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Rock Mass Classification and Probability of Failure in Determining Slope Stability

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ABSTRACT

Scientific research on slopes is always evolving, alongside the development of science itself. In many cases, slope instability is a problem in the field. Most of the roads have a rock slope, which can be unstable because of the rock mass conditions and external factors such as water and seismic activity. The purpose of this research is to analyze slope stability using two methods: rock mass characterization and numerical modeling to calculate safety factor and probability of failure. As a result of this study, inclination 1 is more stable than inclination 2 with each value of 6.03 and 2.02 for each failure probability of 0 per cent and 0.48 per cent. The result of numerical modeling is directly proportionate to the characteristics of the stone's mass using RMR and GSI, and the rock's mass is in the appropriate state for the slope 1, and the stone's mass is classified in the appropriate state for the slope 2. The reasons for the differences in stability on the two slopes will be discussed further in this paper.

INTRODUCTION

The rock slope present on most roadways, particularly in hilly places, frequently has instability issues caused by the rock mass characteristics around the slope, as well as external variables such as water and seismic activity [9]. Internal variables influencing slope stability include frequency and discontinuity plane features, as well as the physical and mechanical qualities of the rock mass. Aside from internal considerations, slope geometry, such as slope height and slope angle, plays a vital influence in slope stability. Rainfall and earthquake activity are two exogenous elements that have an impact [5].

Researchers are occasionally concerned about slope stability. A number of approaches for evaluating slope stability have been developed. Kinematic analysis, boundary equilibrium, numerical modeling, and empirical approaches are divided into four groups [8]. The focus of this paper's study is on empirical techniques and numerical approaches using a probability of failure approach (RS2). The empirical technique is a valuable instrument that is frequently used to examine the early behavior of rock masses [1]. While the numerical technique was established to confirm the empirical method's first evaluation, the calculation results are more accurate and indicative of field settings.

The breccia andesite slopes in the two research locations have two conditions: the first in the agricultural area is fresh, and the second is weathered on the edge of the village road. The presence of these two slopes prompted the authors to do more research on the stability of the slopes in each site in order to identify possible hazards to inhabitants and road users near the slopes. Rock Mass Rating (RMR) and Geological Strength Index are the methodologies used to characterize rock masses (GSI). Meanwhile, the numerical technique employs RS2 software to compute SRF (Strength Reduction Factor) and Failure Probability (PoF).

RESEARCH SITES

The research is being conducted in two locations: Gedangsari Districts, Gunung Kidul, and DI Yogyakarta. The first location is in Jatigulung, Hargomulyo Village, at 7o49'34"S and 110o35'33"E, on a slope above the locals' rice fields. The second place is at Buyutan, Ngalang Village, with coordinates 7o51'31"S and 110o35'6"E, which is a roadside hillside. The two places have breccia andesite rock lithology.

Regionally, it is part of the Southern Mountain range, and geologically (FIGURE 1), it lies in the overlap region of the Kebo-Butak Formation (Tomk) and the Semilir Formation (Tms). The Kebo Butak Formation (Late Oligocene age) is the oldest formation exposed in Gunung Kidul Regency, consisting of layered sandstone, siltstone, claystone, shale, tuff, and agglomerates, with locally andesite fractured basalt and andesite breccia at the top. The Semilir Formation originated in the Early Miocene, overlaying harmoniously above the Kebo Butak formation, which was comprised of tuff, tuffaceous sandstone, and shale [3].

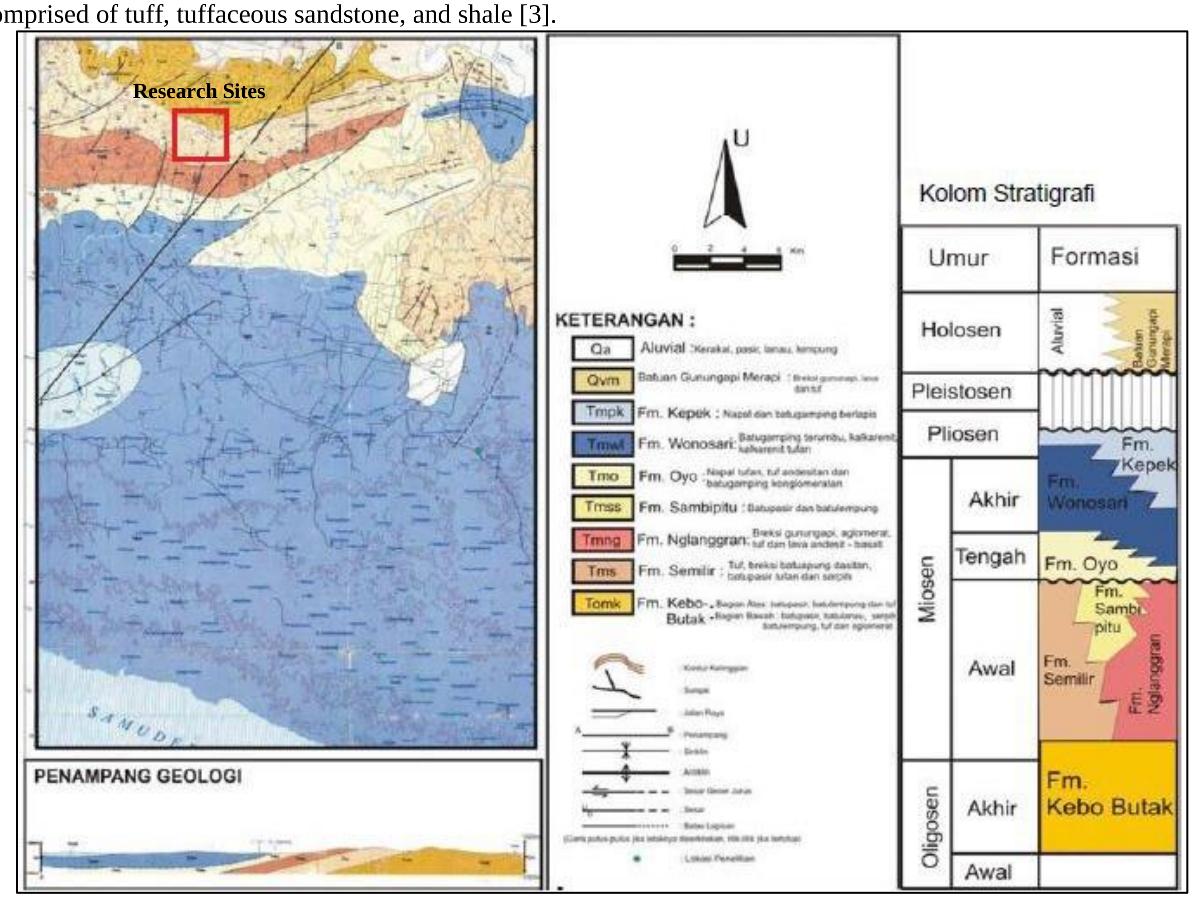

FIGURE 1. Regional geological map and stratigraphic column of research area

LITERATURE REVIEW

The technique of categorizing rock masses by making observations on joint geometry and joint circumstances is known as rock mass characterization. Joint geometry comprises joint orientation, joint spacing, and joint continuity measurements. While joint roughness, joint wall strength, joint opening width, joint filling, weathering, and groundwater discharge in joints are all considered joint conditions [12].

Rock Mass Rating [10, 13] is a categorization system for rock masses developed by Bieniawski (1973-1989) to assess the quality of a rock mass. RMR is made up of five basic characteristics that define rock mass conditions and discontinuities: (1) compressive strength of intact rock (UCS), (2) rock quality designation (RQD), (3) distance between discontinuities/joints, (4) discontinuous/joint condition, and (5) ground water condition. Tables 1 and 2 show the weighting of each parameter and the assessment of rock quality using the RMR classification.

Tabel 1. Parameters of Rock Mass Classification and Weighting

	Parameter		**Rating**						
1	Strengh of intact rock material	PLI (Mpa)	>10	4-10	2-4	1-2	For low compressive strength (UCS)		
		UCS (MPa)	>250	100-250	50-100	25-50	5-25	1-5	<1
	Rating		**15**	**12**	**7**	**4**	**2**	**1**	**0**
2	RQD (%)		90-100	75-90	50-75	25-50	<25		
	Rating		**20**	**17**	**13**	**8**	**3**		
3	Spacing of Discontinuities		>2 m	0.6-2 m	0.2-0.6 m	0.06-0.2 m	<0.06 m		
	Rating		**20**	**15**	**10**	**8**	**5**		
4	**Condition of Discontinuities**								
	Persistence		< 1m	1-3 m	3-10 m	10-20 m	>20 m		
	Rating		**6**	**4**	**2**	**1**	**0**		
	Aperture		None	<0.1 mm	0.1-1 mm	1-5 mm	>5 mm		
	Rating		**6**	**5**	**4**	**1**	**0**		
	Roughess		Very rough	Rough	Slightly rough	Smooth	Slickensided		
	Rating		**6**	**5**	**3**	**1**	**0**		
	Infillings (gouge)		None	Hard filling <5 mm	Hard filling >5 mm	Soft filling <5 mm	Soft filling >5 mm		
	Rating		**6**	**4**	**2**	**2**	**1**		
	Weathering		Unweathered	Slightly weathered	Moderately weathered	Highly weathered	Decomposed		
	Rating		**6**	**5**	**3**	**1**	**0**		
5	**Groundwater Condition**								
	General description		Completely dry	Damp	Wet	Dripping	Flowing		
	Rating		**15**	**10**	**7**	**4**	**0**		

Table 2. Rock Class after Total Weight

Rating	**Class**	**Description**
100-81	I	Very good rock
80-61	II	Good rock
60-41	III	Fair rock
40-21	IV	Poor rock
<20	V	Very poor rock

The Geological Strength Index (GSI) [6], developed by Hoek, Kaiser, and Bawden (1995), is used to evaluate the decline in rock mass strength due by various geological circumstances. The geometric shape of the rock blocks that comprise the rock mass, as well as the surface characteristics of the separating planes between the rock blocks, govern it. An angled rock block with a rough surface area has better rock mass strength than a round rock block with a worn surface area (Figure 2).

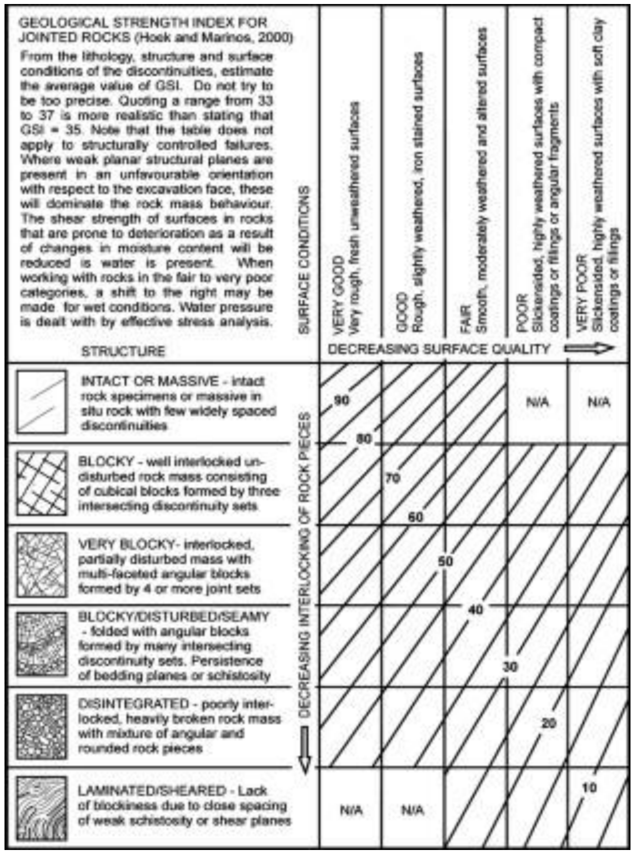

Figure 2. GSI Quantification

The relationship between the Geological Strength Index (GSI) and the Rock Mass Classification RMR) is as follows:

$$\text{For } RMR_{89'} > 23 \tag{1}$$

$$GSI = RMR_{89'} - 5 \tag{2}$$

RESULT DAN DISCUSSION

Rock Mass Rating

Location 1 is a fresh breccia andesite slope, whereas Location 2 is a weathered breccia andesite slope. Tables 3 and 4 offer a summary of the tabulation of RMR values at site 1 and position 2.

Table 3. Results of Rock Mass Classification Location 1

No	RMR Parameter	Hasil	Rating
1	Strengh of intact rock material (UCS)	17.16 MPa (5-25 MPa)	2
2	Rock quality designation (RQD)	99.89 %	20
3	Spacing of Discontinuities	> 2m	20
4	Condition of Discontinuities	15	15
5	Groundwater Condition	Completely dry	15
	RMR total rating		72
	Rock Class		II (Good)

Table 4. Results of Rock Mass Classification Location 2

No	RMR Parameter	Hasil	Rating
1	Strengh of intact rock material (UCS)	6.64 MPa (5-25 MPa)	2
2	Rock quality designation (RQD)	98.59 %	20
3	Spacing of Discontinuities	0.6 - 2m	15
4	Condition of Discontinuities	14	14
5	Groundwater Condition	Damp	7
	RMR total rating		58
	Rock Class		III (Fair)

Geological Srength Index

The results of the RMR are then entered into the equation $GSI = RMR_{89'} - 5$ so that the GSI value for Slope 1 is 67 and is in the Good category (good), while the GSI value for Slope 2 is 53 is in the Fair (medium) category.

Slope Stability and Probability of Failure

The GSI value from the rock mass characterisation is utilized as an input parameter for slope stability analysis, along with other input parameters such as rock constant values (mi) and disturbance factor (D).

Because the stress factor is included in the Finite Element Method approach, it is not only limited to the Safety Factor (SF) that is obtained, but the maximum displacement data when avalanches are also obtained, making it very useful to map the maximum displacement limit of an avalanche slopes as well as useful when reverse analysis of an avalanche [7].

Slope stability analysis using the Finite Element Method approach because the stress factor is included, so it is not only limited to the Safety Factor (SF) that is obtained, but the maximum displacement data when avalanches are also obtained, so it is very useful to map the maximum displacement limit of an avalanche slopes as well as useful when reverse analysis of an avalanche [7].

The appearance of the slopes at locations 1 and 2 is shown in (Figure 3), and the results of the slope stability calculation are shown in (Figure 4).

(a) (b)

Figure 3. (a) Slope of Hargomulyo Hamlet (b) Slope of Ngalang Hamlet

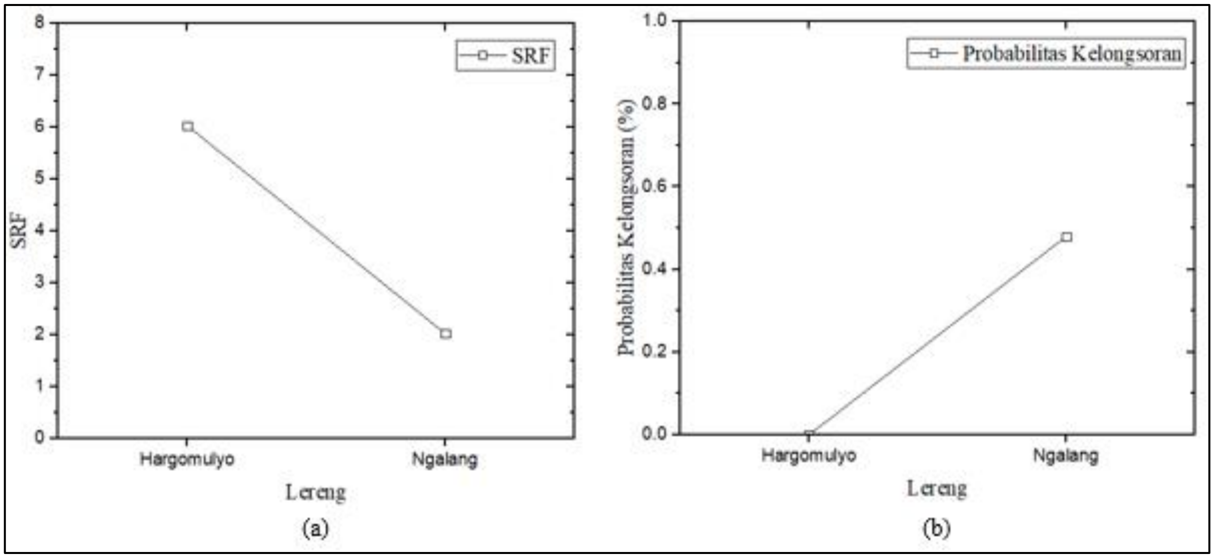

Figure 4. (a) SRF Hargomulyo and Ngalang slopes (b) PoF Hargomulyo and Ngalang slopes

Figure 3 indicates that both slopes are safe, with SRF greater than 1.5. (Slope of Hargomulyo Hamlet with SRF 6.03, PoF 0 percent and Ngalang Hamlet Slope with SRF 2.02, PoF 0.48 percent). The Hargomulyo Hamlet, on the other hand, is in better shape than the Slope of the Ngalang Hamlet. This is proportional to the first estimate of slope stability using the rock mass characterisation technique with RMR and GSI. The slope rock mass of Hargomulyo Hamlet was classed as good by both rock mass categorization methods, whereas the slope of Ngalang Hamlet was classified as fair.

Aside from rock mass classification, another technique was used to determine the source of the discrepancy in SRF values between the two slopes, as shown in (Figure 5).

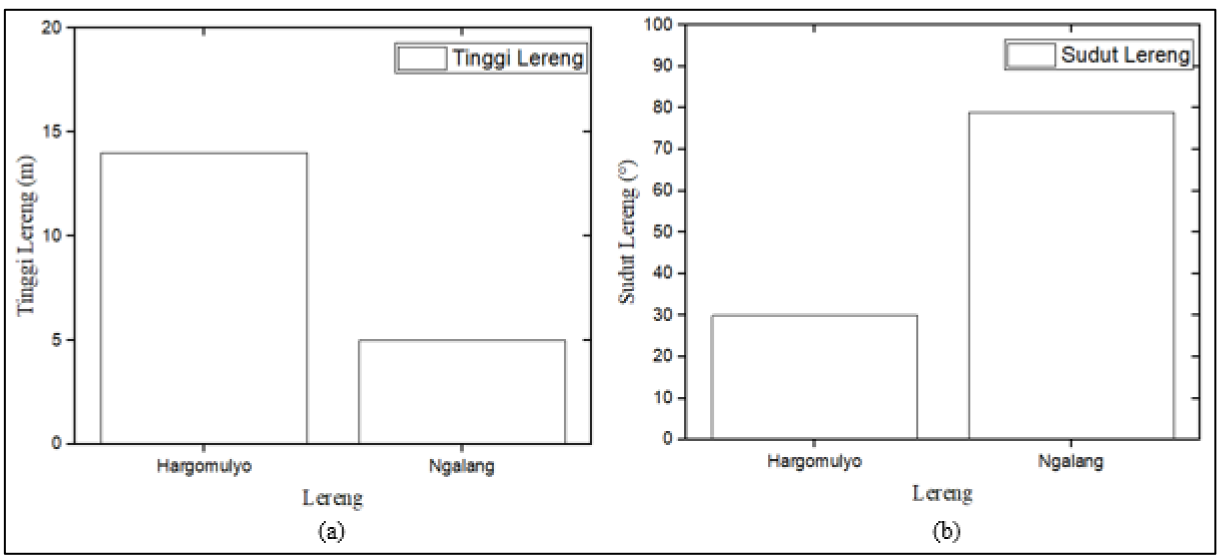

Figure 5. (a) The height of the Hargomulyo and Ngalang slopes (b) The angle of the Hargomulyo and Ngalang slopes

A geometric approach is used to compare the two slopes, and Figure 4 shows that the slopes of Hargomulyo hamlet have a single slope of 14 meters, which is higher than the slopes of Ngalang hamlet, which has a single slope of 5 meters; however, the slopes of Hargomulyo hamlet have a single slope angle that is gentler, which is 30°, and the slope of Ngalang village has a single slope angle of 79°. According to the geometric method, the angle of the slope is an essential aspect that might affect the level of slope stability. Even though the single slope height in Ngalang village is 5 meters, the load received by the slopes is more than the load received by the slopes in Hargomulyo hamlet with a single slope height. 14 meters with a single slope angle of 30 degrees. So lowering the slopes by reducing the angle of the single slope is one technique to strengthen the stability of the slopes in the Ngalang hamlet.

CONCLUSION

Despite the fact that the single slope height in Ngalang village is 5 meters, the load received by the slopes is more than the load received by the slopes in Hargomulyo hamlet with a single slope height. 14 meters with a single slope angle of 30° So, lowering the slopes by reducing the angle of the single slope is one technique to strengthen the stability of the slopes in the Ngalang hamlet.

Despite the fact that the single slope height in Ngalang village is 5 meters, the load received by the slopes is more than that received by the slopes in Hargomulyo hamlet with a single slope height. 14 meters and a single 30° slope angle Sloping the slopes by lowering the angle of the single slope is one technique to strengthen the stability of the slopes in the Ngalang hamlet.

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REFERENCES

1. Duran and K. Douglas, “Experience With Empirical Rock Slope Design”, In: proceedings of ISRM International Symposium, Melbourne, Australia, 2000.
2. A.Sekhavatian, dan A.J. Choobbasti “Comparison of Point Estimate and Monte Carlo Probabilistic Method in Stablity Analysis of a Deep Excavation”, International Journal of Geo-Engineering, 2018.
3. Surono, Toha, and I. Sudarno, Peta Geologi Lembar Surakarta – Giritontro. Bandung: Geological Research and Development Center, 1992.
4. D.C. Wyllie and C.W. Mah, Rock Slope Engineering: civil and mining 4th edition. London: Spoon Press, 2004.
5. D.M.Rezky, A.G. Irwan, S.Saptono, “ The effect of Rock Mass Characterization on Slope Stability Assesment”, in 3rd International Conference on Earth Science, Mineral, and Energy, (030017), 2021.
6. E. Hoek, dan E.T. Brown, The Hoek-Brown Failure Criterion and GSI – 2018 Edition. Journal of Rock Mechanics and Geotechnical Engineering, pp 1-19, 2018.
7. G.Hussain, Y. Singh, G.M. Bhat, S. Sharma, R. Sangra, dan A. Singh, “Geotechnical Characterisation and Finite Element Analysis of Two Landslide Along the National Highway 1-A (Ladakh Region, Jammu and Khasmir”, Journal Geological Society of India, Vol. 94, pp 93-99, 2019.
8. H. Basahel and H. Mitri, “Application of rock mass classification systems to rock slope stability assessment: A case study,” Journal of Rock Mechanics and Geotechnical Engineering, vol. 9, pp. 993-1009, July 2017.
9. L. Pantelidis, “Rock Slope Stability Assessment Through Rock Mass Classification Systems,” International Journal of Rock Mechanics and Mining Sciences, vol.46, pp. 315-325, 2009.
10. M.A. Rai, S. Kramadibrata, and R.K. Wattimena, Mekanika Batuan, Bandung:Geomechanics Laboratory and Mining Equipment ITB, 2011.
11. S.D. Priest and J.A. Hudson, “Discontinuity Spacings in Rock,” International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts, vol 13(1), pp. 135–148, 1976.

12. S. Saptono, S. Kramadibrata, B. Sulistianto, and M. Irsyam, "Studi Jarak Kekar Berdasarkan Pengukuran Singkapan Massa Batuan Sedimen di Lokasi Tambang Batubara," in Prosiding Simposium dan Seminar Geomekanika, vol 1, 2012, pp. 18–28.
13. Z.T. Bieniawski, Engineering rock mass classifications: a complete manual for engineers and geologists in mining, civil, and petroleum engineering. John Wiley & Sons, 1989.