ANALYSIS OF ROCK QUALITY AND LANDSLIDE POTENTIAL IN NORTH JERING HILLS, SLEMAN, YOGYAKARTA

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Abstract *— The purpose of the research was to identify the type and direction of potential landslides and assess the quality of rocks on the slopes of North Jering hills. The data was collected using the scanline method, measuring the plane of failure. The collected data includes the direction, slope level, and condition of the plane of failure, according to the parameters in the RMR table (Bieniawski, 1989). The slope was analyzed kinematically using stereographic projection, and the quality of the rock mass was analyzed based on the weighting results of RMR parameters. The results of the slope's kinematic analysis indicate the potential for a planar avalanche. The RMR value at the research site is 80, which falls under the good rock category. Recommendations for slope strengthening include the use of rockbolt geotechnical engineering with shortcrete or retaining walls.*

Keywords*: Planar, RMR, Rock, Slope*

I. INTRODUCTION

The demand for housing is significant enough to create competition among housing development companies to acquire new land for residential purposes. However, issues arise when these companies expand into hillside areas, such as the Jering hills in the Godean District of Sleman Regency, which is the focus of this research. Areas with significant differences in elevation require supervision and clear rules for housing development companies when cutting slopes in hilly areas. Slope stability analysis is one solution to ensure safe and effective hill cutting methods. The purpose of this research is to analyze the slope on Jering hill by knowing the potential and type of mass movement in the area, because around the slope of Jering hill will be built a housing complex.

In previous research, Setiawan (2020) discussed the study to obtain a detailed geological study of the residential area to be developed and a slope stability study which will later be used as a housing pilot project integrated with geological tourism[1]. In this research, it is only limited to knowing the stability of the slope and focusing on geological tourism. The research has not provided an explanation of the solution to overcome the potential for mass movements in the area. In addition, the author wants to apply the kinematic method used by previous researchers to the author's research area in Jering Hills.

The method to be used is kinematic analysis. This analysis aims to determine the potential type and direction of future landslides[2]. The influence of geological structures such as kinks, faults, and folds is significant in this analysis, requiring careful examination. The results of this analysis will determine whether the slope is safe or not. Using this method, future landslides can be identified based on safety assessments. Bieniawski (1989) developed the Rock Mass Rating (RMR) system, a widely used method for assessing rock quality based on specific parameters outlined in the Bieniawski 1989 RMR table[3].

Geotechnical data was collected at the research site using the scanline method to effectively record and describe fracture data on a slope outcrop[4]. The slope analyzed in this study is an igneous slope located in the North Jering Hills behind a housing estate that is currently under construction. During the slope clearing process, a landslide event occurred. The researcher employed two methods, kinematic analysis and rock mass classification analysis, to analyze the slope condition in the study area.

A. Geological Setting

The research site is located in the North Jering Hills of Godean, Sleman, Yogyakarta. This hill is being cleared for a new housing development. Stratigraphically, the research site is located in the Kulon Progo Mountains stratigraphic unit. In this stratigraphy, the oldest formation is known as the Nanggulan

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Formation, which was later intruded and covered by the old andesitic formation, then the Jonggrangan Formation and the Sentolo Formation were deposited above it in a misaligned manner, where the two ages are the same but different facies according to Van Bemmmelen (1949)[5]. Furthermore, the uppermost is covered by Quaternary volcanic deposits (Figure 1).

a. Nanggulan Formation

According to Bemmelen (1949), explains that the oldest formation exposed in Kulonprogo is the Nanggulan Formation with its depositional environment is littoral[5]. The Nanggulan Formation is composed of lignite sandstone, claystone with limonite concretion, marl, sandstone and tuff.

b. Old Andesit Formation

This formation is composed of andesitic breccias, tuffs, lapilli tuffs, agglomerates and andesitic lava flows. The Old Andesite Formation is unconformably overlain by the Nanggulan Formation up to 500 meters thick. These rocks are derived from the volcanic activity of ancient volcanoes in the area, so Van Bemmelen (1949) called it the Old Andesite Volcano[5]. This formation is of Oligocene age.

c. Jonggrangan Formation

This formation is composed of conglomerate overlain by tuffaceous marl and sandstone with lignite intercalations. The formation gradually changes into coral limestone. The thickness of this formation is about 250 meters with middle Miocene age. This formation is found at an altitude of 700 meters above sea level, so it is known as Jonggrangan Plato.

d. Sentolo Formation

This formation is composed of agglomerate and marl in the lower part, which gradually becomes laminated limestone. Coral limestones occur locally. The age of this formation ranges from Early Miocene to Pliocene with a thickness of about 950 m.

e. Quaternary Volcanic Formation

This formation was deposited on top of all the older formations. These Quaternary volcanic deposits were produced by the eruption of Mount Merapi, which is composed of tuff, lapilli, breccia, agglomerate and andesite lava, the age of these Quaternary volcanic deposits is Pleistocene and has a thickness of 50 meters. Alluvial deposits consist of loose, uncompacted material, fine sand in size, the result of weathering and erosion of older rock units.

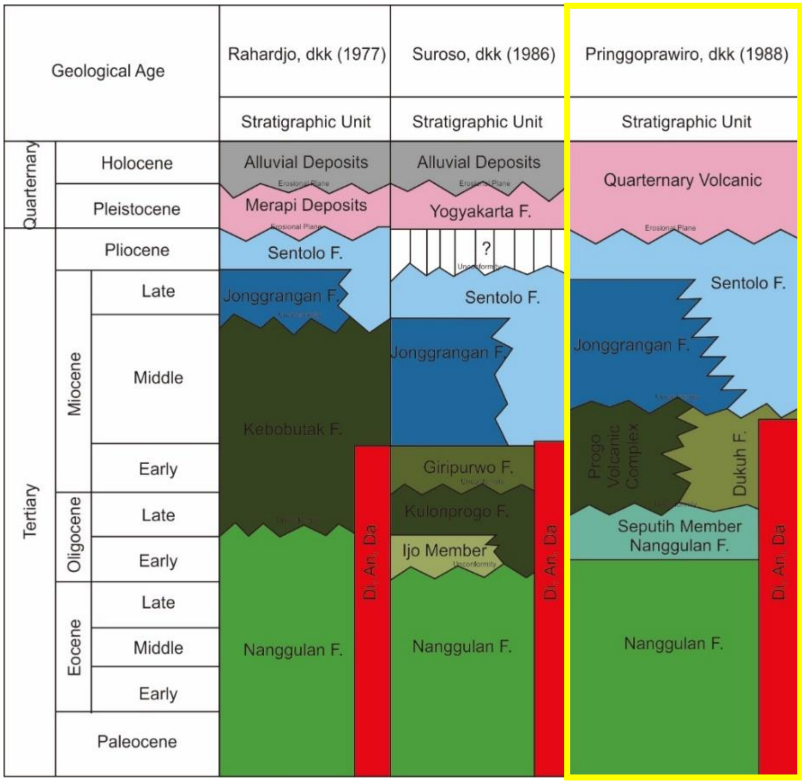

Figure 1 Stratigraphic comparability column of the Kulon Progo Mountains[6]

II. METHODS

During the data collection process, the author utilized tools such as a compass, meter, and geological hammer. The author first identified the lithology to determine the slope characteristics at the research location. Additionally, data on geological structures that play a crucial role in determining slope stability at the research site were collected. Rock samples were carefully selected and taken in their freshest condition for laboratory analysis. Only one rock sample was taken because the lithology at the research site is massive. The slope geometry was identified descriptively based on the parameter requirements in RMR calculation. The data was collected and analyzed using kinematic and Rock Mass Rating (RMR) methods (Figure 2).

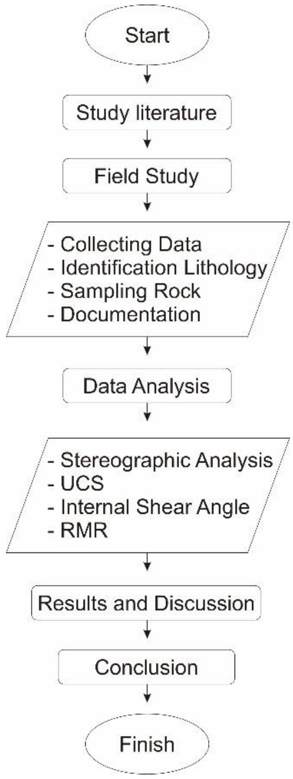

Figure 2 Research Flow Diagram

A. Kinematic Slope Analysis

This analysis is a method of analyzing geological data based on the stereographic projection introduced by Hoek & Bray (1981)[7][8]. This involves projecting a three-dimensional plane of inclination onto a hemisphere into a flat two-dimensional plane. The slope and direction of inclination of the plane of irregularity are plotted into the stereonet, which is then analyzed to determine the type and direction of potential landslides. By reviewing the distribution of the strike and dip of all plotted unslip planes, we can determine the relative strike and dip of an unslip plane for kinematic analysis. Following Hoek and Bray's (1981) stereographic analysis, avalanches can be classified into four types: rotational, planar, wedge, and toppling (Figure 3) [7][9]. Rotational avalanches are rare on rock slopes, but may occur on soil slopes (Figure 3a).

Planar avalanches can occur when a block of rock slides parallel to its rolling plane [10]. This happens when the slope dip (βs) is greater than the unslope plane dip (βj), and the unslope plane dip (βj) is greater than the inner shear angle (φ) (Figure 3.b). Wedge avalanches occur when two intersecting fractures are present. The slope resulting from the fracture intersection (βi) should be gentler than the dip slope (βs), but the plunge value should be greater than the inner shear angle (φ) (Figure 3.c). The next type of avalanche is the rolling type, which occurs due to the collapse of a rock block with a plane of unsuccession opposite to the slope direction (Figure 3.d).

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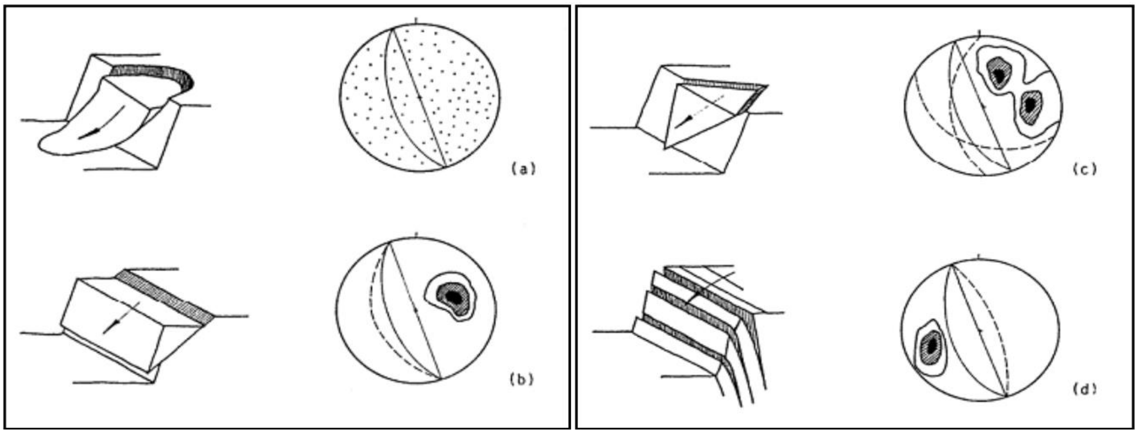

Figure 3 Shows the classification of potential landslide types based on fracture plane conditions. The left image displays the type of landslide, while the right image shows the stereographic representation. The four types of landslides are rotational, planar, wedge, and toppling, as described by Hoek and Bray (1981)[11].

B. Rock Mass Classification Analysis

Bieniawski (1989) developed a rock mass classification system known as the Rock Mass Rating (RMR) to aid in the assessment of rock quality[3]. The RMR method determines the quality of rock mass based on specific parameters outlined in the Bieniawski 1989 RMR table[12]. This research utilizes the Bieniawski rock mass classification system from 1989.

This classification system weights scanline data based on the parameters listed in Table 1. The RMR value is obtained by summing the value of each parameter. The quality of rocks in the research location can be determined using the RMR value.

Table 1 presents the parameters for RMR classification and their corresponding weight values, as proposed by Bieniawski in 1989[3].

Parameter		Conditions and Assessment Ranges						
Intact Rock Strength	Point Load Test	>10 MPa	4-10 Mpa	2-4 MPa	1-2 MPa	Low strength does not use a point load test		
	UCS	>250 Mpa	100-250 Mpa	50-100 Mpa	25-50 Mpa	5-25 Mpa	1-5 Mpa	<1 Mpa
Rating		15	12	7	4	2	1	0
Rock Quality Designation (RQD)		90-100%	75-90%	50-75%	25-50%	<25%		
Rating		20	17	13	8	3		
Spacing of Discontinuities		>2m	0,6-2 m	200-600 mm	60-200 mm	<60 mm		
Rating		20	15	10	8	0		
Condition of Discontinuities		Very rough, fresh walls, not continuous, tight	Rough, exposed <1mm, walls slightly weathered	Slightly rough, <1mm, very weathered walls	Filled, <5mm thick, 1-5mm open, continuous	Filled with soft material >5mm, open >5mm, continuous		
Rating		30	25	20	10	0		
Ground Water	General condition	Completely dry	Damp	Wet	Dripping	Flowing		
Rating		15	10	7	4	0		

III. RESULTS AND DISCUSSION

A. Lithology of the Research Area

Based on field observations, the lithology on the slopes in Jering Hills consists of intermediate plutonic igneous rock. The rock has a fresh gray color and a brownish-beige weathered color. It has a hypocrystalline degree of crystallinity with fine to medium faneric granularity (1-5mm). The crystal shape is euhedral to subhedral, and the relation is inequigranular (hypidiomorphic). The rock is composed of plagioclase, k-feldspar, hornblende, pyroxene, and quartz. According to William's (1954) classification of igneous rocks, the lithology in question is a diorite (Figure 4)[13]. Harjanto's stratigraphic comparability column (2011) includes this lithology in the diorite intrusion unit[6][14]. The diorite intrusion has an Oligocene-Miocene age. The stratigraphic relationship with the surrounding lithology is misaligned.

The slope in the study area is strong due to the presence of diorite igneous rock. This reduces the risk of collapse and minimizes the impact of erosion. Diorite's hardness allows it to withstand earthquakes and erosion by water and wind.

Figure 4 Close-up photo of diorite lithology.

B. Slope Kinematic Analysis Results

Based on the data collection of the unsmoothed field, 33 fracture data were obtained from a 13 meter long track. Data processing is done using Excel and Dips 6.0 software for stereographic analysis. The Excel data is plotted on Dips 6.0 software for contouring. The purpose of this contouring is to determine the direction and relative dip of the unconformity plane (Figure 5).

The results of measurements using a geological compass on the slope at the research site yielded a dip of 60o with a direction of N355oE. Based on the results of contouring the brittle data, four groups of directions and relative inclinations of the unconformity plane were obtained. For the orientation of the unbending plane 1 (joint 1) has a percentage of 55%, unbending plane 2 (joint 2) 21%, unbending plane 3 (joint 3) 15%, and unbending plane 4 (joint 4) 9%.

In the stereographic analysis using Dips 6.0 software, circles are also plotted to represent the internal shear angle data. In addition, the slope position is also plotted using the dip and strike data of the slope at the study site. These two data intersect to create a landslide-prone zone as shown in Figure 4, which is shaded in gray.

Based on the kinematic analysis of the slope shown in Figure 4, it can be seen that a planar landslide is likely to occur. This is because bridle plane 4, shown with a green colored line, has a position that is almost parallel to the position of the slope. According to Wyllie & Mah (2004), the conditions for the occurrence of planar avalanches are when the slope slope is greater than the slope of the unsmoothed plane and the slope of the unsmoothed plane is greater than the inner shear angle [10]. In this case, the dip plane 4 (kekar4) fulfills the conditions for a planar avalanche with the direction of the avalanche being relatively southeast.

C. Rock Mass Classification Results

Based on the geotechnical data collected on the slopes at the research site, some data have been obtained, which are then weighted RMR values based on Table 2. The weighting carried out is taken from the parameters of UCS, RQD, spacing of non-continuous planes, conditions of non-continuous planes and water conditions on the slopes at the research site. After weighting, the obtained results were further classified in the RMR classification table of Bieniawski 1989[3].

The UCS value obtained was 55.36 Mpa based on laboratory tests. The condition of non-continuous field takes data and field facts at the research site, so that the value is obtained according to the parameters required in Table 2. The value of RMR calculation on the slope at the research site has a value of 80. Based on the results of RMR value, it is found that the slope is included in the good rock class.

D. Recommendation

The slope stability analysis, using the Rock Mass Rating (RMR) assessment, indicates that the rock is in good condition with a score of 80. However, the kinematic analysis assessment shows the potential for mass movement with planar movement. Although the rock conditions are generally good, there is a risk of rock fall hazards in the event of disturbances such as heavy rain or earthquakes.

Recommendations for reinforcing slope walls based on the analysis results include installing rockbolts, hardening the slope with cement (shortcrete), or constructing retaining walls (Figure 6).

Table 2 Rock mass classification using RMR parameters on slopes in North Jering hills

Parameters	Result	Quality
UCS	51,36Mpa	7
RQD	61,94%	13
Spacing of discontinous	2,5m	20
Condition of discontinuous	Kasar, terbuka <1mm, dinding sedikit lapuk	25
Water content	Kering	15
Total		80 (Good)

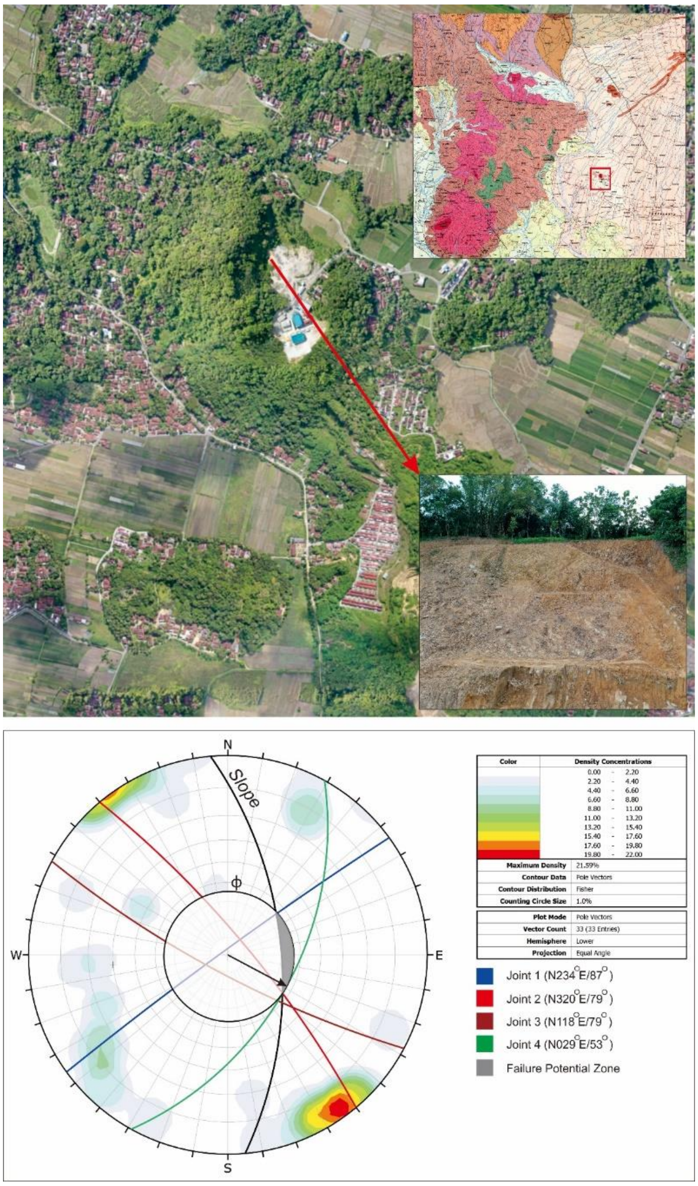

Figure 5 The appearance of the slope at the study site and the results of the projection of the unsmoothed plane into the stereographic projection.[15]

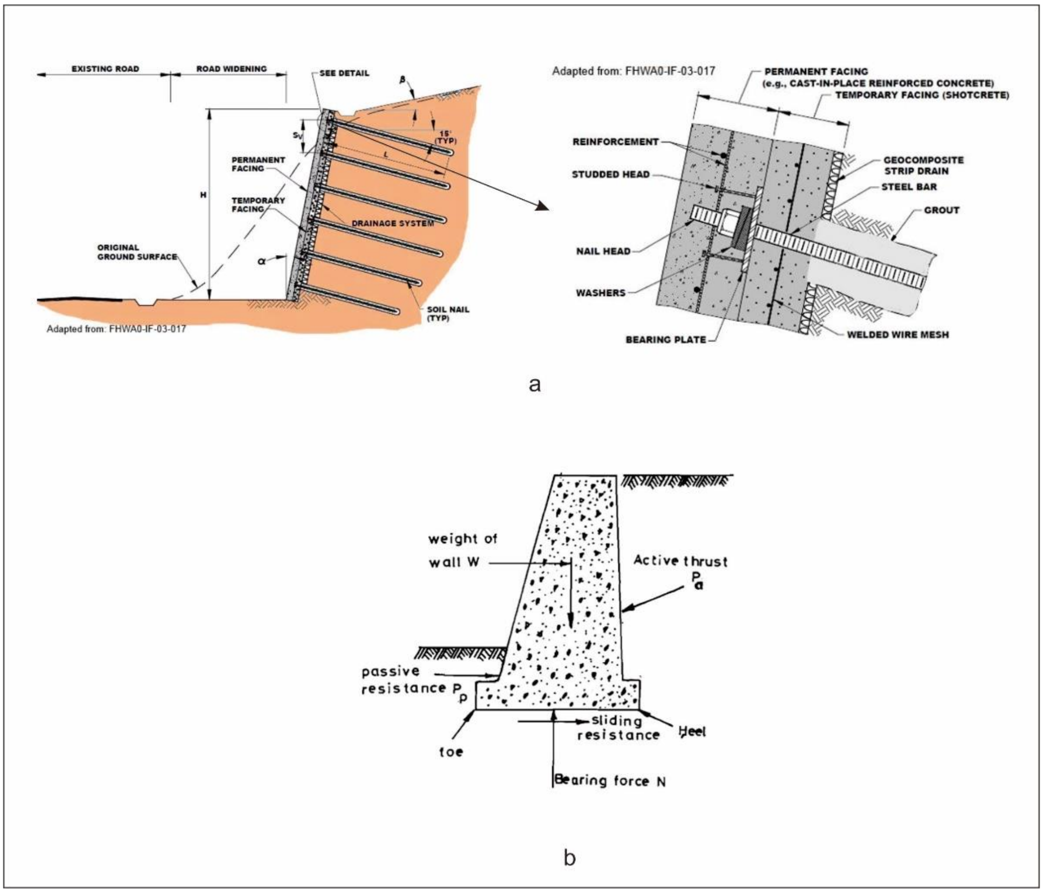

Figure 6 Recommended models that can be applied to the study site slope walls are rockbolt with shotcrete (a) or retaining wall (b).

IV. CONCLUSION

Based on the kinematic analysis of the slope, there is a plane of discontinuity (kekar) on the slope at the Bukit Jering Utara research site. The plane of discontinuity (kekar) affects the type and direction of avalanches that can occur. At the research site, the type of avalanche that can occur is a planar type avalanche with a southeast direction.

Based on the rock mass classification (RMR), the results show that the rock forming the slope at the research site is in the good category. However, due to the avalanche potential that occurs on the slopes at the research site based on the kinematic analysis, there is some geotech engineering to strengthen the field of discontinuity (kekar). The geotech engineering that can be done can be in the form of installing rock bolts, hardening the slope by spraying cement liquid, and retaining walls.

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