kinematics analysis uses *strike dip* fracture data, slope geometry in the form of slope direction and slope and internal shear angle.

a. Segment 1

Segment 1 has a slope direction of N10°E with a slope of 73°, based on the results of data processing on *Rocscience Dips* 7.0 the type of landslide that will occur is a toppling landslide that occurs because the direction of the weak plane is opposite to the direction of the slope, (Figure 4.a.) The Intersection line N198 ° E/37 ° with a landslide probability value of 38.62%. Wedge landslide is unlikely to occur where the probability is 7.74% (Figure 4.b.)

a. b.

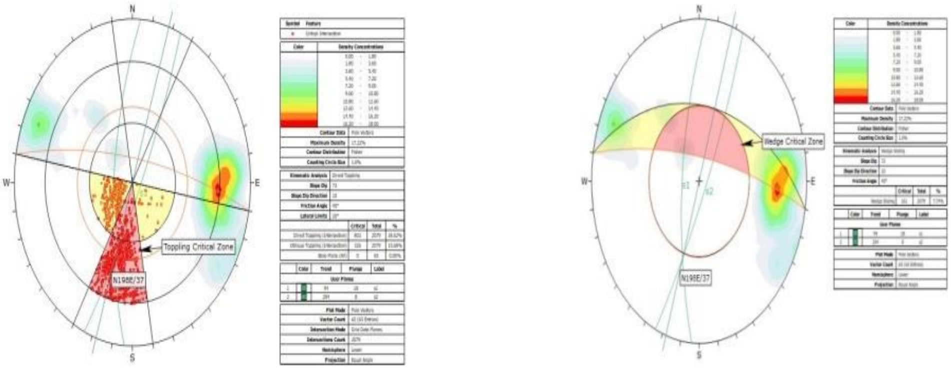

Figure 4. Landslide Segment 1; a. Toppling, b. Wedge

b. Segment 2

Segment 2 has a slope direction of N110°E with a slope of 79°, based on the results of data processing on *Rocscience Dips* 7.0, the type of landslide that will occur is wedge landslide which occurs because the slope is greater than the slope of the intersection line (Figure 5.a.) intersection line N302°E/46°, with a landslide probability of 23.89%. Toppling landslide unlikely to occur where the probability is 21.84% (Figure 5.b.)

a. b.

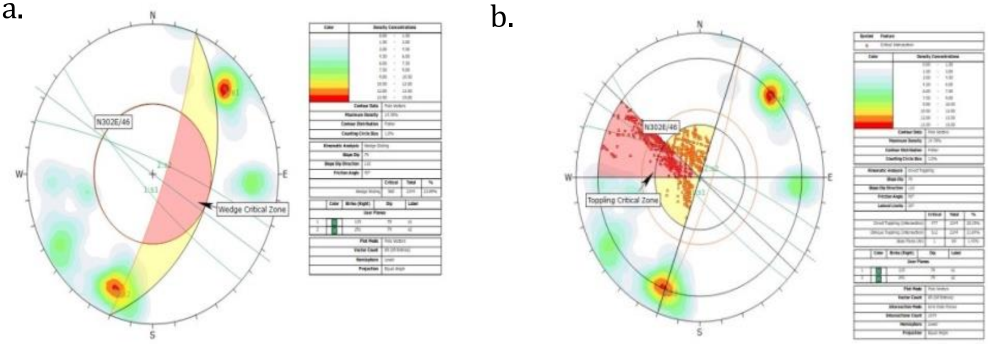

Figure 5. Landslide Segment 2; a. Wedge, b. Toppling

c. Segment 3

Segment 3 has a slope direction of N310°E with a slope of 75°, based on the results of data processing on *Rocscience Dips* 7.0, the type of landslide that will occur is wedge landslide (Figure 6.a.). The wedge lanslide has an intersection line of *N321* °E/66°, the landslide probability value is 36.26%. Topplimh slides are unlikely to occur where the probability is 8.44% with the *Oblique Toppling type.*

a. b.

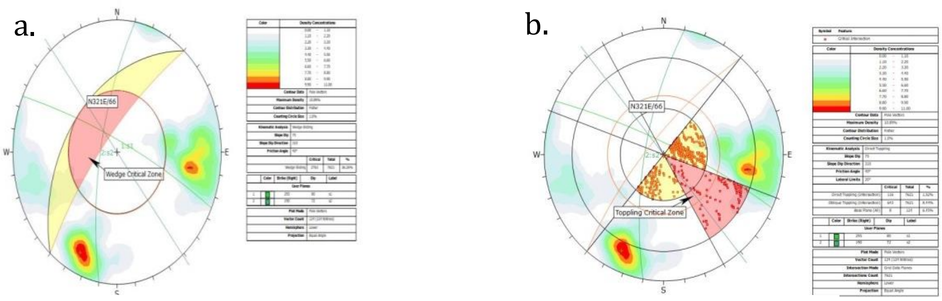

Figure 6. Landslide Segment 3; a. Wedge, b. Toppling

d. Segment 4

Segment 4 has a slope direction of N80°E with a slope of 70°, based on the results of data processing on *Rocscience Dips* 7.0, the type of landslide that will occur is a toppling landslide. The intersection line of N274°E/56° with a landslide probability of 29.82% (Figure 7.)

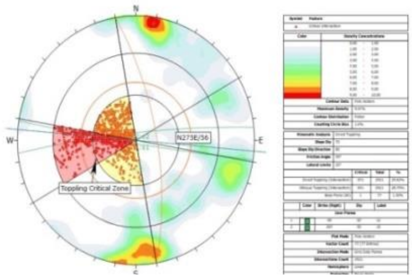

Figure 7. Longsoran Guling segmen 4

1.4. Slope Mass Rating (SMR)

The calculation of the SMR value is determined based on the intersection of the two discontinuity plane lines (*Intersection)* in the kinematics analysis to get the discontinuity strike value (αj) and discontinuity dip (βj), and perform calculations F1, F2, and F3. SMR calculation results (Romana, 1985) in each segment The calculation results of segment 1 SMR value obtained a value of 77.9 is in class II or stable (60-80). SMR class II has a landslide probability of 0.2 or 20% with the possibility of landslides in the form of rock blocks. Segment 2, the results of the SMR calculation, obtained a value of 78 which was in class II or stable (60-80). SMR class II has an landslide probability of 0.2 or 20% with the possibility of landslides in the form of rock blocks. Segment 3 results from the calculation of the wedge slide SMR obtained a value of 33 is in class IV or unstable (20-40). SMR class IV has an landslide probability of 0.6 or 60% and a large wedge probability landslide. Segment 4, the results of the SMR calculation of toppling, obtained a value of 67.5 which is in class II or stable (60-80). SMR class II has an landslide probability of 0.2 or 20%.

2. Discussion

Based on the RMR weighting for each segment, the rocks that make up the slopes have good rock mass quality in segment 1, segment 2 and segment 4, while segment 3 has moderate rock mass quality. The results of the stereographic analysis of each segment indicate the possibility of landslides in the form of wedges and rolls with avalanche directions of Southwest – Northeast and Northwest – Southeast.

Slope stability is determined based on the SMR value, the SMR results in segment 1 have a value of 77.9, segment 2 has a value of 78, segment 3 has a value of 33, and segment 4 has a value of 67.5. Based on the SMR value of each segment, the slopes are categorized as stable and unstable, where segment 3 has unstable slopes. The influence of the unstable slope in segment 3 is influenced by the condition of the rock mass based on the RMR value that is included in the fair rock. Several geological observations were made in the form of lithological observations and fracture observations consisting of fracture spacing, fracture conditions and groundwater conditions.

Judging from the lithology of segment 3, it is in the form of contacts between granodiorite and andesite rocks which have many fractures in rock outcrops. The number of fractures greatly affects the rock from the RQD value and fracture spacing. Fracture spacing affects rock quality where the closer the fracture spacing is, the lower the fracture spacing value. This is because the many fractures contained in the rock can trigger weathering which can cause the slope to become unstable.

Unstable slopes need to do Slope reinforcement is based on the SMR value according to its class. Slope reinforcement is a building that serves to stabilize rock conditions which are generally installed in unstable cliff areas. Segment 3 is in the class IVa category, so the types of slope reinforcement are steel cable anchors (anchors), systematic spray concrete (Systematic Shotcrete), retaining concrete walls and excavation, drainage.

D. Conclusion

The rock mass quality value in segment 1 is 68 with rock mass class II (Good Rock), segment 2 has a value of 72 with rock mass class II (Very Rock), segment 3 has a value of 58 with rock mass class III (Fair Rock), segment 4 has a value of 70 with rock mass class II (Good Rock). Types of landslides that may occur in each segment are wedge landslide and toppling landslide. Recommendations slope reinforcement based on the Slope Mass Rating (SMR) value are carried out in segment 3 where the SMR value of 33 falls into class IV (unstable). Segment 3 has unstable slope conditions because seen from the quality of the rock mass segment 3 enters into moderate rock (fair rock) so it is necessary to do slope reinforcement in the form of anchors with a combination shorcrete. While segment 1 SMR value of 77.9, segment 2 SMR value of 78, and segment 4 SMR value of 67.5 did not do slope reinforcement because the SMR value ranged from 67-78 which entered into a stable slope.

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