POTENTIAL COLLAPSE BASED ON DISCONTINUITY PLANE IN THE ANDESITE QUARY OF MOUNT GEULIS, JATINANGOR DISTRICT, SUMEDANG REGENCY, WEST JAVA

Mochamad Muslim Taufiq[1], Irvan Sophian[2], Nur Khoirullah[2], Zulfialdi Zakaria[2]
[1]Faculty of Engineering Geology, Padjadjaran University
[2]Department ofx Applied Geology, Padjadjaran University
Corresponding author: muslimtaufiq17@gmail.com

ABSTRACT

Landslides are natural disasters that often occur in West Java, in 2020 landslides have occurred 852 times. In an effort to prevent the occurrence of rock landslides, it is necessary to study the stability of rock slopes, so it is necessary to evaluate the discontinuity of the rock and take engineering geological. The purpose of this study is to analyze the stability of rock slopes in the study area so that the types of landslides that can occur can be known. Method used is Kinematic Analysis where the object of research is an andesite outcrop located at the northwest foot of Mount Geulis, Cinanjung Village, Jatinangor District. Kinematic analysis is an analysis of the movement of objects without considering the forces that cause them. Various types of slope failure are associated with geological structures that result in a discontinuity plane in the rock body. The results of the study are in the form of determining the potential for landslides that can occur in the research area. Based on the kinematic analysis of the types of failure in the research area that can occur are wedge types in the MT-2, MT-5, and MT-6 segments and toppling types in the MT-3, MT-4, MT-7 segments and Planar failure found in the MT - 1 segment. The potential failures in the study area are toppling and wedge with percentage values for the possibility of landslides were obtained, namely: wedge failure is 1.82% - 3.91% and toppling failure is 21.82% - 38.95% and Planar failure is 55.81%

Keyword: Kinematic Analysis, Discontinuity, Andesite.

INTRODUCTION

Landslides are natural disasters that often occur, according to Anonymous (2020), which states that 852 landslides have occurred in West Java throughout 2020. Some of them have claimed lives. most areas in West Java, most likely experiencing landslide. One of them is the Sumedang Regency area, precisely in the Gunung Geulis area, Jatinangor District. (Anonymous, 2020). The occurrence of landslides is due to an imbalance of forces acting on the slopes, namely the retaining force and the sliding force caused by an external force that causes the sliding force to be greater than the retaining force (Naryanto et al., 2019).

In an effort to prevent the occurrence of soil/rock landslides, it is necessary to study the stability of soil/rock slopes, therefore the potential problems of slope stability are important (Lollong et al., 2019). According to Rusydy (2017), The rocks stability can be seen by evaluating the discontinuity of an outcrop rocks, hence the need to collect engineering geological data. This data will be a reference in calculating the slope stability value so that failure can be avoided. Rock collapse starts from rock discontinuities, bedding planes, faults and types of joint in rock.

The research location is in the Mount Geulis area which is administratively within the Cunanjung Village, Jatinangor District, Sumedang Regency, West Java. Geographically, the research area is at the coordinates of 107°47'56.48"E 6°55'18.32"S. The height of the research area is about 1000 masl.

E-ISSN : 2579 – 3136

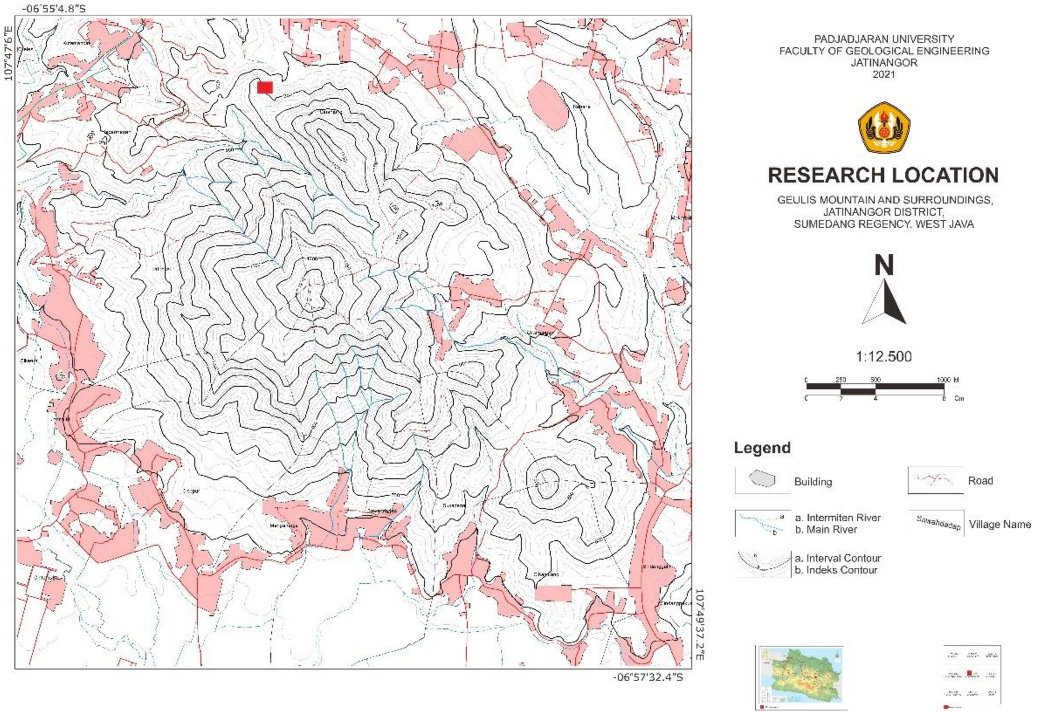

Figure 1. Research Location

RESEARCH METHOD

The method used in this research is the collection of primary and secondary data. Primary data collection was carried out by observing andesite outcrops located at the northwest foot of Mount Geulis, Cinanjung Village, Jatinangor District, namely in the form of lithology types, joint measurements & slope measurements of the outcrop. Meanwhile, secondary data collection is in the form of material properties on rocks. The results from primary and secondary data are combined to analyze kinematics by processing strike/dip data using the Dips 6.0 software so that the percentage of landslide types that may occur in each segment is known. In this kinematic analysis the internal friction angle parameter was also added. It was obtained from the Roc-lab simulation results, and the slope data measured during field observations. This analysis aims to determine the potential types of *wedge* failure, plane failure, or toppling failure.

Discontinuity data retrieval is done by mapping the discontinuity plane with the method *scanline,* so that 7 observation segments are obtained with segment codes: MT – 1, MT – 2, MT – 3, MT – 4, MT – 5, MT – 6, MT – 7.

a. Geological Conditions of the Study Area

Based on the regional geological map sheet Bandung (Silitonga, 1973) the research area is located in the Qyl formation (quarter young lava). This unit is a young lava flow, originating from Mount Tangkubanparahu and Mount Tampomas. This lava is generally basalt and contains many gas holes.

E-ISSN : 2579 – 3136

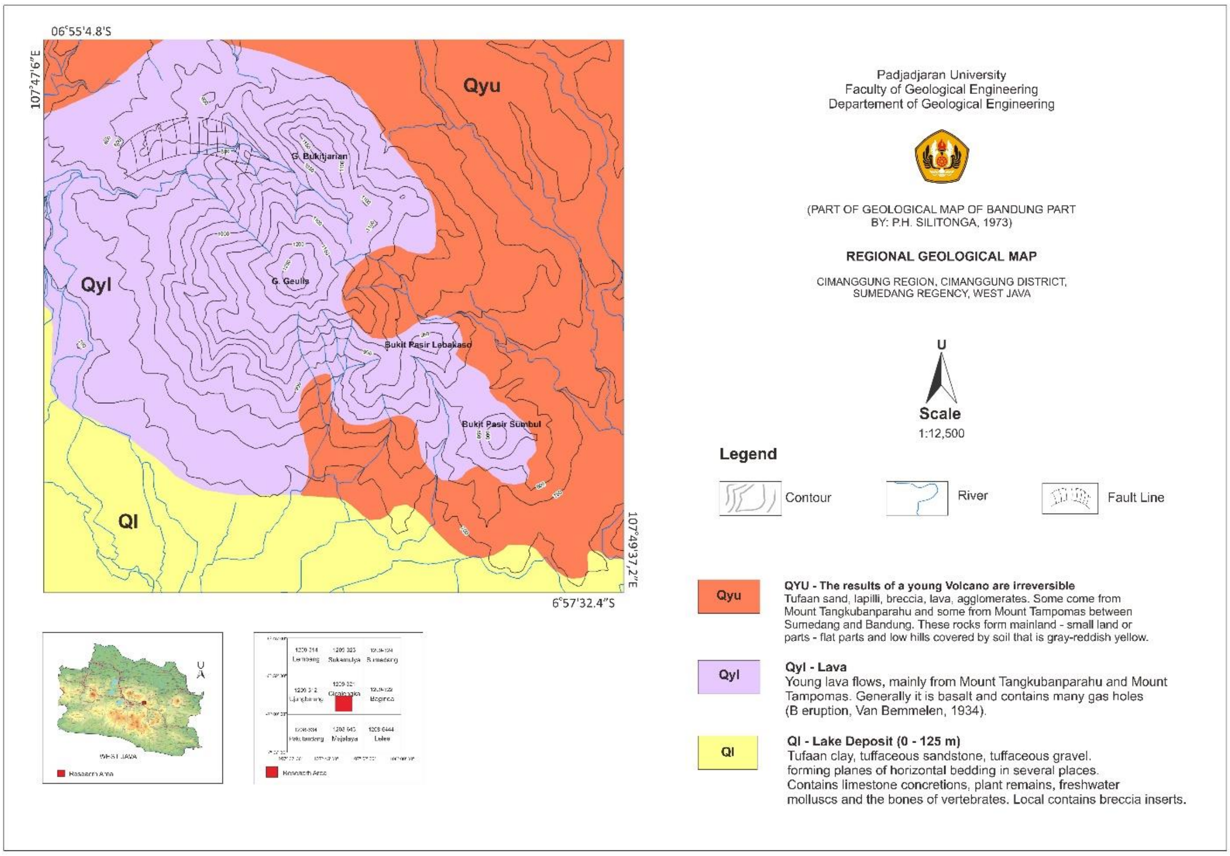

Figure 2. Regional Geological Map

b. Internal Friction Angle

Internal friction angle is the angle formed from the relationship between the normal stress and the shear stress in a soil or rock material. This angle is formed by the collapse boundary line (failure envelope) with a horizontal axis (normal voltage) (Elvina, 2019)

c. Kinematic Analysis

Kinematic analysis is an analysis of the movement of objects without considering the forces that cause them. Various types of slope failure are associated with geological structures that result in a discontinuity plane in the rock body. According to Wibowo (2018), kinematic analysis aims to determine the type and direction of landslides that may occur on slopes based on the condition of their geological structure. This analysis was developed by Goodman, (1995). This analysis refers to the consideration of the formation of a rock block resulting from the existence of several intersections in the discontinuity plane, as well as identifying critical blocks. This critical rock block is called the key block. This theory assumes that tensile joints at the surface of the slope should be neglected.

Based on Wyllie & Mah, (2017), the type of block failure can be identified by stereographic identification. The following are some types of landslides that are often found in rocks:

1. Plane Failure

Plane failures are usually rare, but if there are conditions that make it possible for this type of landslide to occur, it will be larger (by volume) than other types of failure. Therefore, a study of plane failure is very necessary, so that we can overcome them so as to minimize losses when this type of this failure occurs. The following are the characteristics of the planar failure type with 2- dimensional analysis: the slip plane has a strike that is parallel or almost parallel (maximum 20°) with the strike of the slope, has value dip of rock smaller than the slope dip, traces the bottom of the discontinuity plane that becomes the plane. the slope of the slip plane is greater than the internal friction angle, there is a release plane that becomes a barrier at each sliding block boundary.

E-ISSN : 2579 – 3136

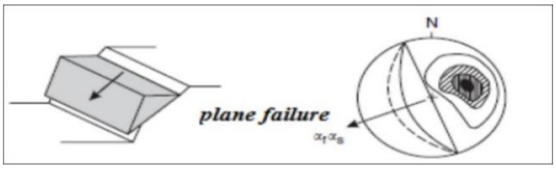

Figure 3. Modeling of Plane Failure

2. Wedge Failure

A wedge type failure occurs when two or more discontinuity areas intersect in such a way that they form a wedge against the slope. The following will discuss the characteristics of the wedge type of landslide: there is a line of intersection of the two discontinuity planes through the slope surface, the direction of the trend line of the two discontinuity planes approaches the slope of the slope, the slope angle is greater than the angle of the line of intersection of the two discontinuity planes, plunges from the line of intersection the two discontinuity planes are greater than the internal shear angle.

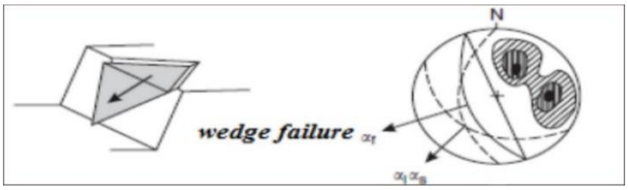

Figure 4. Modeling of Wedge Failure

3. Toppling Failure

Type of toppling failure usually occurs on steep slopes and hard rock with a column-shaped weak plane structure. Overturning avalanches will occur if the weak areas on the slope are generally the opposite slope to the slope (Hoek et al., 1981). The following are conditions that can cause overturning type failure: there are moves from the discontinuity plane in the form of parallel or close to parallel with the slope surface stance (the maximum direction difference is 20º), there is a similarity in the slope angle of the discontinuity plane with the slope of the slope surface, the plunge value of the slip plane is less than the slope of the surface of the slope minus the internal shear angle of the slip plane.

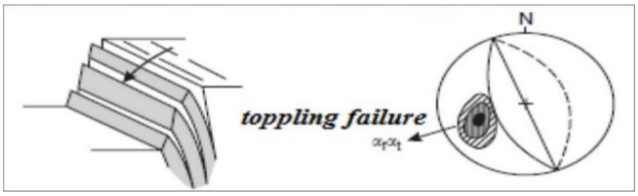

Figure 5. Modeling of Toppling Failure

RESULTS AND DISCUSSION

Lithological Characteristics of Rocks

a. Lithological Characteristics of the MT – 1 Segment

Figure 6. Outcrop photo of MT - 1 Segment

Based on megascopic observations, the rocks in this segment have a fresh gray-black color and weathered brownish color, mesocratic color index, have aphanitic granularity, have a massive structure, with a mafic mineral composition of 30% - 90%. This rock is composed of 70% plagioclase minerals, 5% k-feldspar, 18% amphibole and 8% opaque minerals, which means that the rocks in the MT – 1 segment is andesitic rock (Streckeisen, 1976)

b. Lithological characteristics of the MT – 2 segment

Figure 7. Outcrop photo of MT - 2 Segment

Based on megascopic observations, the rock in this segment has a fresh dark gray color and weathered brownish gray color, mesocratic color index, has aphanitic granularity, has a massive structure, with a mafic mineral composition of 30 - 90 %. This rock is composed of 65% plagioclase minerals, 15% k-feldspar, 15% amphibole, and 5% opaque minerals, which means that the rocks in the MT – 2 segment is andesitic rock (Streckeisen, 1976)

E-ISSN : 2579 – 3136

c. Lithological characteristics in the MT – 3 segment

Figure 8. Outcrop Photo of MT - 3 Segment

Based on megascopic observations, rocks in this segment have a fresh gray color and weathered dark gray color, a mesocratic color index, have an aphanitic granularity, have a massive structure, with a mafic mineral composition of 30 - 90%. This rock is composed of 80% plagioclase minerals, 10% k-feldspar, 5% amphibole, and 5% opaque minerals, which means that the rocks in the MT – 3 segment is andesitic rock (Streckeisen, 1976).

d. Lithological characteristics in the MT – 4 segment

Figure 9. Outcrop Photo of MT - 4 Segment

Based on megascopic observations, the rocks in this segment have a fresh color of light gray and weathered color of blackish gray, mesocratic color index, have aphanitic granularity, have a massive structure, with a mafic mineral composition of 30 - 90 %. This rock is composed of 78% plagioclase minerals, 10% k-feldsfar, 7% amphibole, and 5% opaque minerals, which means the rocks in the MT – 4 segment is andesitic rock (Streckeisen, 1976).

e. Lithological characteristics in the MT – 5 segment

Figure 10. Outcrop Photo of MT - 5 Segment

Based on megascopic observations, the rocks in this segment have a fresh color of blackish gray and weathered color of brownish gray, mesocratic color index, have aphanitic granularity, have a massive structure, with a mafic mineral composition of 30 - 90 %. This rock is composed of 77% plagioclase minerals, 10% k-feldspar, 8% amphibole, and 5% opaque minerals, which means the rocks in the MT – 5 segment is andesitic rock (Streckeisen, 1976)

f. Lithological characteristics of the MT – 6 segment

Figure 11. Outcrop Photo of MT - 6 segment

Based on megascopic observations, the rock in this segment has a fresh dark gray color and weathered brownish gray color, mesocratic color index, has aphanitic granularity, has a massive structure, with a mafic mineral composition of 30 - 90 %. This rock is composed of 74% plagioclase minerals, 13% k-feldsfar, 8% amphibole, and 12% opaque minerals, which means that the rocks in the MT-6 segment is andesitic rock (Streckeisen, 1976).

g. Lithological characteristics of the MT – 7 segment

E-ISSN : 2579 – 3136

Figure 12. Outcrop of MT - 7 Segment

Based on megascopic observations, the rocks in this segment have a fresh color of light gray and weathered color of blackish gray, mesocratic color index, have aphanitic granularity, have a massive structure, with a mafic mineral composition of 30 - 90 %. This rock is composed of 63% plagioclase minerals, 10% k-feldspar, 12% amphibole, and 5% opaque minerals, which means that the rocks in the MT-7 segment is andesitic rock (Streckeisen, 1976).

SLOPE AND INTERNAL FRICTION ANGLE

The slope angle value is obtained from the results of field measurements in each segment using a geological compass.

Figure 13. Slope Data Analysis

Then the value of the slope is obtained as follows.

Table 1. Slope data

Segment Code	Slope(°)
MT – 1	78°
MT – 2	58°
MT – 3	81°
MT – 4	63°
MT – 5	85°
MT - 6	60°
MT - 7	86°

The value of the internal friction angle is obtained from a simulation using Roc-lab software by entering lithological data and the value of the compressive strength of rocks in each segment. Then the value of the internal shear angle in each segment is obtained as follows.

Table 2. Internal Friction Angle Data

Segment Code	Internal Friction Angle (φ)
MT – 1	56°
MT – 2	61°
MT – 3	58°
MT – 4	58°
MT – 5	60°
MT - 6	60°
MT - 7	59°

KINEMATIC ANALYSIS

In this analysis, parameters such as strike/dip slope, internal friction angle, and lateral limit are also input. The value of the internal shear angle is obtained from the Roc-lab simulation, the lateral limit value in the toppling landslide is the same as in the plane slide based on empirical observations by determining the lateral area of the Primary Critical Zone with the slope direction by (Goodman 1980, Hudson and Harrison 1997), where the value range lateral suggested limit of 20º-30º.

A. Kinematic Analysis of the MT-1 Segment

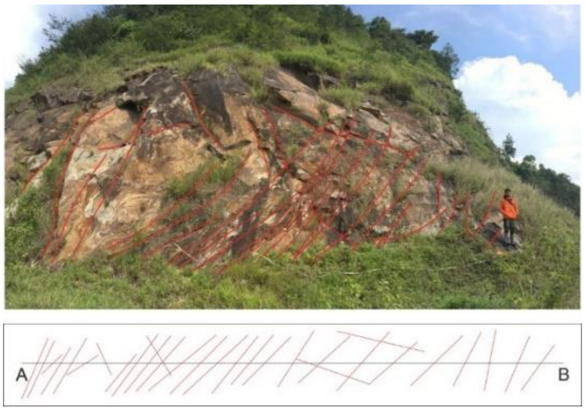

Figure 14. Outcrop Photo of the MT - 1 Segment

Based on the results of the stereonet projection, it shows that there is a pole peak of the measured joint. From the top of the pole, it can be seen the strike/dip value by adding a plane to the peak of the pole, so that the plane from the pole is obtained with a strike/dip value of N36º E/65º, From this plane, as known as that there is a joint set that has a relative direction to the same, so that there is no intersection of the discontinuity planes. This segment also has a rock dip value that is smaller than the slope value, and the joint set has a direction that is relatively the same as the face angle. Therefore, it can be interpreted that the MT-1 segment has a potential Planar failure. Then based on a simulation using Dips 6.0 software, by adding parameters such as the lateral limit value, the internal friction angle value of 56o, and the slope angle of 78º. So, the percentage value of the possibility of failure is 55.81%.

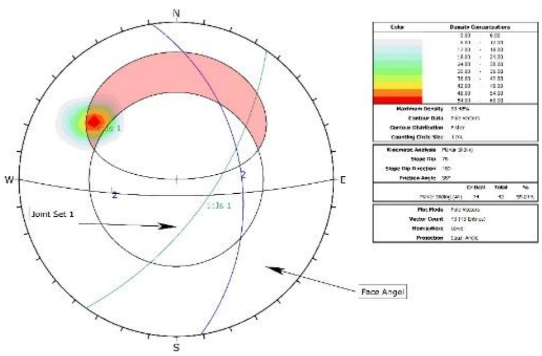

Figure 15. Kinematic Analysis on Segment MT – 1

B. Kinematic Analysis of the MT-2 Segment

Figure 16. Outcrop Photo of the MT- 2 Segment

Based on the results of the stereonet projection, it shows that there are two pole peaks of the measured joint. From the top of the pole, the strike/dip value can be known by adding a plane to the top of the pole, so that it can be seen that the strike/dip value of the first plane is N278º E/69º and from the second plane is N307ºE/29º, from these two planes it can be seen that there are two sets of joints that intersect each other. The two lines of intersection of the discontinuity planes penetrate the slope surface, have the direction of the line of intersection relatively close to the slope, and the slope angle value is greater than the angle line of intersection. Therefore, it can be interpreted that the MT-2 segment has a potential type of Wedge failure. Then based on a simulation using Dips 6.0 software, by adding parameters such as the lateral limit value, the internal friction angle value of 61º, and the slope angle of 58º. So, the percentage value of the possibility of landslides is 1.82%.

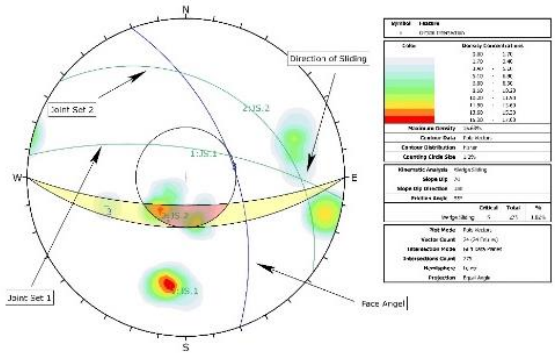

Figure 17. Kinematics Analysis on Segment MT - 2

C. Kinematic Analysis of the MT - 3 Segment

E-ISSN : 2579 – 3136

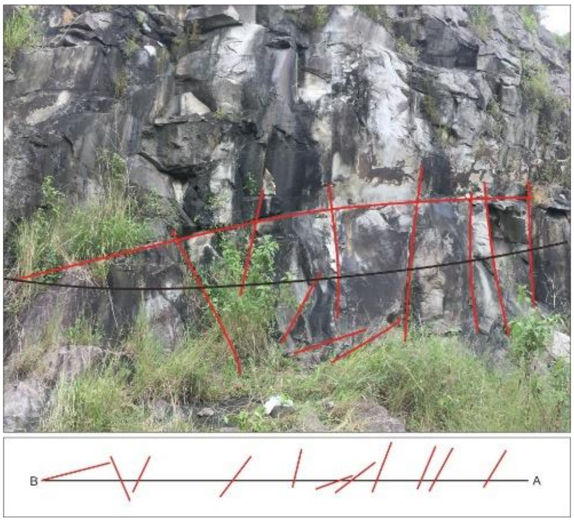

Figure 18. Outcrop Photos of the MT - 3 Segment

Based on the results of the stereonet projection, there are two peaks as a joints pole result of the projection of the measured. From the top of the pole, the strike/dip value can be known by adding a plane to the peak of the pole, so that the strike/dip value of the first plane is N143°E/73° and from the second plane is N168°E/86°. From the strike/dip plane, we can see that there are two sets of intersecting joints. Has the direction of the intersection of the line of intersection opposite to the direction of the face angle and has a slope angle that is relatively the same as the slope of the discontinuity plane. Therefore, it can be interpreted that the MT-3 segment has the potential for the type of Toppling failure. Then based on the simulation using Dips 6.0 software, by adding such as the lateral limit value, the internal friction angle value of 58°, and the slope angle of 81°. So, the percentage value of the possibility of landslides is 21.82%.

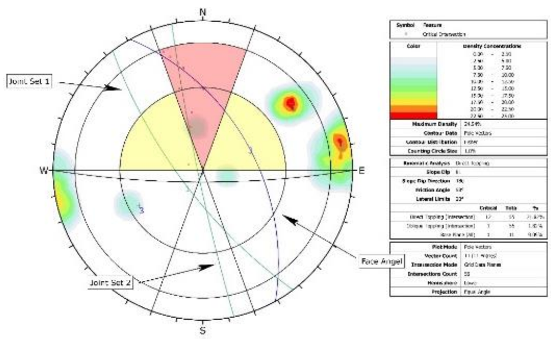

Figure 19. Kinematics Analysis on Segment MT - 3

D. Kinematic Analysis of the MT-4 Segment

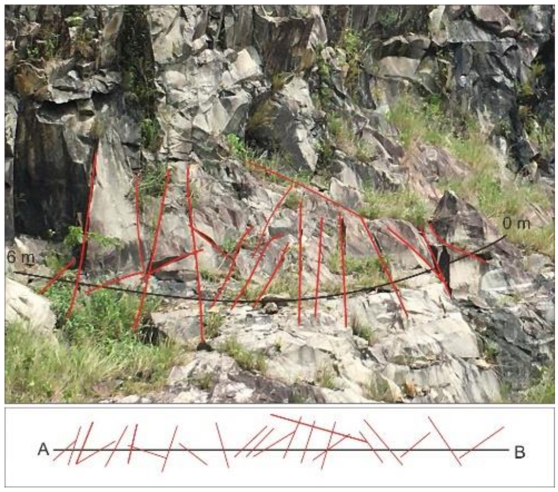

Figure 20. Outcrop Photo of the MT-4 Segment

Based on the results of the stereonet projection there are two peaks' joints pole of the measured. From the top of the pole, it can be known the strike/dip value by adding a plane to the peak of the pole, so that the plane from the pole is obtained with the strike/dip value of the first plane, namely N144°E/84° and the second plane is N182°E/81°. From these two planes we can see that there are two sets of intersecting joints. Has the direction of the line of intersection opposite to the direction of the face angle. Therefore, it can be interpreted that the MT- 4 cement has the potential for type of toppling failure. Then based on the simulation using the Dips 6.0 software, by adding such as the lateral limit value, the internal friction angle value of 58°, and the slope angle of 63°. So, the percentage value of the possibility of landslides is 38.95%.

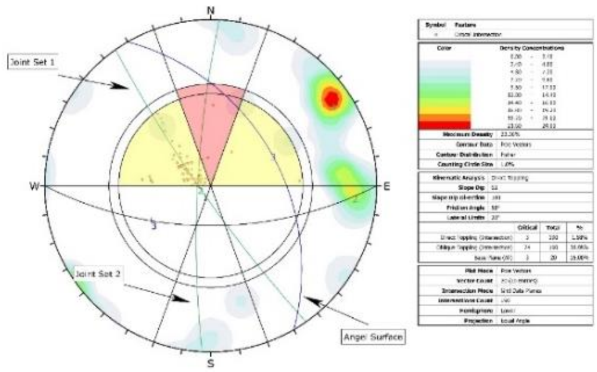

Figure 21. Kinematic Analysis on Segment MT - 4

E. Kinematic Analysis of MT – 5

E-ISSN : 2579 – 3136

Figure 22. Outcrop Photos of the MT-5 Segment

Based on the results of the stereonet projection there are two pole peaks of the measured joints. From the top of the pole, the strike/dip value can be known by adding a plane to the top of the pole, so that the strike/dip value of the first field is N341ºE/70º and the second plane is N249ºE/81º. From these two planes we can see that there are two sets of intersecting joints. Having two lines of intersection of discontinuity planes that penetrate the slope surface, there is a direction from the line of intersection to the slope of the slope, the plunge from the line of intersection has a greater value than the internal friction angle. Therefore, it can be interpreted that the MT-5 segment has a potential type is Wedge failure. Then based on a simulation using Dips 6.0 software, by adding parameters such as the lateral limit value, the internal friction angle value of 60º, and the slope angle of 85º. So, the percentage value of the possibility of landslides is 3.91%.

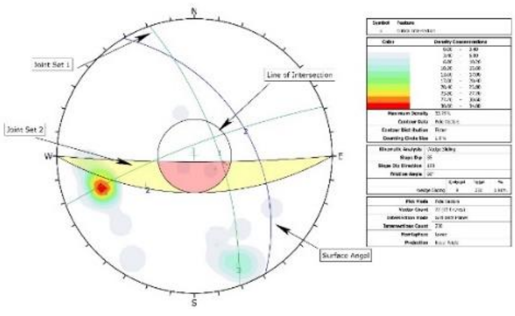

Figure 23. Kinematic Analysis on Segment MT - 5

F. Kinematic Analysis of the MT – 6

Figure 24. Photos of the MT - 6 Segment

Based on the results of the stereonet projection, there are two peaks joint pole from the measured projection. From the peak of the pole, the strike/dip value can be determined by adding a plane to the peak of the pole, so that the strike/dip value of plane the first is N340ºE/72º and the second plane is N248ºE/84º. From these two planes we can see that there are two sets of intersecting joints. The two lines of intersection of the discontinuity planes penetrate the slope surface, have the direction of the line of intersection approaching the slope of the slope, and the value of the plunge line of intersection is greater than the internal friction angle. Therefore, it can be interpreted that the MT-6 segment has a potential type of Wedge failure. Then based on a simulation using Dips 6.0 software, by adding such as the lateral limit value, the internal friction angle value of 60º, and the slope angle of 55º. So, the percentage value of the possibility of failure is 11.76%.

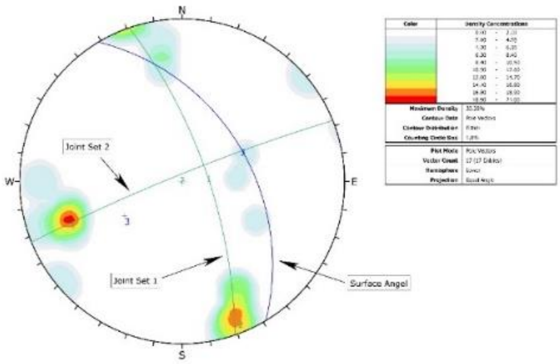

Figure 25. Kinematic Analysis on Segment MT - 6

G. Kinematic Analysis of the MT - 7 Segment

E-ISSN : 2579 – 3136

Figure 26. Outcrop Photos of the MT-7 Segment

Based on the stereonet projection there are two pole peaks from the measured joint projection. From the top of the pole, the strike/dip value can be known by adding a plane to the top of the pole, so that the strike/dip value of the first field is N133ºE/21º and from the second plane is N82ºE/17º. From these two planes we can see that there are two sets of intersecting joints. Has the direction of the line of intersection opposite to the direction of the face angle. Therefore, it can be interpreted that the type of landslide that may occur in the MT-7 segment is the type of Toppling failure. Then based on a simulation using Dips 6.0 software, by adding such as the lateral limit value, the internal friction angle value of 59º, and the slope angle of 86º. So, the percentage value of the possibility of landslides is 34.85%.

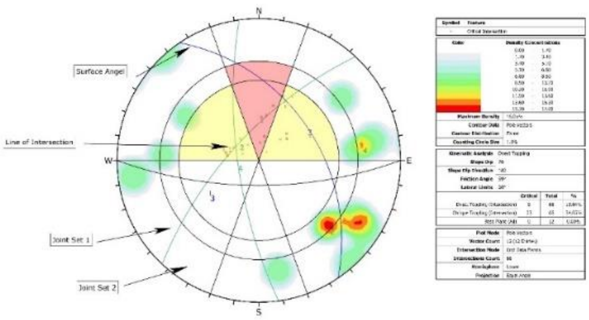

Figure 27. Kinematic Analysis on the MT - 7 Segment

From the results of data processing that has been carried out, it can be seen that there are three types of failure that can occur in the study area, namely planar failure, wedging failure, and toppling failure. This is due to the difference in the intensity of the discontinuity field in each segment. In addition, the study area has a different failure percentage value for each type of landslide. This is due to the difference in the value of the internal friction angle.

CONCLUSION

Based on the results of the research that has been carried out, the conclusions are: The lithology in the research area is andesite igneous rock. Based on the kinematic analysis of the types of failure in the research area that can occur are wedge types in the MT-2, MT-5, and MT-6 segments and toppling types in the MT-3, MT-4, MT-7 segments and Planar failure found in the MT - 1 segment. Based on the simulation carried out using the dips software, the percentage values for the possibility of failure were obtained, namely: wedge failure is 1.82% - 3.91%, toppling failure is 21.82% - 38.95% and planar landslide failure is 55.81%.

ACKNOWLEDGMENTS

Thank you to the Geotechnical Laboratory and all those who have assisted in this research activity, as well as lecturers of the Geological Engineering Study Program, Padjadjaran University.

REFERENCES

Elvina, G., Sophian, I., & Zakaria, Z. (2019). Korelasi Parameter Kuat Geser Tanah terhadap Nilai N-SPT pada Kawasan Pendidikan Universitas Padjadjaran , Jatinangor. *Padjadjaran Geoscience Journal*, 86–94.

Goodman, R. E. (1995). Block theory and its application. *35th U.S. Symposium on Rock Mechanics, USRMS 1995*, *3*, 3–15. https://doi.org/10.1016/0148-9062(96)84007-1

Hoek, E., Carranza, C., & Corkum, B. (1981). Hoek-brown failure criterion – 2002 edition. *Narms-Tac*.

Streckeisen, A. (1976). To each plutonic rock its proper name. *Earth Science Reviews*, *12*(1). https://doi.org/10.1016/0012-8252(76)90052-0

Wibowo, S., Rinaldi, M., Azzam, M. A., Zakaria, Z., & Sophian, I. (2018). *d*. 364–375.

Wyllie, D. C., & Mah, C. W. (2017). Rock slope engineering: Civil and mining, 4th edition. In *Rock Slope Engineering: Fourth Edition*. https://doi.org/10.1201/9781315274980

E-ISSN : 2579 – 3136