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Analysis Slope Stability Using RMR and SMR Method in Nupaomba Area Tanantovea Donggala

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ABSTRACT

Landslide disasters frequently occur in the Nupabomba area due to its steep slopes and its role as a primary access road for the local community. This study aims to analyze slope stability using the Rock Mass Rating (RMR) and Slope Mass Rating (SMR) methods to assess the potential for landslides. The research was conducted at coordinates (Universal Transverse Mercator) UTM 829117.90 – 831853.89 mE and 9920980.82 – 9920308.34 mS. Data collection involved field measurements using the scanline method, focusing on discontinuities, lithology, and rock strength. The results indicate that at Station 01, the slope consists of slate rock with an RQD value of 70% and UCS of 23 MPa. The calculated RMR value is 58, placing it into Class III (fair rock), with an SMR value of 55.4, indicating partially stable conditions. Meanwhile, at Station 02, the slope consists of phyllite rock with an RQD value of 70% and UCS of 52 MPa. The RMR value is 62, classifying it as Class II (good rock), and the SMR value is 61.6, indicating a stable condition. These findings provide crucial insights into the geotechnical characteristics of the area, which are essential for landslide risk mitigation and infrastructure planning. The study highlights the need for continuous monitoring and possible reinforcement strategies, particularly in areas categorized as partially stable. Further research incorporating geotechnical modeling and additional stability analysis is recommended to enhance slope stability predictions and inform mitigation strategies.

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1. INTRODUCTION

Slope stability analysis is a crucial aspect of geotechnical engineering, particularly in regions prone to landslides. Landslides are triggered by various factors, including slope geometry, rock physical and mechanical properties, geological structures, weathering, and groundwater conditions (Bieniawski, 1989). The Nupabomba area in Tanantovea District, Donggala, Central Sulawesi, frequently experiences landslides due to its steep terrain and active geological processes. Given that this area serves as a primary access road for the local community, ensuring slope stability is essential for infrastructure safety and disaster risk reduction. A systematic approach to evaluating slope stability is therefore necessary to assess potential hazards and implement suitable mitigation strategies.

Several methodologies are available for slope stability assessment, with geomechanical classification systems playing a significant role in evaluating rock mass characteristics. The Rock Mass Rating (RMR) system, initially introduced by Bieniawski (1973) and later updated in 1989, is widely used in rock engineering projects. This classification method considers six key parameters, including Uniaxial Compressive Strength (UCS), Rock Quality Designation (RQD), discontinuity spacing and conditions, groundwater presence, and the orientation of discontinuities (Bieniawski, 1989). Meanwhile, the Slope Mass Rating (SMR) system, developed by Romana (1985), modifies the RMR classification by incorporating slope geometry and excavation methods, making it particularly suitable for assessing slope stability in both natural and engineered environments (Romana et al., 2003).

Previous studies have demonstrated the effectiveness of these classification methods in slope stability analysis. Pangaribuan and Retongga (2022) applied RMR and SMR to assess slope safety in Yogyakarta, Indonesia, and found that integrating these systems provided a reliable estimate of slope stability conditions. Similarly, Syam et al. (2018) used these methods to evaluate slopes in East Kalimantan, highlighting their applicability in different geological settings. These studies confirm that RMR and SMR are effective tools for predicting slope stability and informing engineering decisions regarding slope reinforcement and risk management.

Despite extensive research on the application of RMR and SMR, limited studies have focused on Central Sulawesi, particularly the Nupabomba area. Geological variations, including differences in lithology, weathering intensity, and structural discontinuities, necessitate localized assessments to ensure accurate stability predictions. This study fills this research gap by conducting a comprehensive analysis of slope stability in the Nupabomba area, providing essential geotechnical data for future infrastructure planning and landslide mitigation efforts.

This study aims to analyze slope stability in the Nupabomba area using RMR and SMR classification methods. The research objectives include classifying rock masses based on geomechanical properties, determining the stability levels of slopes, and providing recommendations for slope reinforcement. The novelty of this study lies in its application of RMR and SMR in an area with limited prior research, contributing valuable insights into slope stability assessment in Central Sulawesi. The scope of this research includes field observations, laboratory analyses, and data interpretation to classify rock masses and evaluate slope stability conditions. Through this study, we aim to provide a comprehensive understanding of slope stability in the Nupabomba area and propose suitable mitigation measures to enhance infrastructure resilience against landslides.

2. METHOD

2.1. Materials

This study utilizes various geological and geotechnical instruments for data collection and analysis. The primary field equipment includes a geological compass for measuring discontinuity orientations, a measuring tape for determining slope geometry, and a Schmidt hammer for estimating the Uniaxial Compressive Strength (UCS) of rock samples. In addition, rock samples were collected for laboratory analysis, where Rock Quality Designation (RQD) and UCS tests were conducted using standardized geotechnical testing procedures.

2.2. Sample Preparation

Rock samples were collected from two observation stations, where lithological characteristics were examined, and geomechanical properties were measured. The samples were categorized based on their physical characteristics, including color, texture, and mineral composition. Laboratory tests were conducted to determine UCS values, and the RQD of rock core samples was assessed following the methodology proposed by Deere and Miller (1966). The samples were prepared according to ASTM D 3148-02 standards for uniaxial compression testing.

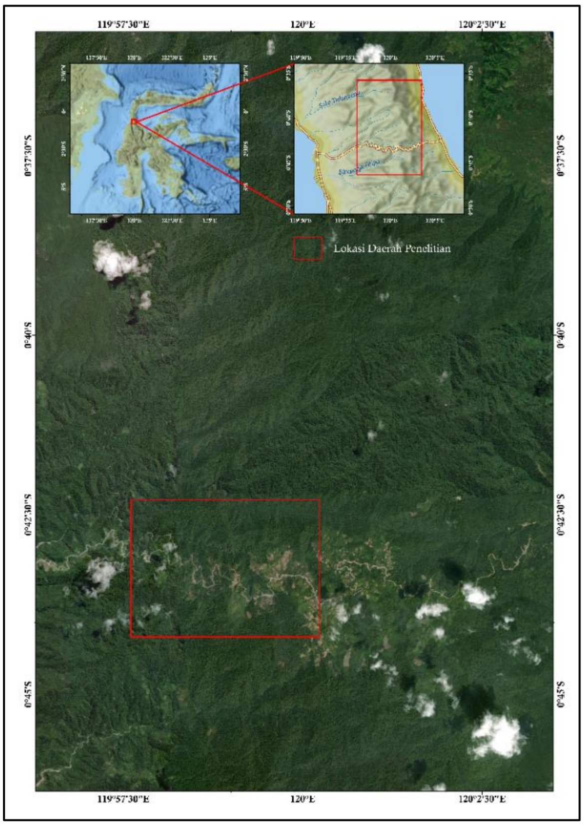

Figure 1. Map showing location of research area

2.3. Experimental Set-up

The experimental setup consisted of three main stages: field data collection, laboratory testing, and data analysis. Field measurements included slope angle determination, azimuth of discontinuities, spacing and condition of discontinuities, and groundwater presence. A scanline survey was performed at both stations to measure discontinuity characteristics such as persistence, roughness, aperture, and infilling material. The laboratory testing phase involved measuring the UCS of intact rock samples, assessing rock density, and calculating the RQD value based on core sample analysis.

2.4. Parameters

The key parameters measured in this study include the following:

a. Rock Mass Rating (RMR) – This was determined based on five parameters: UCS, RQD, discontinuity spacing, discontinuity conditions, and groundwater conditions (Bieniawski, 1989).
b. Slope Mass Rating (SMR) – The SMR value was calculated using the adjusted RMR values, incorporating four additional adjustment factors: slope orientation, discontinuity dip, excavation method, and joint condition (Romana, 1985).
c. Schmidt Hammer Test (JCS Estimation) – Used to estimate the rock joint compressive strength.
d. RQD Value – Calculated using the equation:

$$RQD = \frac{\Sigma \text{ length of intact core pieces} > 10 \text{ cm}}{\text{Total core run length}} \text{ X } 100\% \quad (1)$$

e. Slope Geometry – Measurements of slope height, length, and dip angles using a geological compass and measuring tape.

2.5. Statistical Analysis

Data obtained from field measurements and laboratory tests were processed using weighted calculations for RMR and SMR classification. The RMR values were assigned based on Bieniawski's (1989) classification system, while SMR values were calculated using Romana's (1985) formula:

$$RMR = SMR + (F1 . F2 . F3) + F4 \quad (2)$$

where F1, F2, F3, and F4 are correction factors related to slope orientation and excavation methods. The statistical analysis involved comparing obtained RMR and SMR values with standard classification charts to determine slope stability levels. The final results were used to classify slope stability and identify necessary reinforcement measures to prevent potential landslides in the study area.

3. RESULTS AND DISCUSSION

3.1. Findings from Field and Laboratory Analysis

Field measurements and laboratory tests were conducted at two stations to determine slope stability in the Nupabomba area using Rock Mass Rating (RMR) and Slope Mass Rating (SMR) classifications. The primary parameters measured included slope angle, RQD, UCS, and discontinuity characteristics.

3.1.1. Station 01

At Station 01, the slope consists of slate rock, which has a fresh brownish-black color, a lepidoblastic texture, and a mineral composition of biotite (45%), hornblende (25%), quartz (15%), and plagioclase (15%). Using a geological compass, the measured slope angle was 54°, with a second angle of 41° measured at a height of 13.5 meters (Figure 2).

Figure 2. Location of observation and data retrieval slope at Station 01

Based on the scanline measurements, the RQD value was calculated as 70%, as shown in Figure 4, which represents the plotted RQD frequency distribution.

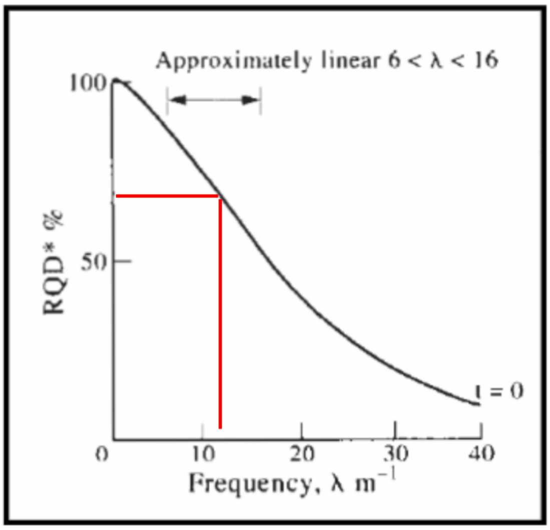

Figure 3. RQD chart for Station 01.

Further laboratory testing using the Schmidt hammer estimated the Uniaxial Compressive Strength (UCS) value at 23 MPa (Table 1). The results from the RMR calculation placed the slope into Class III (fair rock) with a value of 58, indicating a moderate stability category (Table 2). The SMR value was determined as 55.4, categorizing the slope as partially stable (Table 3).

Table 1. Schmidt Hammer Test JCS Estimation at Station 01

Parameter	Value
UCS (MPa)	23

Table 2. RMR Classification at Station 01

Parameter	Value	Classification
Rock Strength (UCS)	23	Fair
RQD	70%	Good
Discontinuity Spacing	11.6	Moderate
Discontinuity Condition	Fair	Fair
Groundwater Influence	Low	Stable
Total RMR Score	58	Class III

Table 3. Slope Mass Rating (SMR) Classification at Station 01

Parameter	Value	Classification
RMR Score	58	Class III
RQDAdjustment Factors (F1 × F2 × F3)	-2.6	-
Excavation Method (F4)	0	-
Final SMR Score	55.4	Partially Stable

3.1.2. Station 02

At Station 02, the lithology consists of phyllite rock, which is characterized by a fresh gray color, a lepidoblastic texture, and a mineral composition of biotite (45%), quartz (35%), and hornblende (20%). The slope angle measured at this station was 60°, with a second angle of 39°, and a total slope height of 9.3 meters (Figure 5).

Table 4. Location of observation and data retrieval slope at Station 02.

The RQD value obtained was 70%, as depicted in Figure 5, which represents the frequency distribution of RQD measurements.

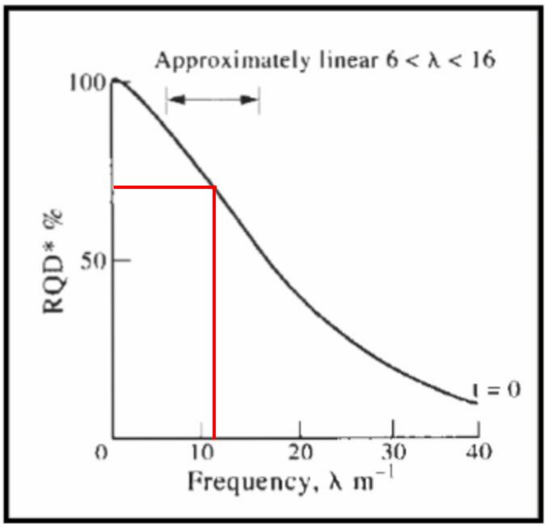

Table 4. RQD chart for Station 02.

Laboratory results indicated that the UCS value was 52 MPa (Table 4). The RMR calculation resulted in a classification of Class II (good rock) with a score of 62 (Table 5). The SMR score was 61.6, indicating that the slope is stable (Table 6).

Table 4. Schmidt Hammer Test JCS Estimation at Station 02

Parameter	Value
UCS (MPa)	52

Table 5. RMR Classification at Station 02

Parameter	Value	Classification
Rock Strength (UCS)	52	Good
RQD	70%	Good
Discontinuity Spacing	11.3	Moderate
Discontinuity Condition	Good	Good
Groundwater Influence	Low	Stable
Total RMR Score	62	Class II

Table 6. Slope Mass Rating (SMR) Classification at Station 02

Parameter	Value	Classification
RMR Score	62	Class II
RQDAdjustment Factors (F1 × F2 × F3)	-0.4	-
Excavation Method (F4)	0	-
Final SMR Score	61.6	Stable

3.2. Discussion

The results of this study align with previous research findings on slope stability using RMR and SMR methods. For Station 01, where the slope is classified as partially stable, similar observations have been made in studies by Syam et al. (2018), who found that slopes in Class III (RMR 41–60) require monitoring and potential reinforcement to prevent progressive failure. Additionally, Pangaribuan and Retongga (2022) demonstrated that slopes with SMR values between 40 and 60 may become unstable under external factors such as heavy rainfall or seismic activity.

For Station 02, where the slope is categorized as stable, the findings are consistent with previous studies indicating that RMR values above 60 and SMR values above 60 typically correlate with long-term slope stability (Sukur & Candra, 2019). The higher UCS value (52 MPa) at this station further supports the classification, as strong rock masses tend to have lower susceptibility to failure under natural conditions (Romana et al., 2003).

The classification of Station 01 as partially stable suggests that preventive measures should be considered to mitigate potential slope failure risks. Recommended reinforcement strategies include installation of rock bolts, surface drainage improvements to control groundwater infiltration, and vegetation cover to reduce surface erosion.

For Station 02, which has been classified as stable, no immediate reinforcement is necessary; however, periodic monitoring is recommended to assess potential long-term changes due to weathering and erosion. These findings contribute to understanding slope stability in the Nupabomba area and offer valuable insights for infrastructure planning, landslide risk management, and geotechnical hazard mitigation in Central Sulawesi.

Future research incorporating numerical slope stability modeling, geotechnical simulations, and additional borehole data is recommended to further refine stability assessments and develop more effective risk mitigation strategies.

4. CONCLUSIONS

From the results of data processing in two stations conducted in the area of nutabomba obtained several different values. On Station 01 with the litology of metamorphic rock that has a slope height of 13,5 meters, RQD value of 70%, For the value of UCS obtained is 23 then according to RMR data with a value of 58 can be said slope at station 01 is entered into class III which indicates the potential of passage into the medium category so that its SMR value is 55,4 with partially stable stability. Then station 02, obtained back outcrops with the lithology of metamorphic rocks that are phylite rock that has a slope height of 9.3 meters, RQD value of 70%, For UCS value obtained is 52 then according to RMR data with a value of 62 can be said slope at station 02 is entered into class II indicating the potential passage into a good category so that its SMR value is 61.6 with stability is a stable.

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