



Quantifying Rock Slope Stability with Kinematic and Limit Equilibrium Methods for KM29 of Karak Highway, Malaysia

Nurul Afiffah Khairulazman¹, Jestin Jelani^{1*}, Suriyadi Sujipto¹, Zainuddin Md Yusoff², Zuliziana Suif¹, and Mohd Rozi Umor³

¹ Department of Civil Engineering, Faculty of Engineering, National Defence University of Malaysia, Sungai Besi, 57000, MALAYSIA

² Department of Civil Engineering, Faculty of Engineering, University of Putra Malaysia, MALAYSIA

³ Department of Earth Sciences and Environment, Faculty of Science and Technology, National University of Malaysia, MALAYSIA

*Corresponding Author: jestin@upnm.edu.my

DOI: <https://doi.org/10.30880/ijie.2024.00.00.000>

Article Info

Received: Day Month Year

Accepted: Day Month Year

Available online: Day Month Year

Keywords

Rock slope stability, Rocscience Dip, Kinematic, Limit Equilibrium Method, Slope/W

Abstract

Engineering geology focuses heavily on ensuring the stability of rock slopes, especially to ensure that cut slopes next to roads are safe and functional. Kinematic analysis is a commonly utilized technique to assess the stability of rock slopes in Malaysia. This method employs a stereographic plot to identify potential failure modes based on geological discontinuities; however, it does not quantify the forces that could influence these failures. This restriction is addressed by calculating the slope's safety factor using the Limit Equilibrium Method (LEM), which offers a more thorough evaluation. This study used kinematic analysis and LEM to evaluate the stability of a rock slope at KM29 near the Gombak toll on the Karak Highway in Malaysia. Key parameters, including geological discontinuities and mechanical properties, were analyzed through Schmidt hammer rebound surveys and shear strength tests. A Schmidt rebound hammer was used to assess the rock's hardness; slope sections G1, G2, and G3 had average values of 61.60 MPa, 60.00 MPa, and 54.40 MPa, respectively. Equivalent rock strength values of 163.97 MPa, 150.65 MPa, and 113.98 MPa were obtained by correlating these values with the uniaxial compressive strength (UCS). The shear strength test indicated an average cohesion value of 20.56 kPa and a friction angle of 56.79°, derived from four rock samples. Kinematic analysis, conducted using Rocscience Dips software, revealed that slope sections G1, G2, and G3 were susceptible to wedge and planar failures. In contrast, the factor of safety (FOS) determined by LEM, simulated using Slope/W, confirmed that all slope sections are stable, with FOS values exceeding 1.5. The integration of kinematic analysis and LEM should be considered essential for evaluating rock slope stability and reinforcing the final decision-making process.

1. Introduction

Over the last few decades, Malaysia has dedicated significant funding to developing a highway network to connect the urban, suburban, and rural areas throughout the country. The challenges frequently encountered are to deal with rugged and hilly terrain. This has frequently resulted in design choices, including cutting rock slopes with varied dip degrees, necessitating special considerations to prevent instability and potential rock slope failure [1]. In mountainous or hilly regions, various types of rock slope failures have been observed, including rock, earth, and debris flows. These failures can occur suddenly or gradually. The main trigger for rock slope failure is rainfall; however, earthquakes, other natural causes, and human activities can also contribute to these events. This includes alteration slope geometry, excessive surcharge load, and improper terrain cutting procedures, to name a few [2][3].

To evaluate the stability of rock slopes, numerous researchers have used a variety of techniques [4]. These techniques fall into two categories: kinematic and non-kinematic. Non-kinematic approaches compute the factor of safety (FOS) using the Limit Equilibrium Method (LEM), which takes force-induced instabilities into account. Kinematic analysis, on the other hand, depends on stereographic projection and does not measure the forces that could cause failure.

Kinematic analysis has been commonly utilized since the 1990s to assess potential rock slope collapse scenarios. This technique uses information gathered from the site about discontinuities and joint orientations, such as dip angles and dip directions, to determine failure modes like planar, wedge, and toppling [5]. Discontinuities are critical in rock slope failure because they exhibit significantly lower strength than intact rock. The fundamental principle of this analysis involves examining the angular relationships between discontinuity planes to predict possible failure types in jointed rock masses, without accounting for the forces that might trigger movement. To analyze and visualize structural discontinuity, the Dips 7.0 software is commonly utilized. However, kinematic analysis requires massive data collection (i.e., discontinuity orientation, drill core structural logging data) to represent actual slope conditions at the site [6].

On the other hand, LEM assesses slope stability by calculating the factor of safety, which is the proportion of forces that resist movement to forces that cause movement on the failure plane [7]. This technique divides the rock mass into a specific amount of vertical slices and examines the forces on the potential failure plane, taking into account properties like cohesion, friction angle, unit weight, and others. Several material models are available to represent rock mass, such as Mohr-Columb, Shear Normal Function, Barton Brandis, and Hoek Brown. Due to their simplicity and precision, LEM has been the most popular approach for resolving slope stability. However, LEM is unsuitable to model slopes with complex geometry, non-linear problems, and heterogeneous materials.

The study utilized both the kinematic method and Limit Equilibrium Method (LEM) to investigate the rock slope near the Gombak toll area on Karak Highway, specifically at KM29. The kinematic method was used to identify the failure modes of rock slopes, with the Limit Equilibrium Method (LEM) being used to assess the stability of the slope in terms of Factor of Safety (FOS).

1.1 Research Significance

Performing a rock slope stability assessment within the study region is crucial in evaluating the threat of rock falls and pinpointing possible solutions. Suggestions can be made by installing rock anchors, wire mesh, dowels and slope monitoring system to protect the risky areas [8]. The resulting outcome will be significantly useful for future development planning for highway concessionaires to ensure the safety and effective operation of highway networks. Until now, there has not been any assessment conducted in the study area to determine the stability of rock slopes. Thus, the aim of this study is to evaluate the potential impact of discontinuities on rock slope failure through the integration of the kinematic method and LEM.

1.2 Geological Setting of the Study Area

Karak Highway serves as a main road connecting Kuala Lumpur to East Coast states in Peninsular Malaysia. The expressway starts in Gombak, Selangor and ends in Lanchang, Pahang. The road was built on the flat to hilly landscape, passing through three distinct formations (i.e., the Kuala Lumpur Granite, the Genting Sempah complex and the Bentong-Raub Suture zone), as illustrated in Fig 1. These formations can be found in the Main Range region, also known as Western Belt Granites [9]. KM29 falls between coordinates 3°18'55.0"N 101°44'13.0"E, near Gombak, Selangor. The study area has a tropical rainforest climate with average monthly temperatures ranging from 33.88°C to 24.63°C. The area receives approximately 77.89 mm of rainfall intensity for approximately 212 days, or 58.13% of the year.

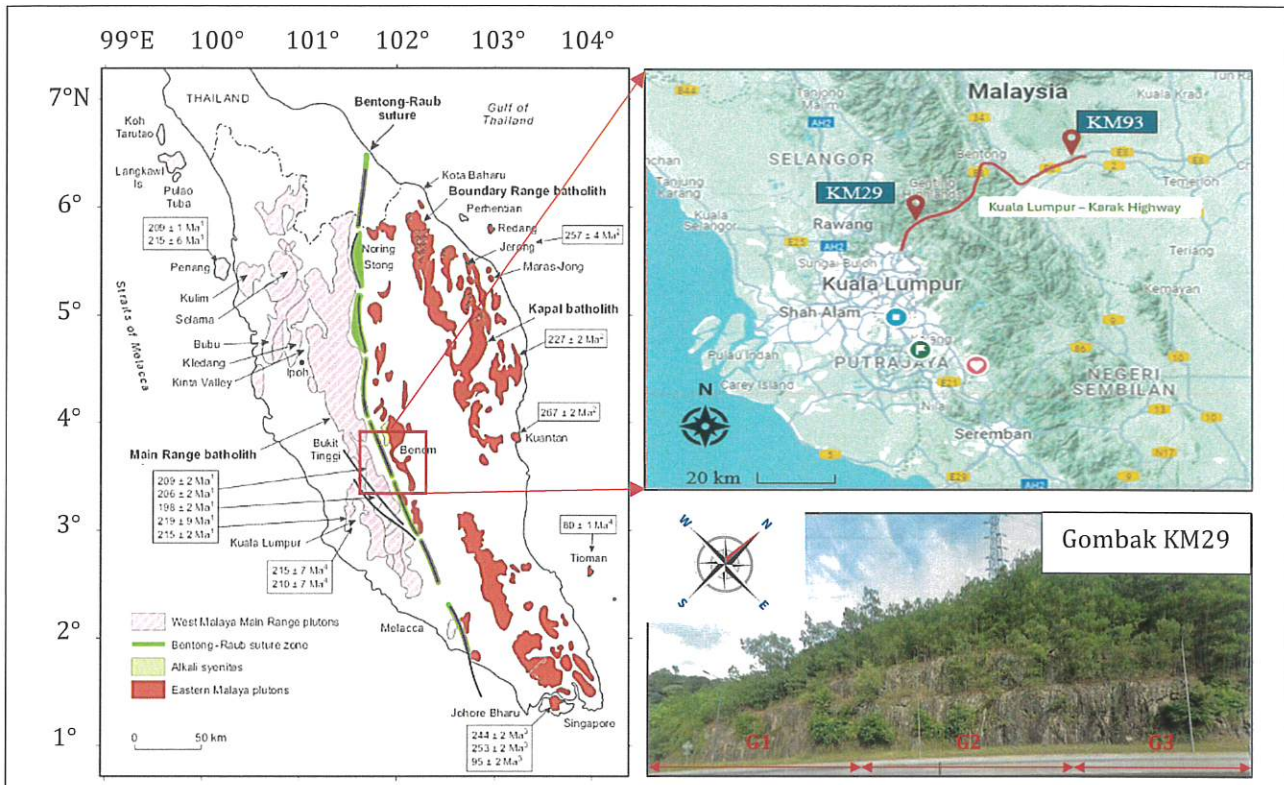


Fig. 1 Location of study area (modified from [10])

2. Methodology

The methodology of this study consists of three stages. The first stage involved site visits, field testing and rock sample collection. The next step was to perform laboratory tests and assess the stability of rock slopes using kinematic and limit equilibrium methods (LEM).

2.1 Site Visits, Field Testing and Rock Samples Collection

Site visits were conducted to gather information about the slope, including dimensions, discontinuity orientation, field testing, and rock samples. The slope section at kilometer 29 is separated into three parts: G1, G2, and G3, with lengths of 550 m, 355 m, and 345 m respectively. The total slope length is 1250 m, with a peak height of 15 m at section G2. The slope angle for each slope section is determined at the site at approximately 88°, 78°, and 80°. A total of 950 dip angle (DA) and dip direction (DD) data were collected using a GeoCompass application, with 400, 350, and 200 data points for sections G1, G2, and G3, respectively.

Research conducted by [11] suggested that between 150 and 350 measurements are sufficient to describe a uniform region of rock mass in each segment. Moreover, the gathered information was confirmed in the field with the help of a geological compass. A mineral hammer was used to collect rock samples for testing shear strength, while 600 rebound hammer data points were taken with a Schmidt hammer to analyze rock surface hardness.

2.2 Laboratory Testing

2.2.1 Shear Strength Test

The shear strength test was conducted using a portable rock shear box apparatus on four rock samples (S1, S2, S3, and S4) collected randomly from G1, G2, and G3 slope sections. The procedure was performed in accordance with ASTM D5607-16 [12]. Four blocks of granite containing joint surfaces were prepared by cutting them into rectangular shapes with sizes of 115 x 125 mm. The lower half and upper half samples were encapsulated in separate mold, and then cement mortar was poured into the shear box mold. The prepared samples for the shear strength test are shown in Fig 2.

Before the test, the encapsulated lower half and upper half of the rectangle shape sample were aligned carefully so that the plane to be sheared was in a horizontal position. A 1kN force was exerted on the specimen, and the shear force was raised until the displacement gauge showed readings of 2 mm, 4 mm, 6 mm, and 8 mm. The shear load reading was recorded for each displacement increment. These processes were repeated for another three samples, with increment normal load values of 2 kN, 3 kN, and 4 kN.

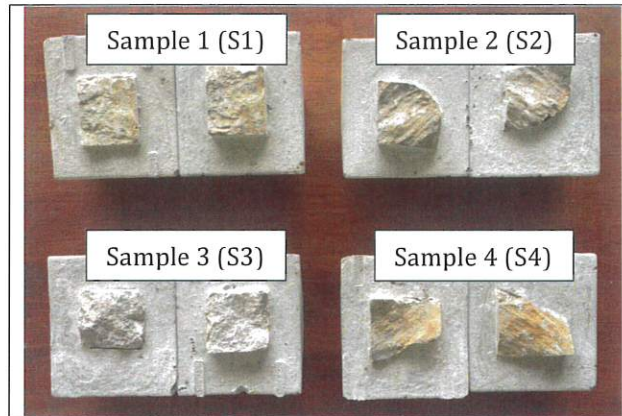


Fig. 2 Encapsulated rock samples for shear test

2.2.2 Surface Hardness Test

The Schmidt rebound hammer test is employed in this research to ascertain the uniaxial compressive strength (UCS) of rock due to its straightforwardness, speed, and portability. To conduct the test, the hammer is placed perpendicularly on the rock surface, and the plunger is pressed against the rock, as illustrated in Fig. 3. The rebound value, which reflects the surface hardness and provides an indirect measure of compressive strength, is recorded on a scale to the nearest whole number [13] for each impact. These values are then averaged to determine a representative rebound number. Ultimately, the rebound values are linked to the UCS utilizing Eq. (1) [14], where Hr stands for the Schmidt hammer rebound value.

$$UCS = \frac{6222}{88.15 - Hr} = 70.38 \quad (1)$$

The Schmidt hammer is preferred over UCS testing for quick, non-destructive, and cost-effective preliminary field assessments, especially in large-scale surveys where sample preservation is crucial. It is important to note that there are limitations and potential sources of error associated with this correlation. Factors such as rock type, anisotropy, moisture content, and surface condition can affect the relationship between rebound values and UCS. Different rocks may have varying hardness levels due to differences in mineral composition and grain size, leading to variations in rebound values. Additionally, the condition of the rock's surface, including weathering or the presence of micro-cracks, can impact the accuracy of the readings. Therefore, calibration and consistency in applying force have been considered in this study to minimize errors.



Fig. 3 Collecting rebound data using Schmidt hammer

3. Result and Discussion

The mean cohesion and friction angle values were 20.56 kPa and 56.79°, respectively, based on the analysis of the four rock samples. These values were found to be high due to the interlocking texture of mineral grains in granite rock, which is primarily composed of quartz. The quartz mineral is hard and resistant to weathering [15]. However, according to [16], the shear strength parameters of biotite granite saprock at KM31 of the Karak Highway is 14.5 kPa with 34.3° for cohesion and friction angle, which is relatively lower than the rock strength at KM29. The difference is due to weathering that has changed the granite saprock at KM31 into the soil, thus reducing its strength.

The UCS values are tabulated in Table 1. Both rock slope sections G2 and G3 are categorized as strong rock, whereas slope section G1 is categorized as very strong rock [17]. Strengths differ depending on various factors, including weathering, the presence of fractures or gaps, and in-situ stress. Granite, in its pristine, un-weathered state and with minimal fractures, boasts the highest strength. In contrast, weathered granite with unfavourably oriented fractures tends to be weaker and more susceptible to failure.

Table 1 Schmidt hammer rebound value and corresponding UCS (MPa)

Location	Symbol	Schmidt hammer rebound value	Av: of five highest values	UCS (MPa)
Gombak KM29	G1	64,63,62,60,59	61.60	163.97
	G2	62,61,60,59,58	60.00	150.65
	G3	58,55,54,53,52	54.40	113.98

3.1 Stability Analysis

3.1.1 Kinematic Analysis

The Rocscience Dips 7.0 software was utilized to perform kinematic analysis to assess possible failure modes, including planar, wedge, and toppling [18]. Section G1 has a slope orientation of $88^\circ/125^\circ$, while section G2 is at $78^\circ/127^\circ$, and section G3 is at $80^\circ/154^\circ$. Each of the rock slope sections G1, G2, and G3 experienced planar failure, as shown in figures 4a, 4d, and 4g. Identifying planar failure required locating the pole of the joint set in a critical zone highlighted in red. In section G1, the pole of joint set F3 fell within the critical zone, indicating that joint set F3 caused the planar failure, as shown in Fig 4a. Similarly, the joint pole located in section G2 was situated in a critical zone for planar failure, indicating that it was the cause of the failure in that specific area, as illustrated in Fig 4d. In section G3 (see Fig 4g), planar failure was associated with joint set F2, which is situated in the critical zone as well.

Moreover, the wedge failure occurred due to the intersection of two joint sets within the critical zone, which was also highlighted in red. Wedge failure was noticed in important rock slope segments G1, G2, and G3. In section G1, as depicted in Fig 4b, the intersection of joint sets F3 and F2 resulted in wedge failure, with the potential for the wedge to slide toward 88° . In section G2, shown in Fig 4e, wedge failure was caused by the intersection of joint sets F1, F3, and F4 with F2, as well as F3 intersecting with F4, all occurring within the critical zone, leading to a probable failure direction toward 78° . In section G3 (see Fig 4h), the discontinuity of F5 intersects with F2 and F3, while F3 also intersects with F4, all within the critical zone, suggesting a potential slide direction toward 80° . However, no toppling failures were observed in slope sections G1, G2, and G3. The output were simplified in Table 2.

Based on this analysis, wedge failures exhibit a higher likelihood of occurrence compared to planar and toppling failures due to the intersecting planes of weakness that define the geometry of a wedge. This setup offers multiple directions for potential movement, unlike planar or toppling failures that rely on a single weak plane or axis. Wedge failures also tend to involve larger volumes of rock, which adds weight and increases the chance of sliding. Additionally, the wedge's alignment with the slope often allows it to slide along the intersection line, making failure more likely than in simpler failure types. These factors together lead to a higher rate of wedge failure on rock slopes.

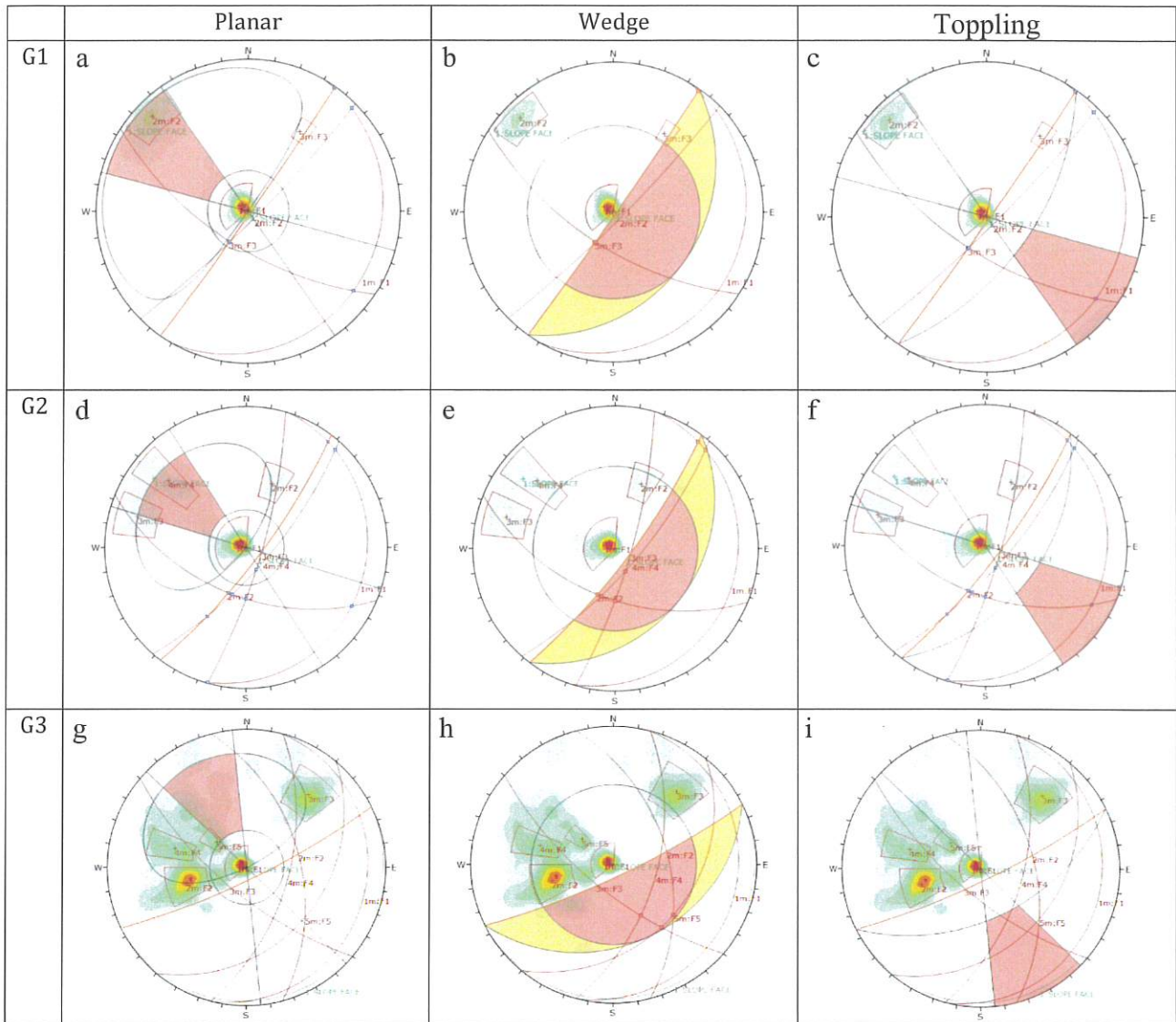


Fig. 4 Kinematic results using Rocscience Dips software for slope section G1, G2, and G3: planar, wedge, and toppling mode of failures

Table 2 Summary of kinematic analysis at KM29

Section	Modes of failure	Slope face orientation (DA/DD)	Percentage of failure (%)
G1	Planar		20
	Wedge	88°/125°	50
	Toppling		0
G2	Planar		14.3
	Wedge	78°/127°	60
	Toppling		0
G3	Planar		8
	Wedge	80°/154°	20
	Toppling		0

3.1.2 Non-Kinematic Analysis

The stability analysis of all slope sections was performed using the LEM approach, simulated using Geostudio 2023 through Slope/W software. The rock material was modelled using the Shear-Normal function to calculate

friction angle and cohesion intercept. The essential analysis input parameters comprised of the granite rock's unit weight, cohesion, and friction angle. These values, obtained from a laboratory test and a previous study, were 18 kN/m³ [19], 23.81 kPa, and 26.35°, respectively. The LEM result showed that the FOS for all slope sections exceeded 1.5, as shown in Fig 5a-5c, indicating that the slope was stable [20].

Kinematics and LEM revealed a contradictory result. The main limitation of LEM is that it overlooks the condition of the rock mass. As a result, a highly fractured rock mass may be incorrectly represented as stable and posing no risk of failure.

Slopes showing kinematic instability are at risk of experiencing planar, wedge, or toppling failures, especially when the discontinuities are poorly oriented. Nevertheless, it is crucial to recognize that kinematic instability alone does not guarantee slope failure, as the factor of safety in limit equilibrium could still exceed 1.0. On the other hand, slopes are considered stable if their limit equilibrium factor of safety is above 1.0, regardless of potential failure modes revealed by kinematic analysis. The safety factor in limit equilibrium indicates both the margin of safety and the likelihood of failure [21]. Kinematic analysis identifies potential failure modes but does not quantify stability, while limit equilibrium calculates the safety factor against failure. A slope may be kinematically unstable but still have an adequate limit equilibrium FOS. Therefore, it is crucial to consider both kinematic and LEM analysis methods when evaluating rock slope stability and determining next steps.

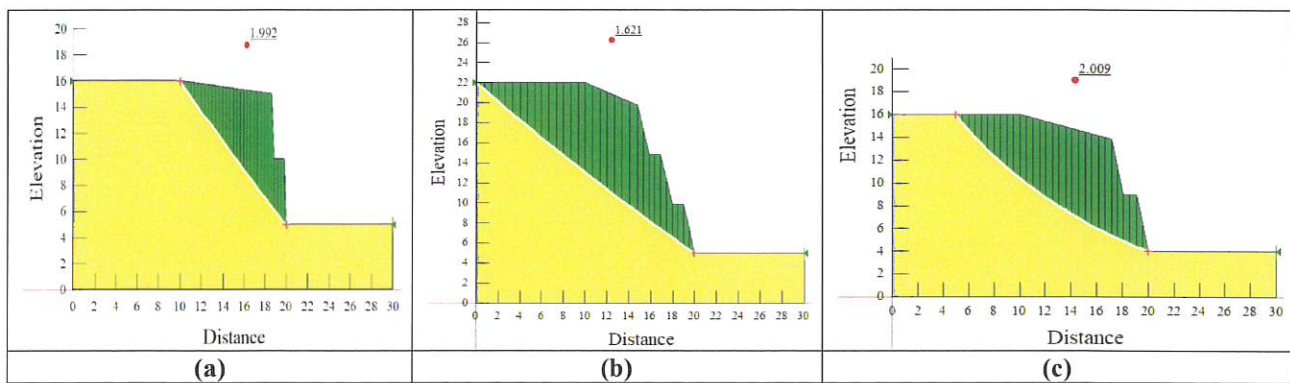


Fig. 5 Slope stability analysis using LEM for rock slope section (a) G1, (b) G2 and (c) G3

Conclusions

This study combines kinematic and LEM analyses to assess rock slope stability at KM29 of the Karak Highway, close to the Gombak toll. Parameters such as discontinuities and mechanical properties were used to analyze the slope. The surface rock hardness was measured using the Schmidt rebound hammer, yielding an average reading of 61.60, 60.00, and 54.40 MPa for slope sections G1, G2, and G3, respectively. The results were correlated to the UCS and the equivalent rock strength of approximately 163.97, 150.65, and 113.98 MPa. Experiments conducted on four rock specimens revealed an average cohesion value of 20.56 kPa and a friction angle of 56.79°. The kinematic analysis showed that slope sections G1, G2, and G3 experienced wedge and planar failures, analyzed using Rocscience Dips software. On the other hand, the safety factor (SF) calculated by LEM and modeled with Slope/W showed that all slope segments are secure, having a ratio higher than 1.5. Take into account combining kinematic and LEM analysis techniques to assess the rock slope's stability and strengthen the ultimate conclusion.

Acknowledgement

The National Defence University of Malaysia is acknowledged by the authors for providing funding and support for this project through a grant, with project code: UPNM/2023/GPJP/TK/2. We also acknowledge the technical support and data access provided by MTD Group and ANIH Berhad.

Conflict of Interest

The authors clarify that there are no conflicts of interest concerning the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: **study conception and design:** Nurul Afiffah Khairulazman, Jestin Jelani; **data collection:** Nurul Afiffah Khairulazman, Jestin Jelani; **analysis and interpretation of results:** Nurul Afiffah Khairulazman, Jestin Jelani, Zainuddin Md Yusoff, Mohd Rozi Umor; **draft manuscript preparation:** Nurul Afiffah Khairulazman, Jestin Jelani, Suriyadi Sujipto. All authors reviewed the results and approved the final version of the manuscript.

References

- [1] İnan Keskin, & Polat, A. (2022). Kinematic Analysis and Rockfall Assessment of Rock Slope at the UNESCO World Heritage city (Safranbolu/Turkey). *Iranian Journal of Science and Technology Transactions of Civil Engineering*, 46(1), 367–384. <https://doi.org/10.1007/s40996-021-00803-8>
- [2] Ishak, A. S. A., Jelani, J., Wong, S. Y., Suif, Z., & Mazuki, A. L. A. (2024). Experimental and Numerical Study on the Behaviour of Silica Sand Slope Model Subjected to Surcharge Load. *Jurnal Teknologi*, 86(1), 165–173. <https://doi.org/10.11113/jurnalteknologi.v86.20463>
- [3] Jelani, J., Abdul Rahman, M. S. S., Sojipto, S., Wan Mohamed Sabri, M. S. W., Lee, M. L., & Ahmad, N., (2024). Geotechnical Investigation of a Landslide Incident in Hulu Kelang, Malaysia. *International Journal of GEOMATE*, 27(120), 138-145. <https://doi.org/10.21660/2024.120.g13382>
- [4] Kazmi, D., Qasim, S., Harahap, I. S. H., & Vu, T. H. (2017). Analytical study of the causes of the major landslide of Bukit Antarabangsa in 2008 using fault tree analysis. *Innovative Infrastructure Solutions*. 2(1) <https://doi.org/10.1007/s41062-017-0105-4>
- [5] Martireni, A. P., K Sugianti, K Hermawan, A Tohari, S Wibawa, & E Soebeowo. (2023). Rock slope stability assessment using kinematic analysis at Gunung Batu, Lembang, West Java, Indonesia. *IOP Conference Series*, 1173(1), 012026–012026. <https://doi.org/10.1088/1755-1315/1173/1/012026>
- [6] Shariati, M., & Fereidooni, D. (2021). Rock slope stability evaluation using kinematic and kinetic methods along the Kamyaran-Marivan road, west of Iran. *Journal of Mountain Science*, 18(3), 779–793. <https://doi.org/10.1007/s11629-020-6438-z>
- [7] Lamessa, G., & Meten, M. (2021). Stability analysis of rock slope along selected road sections from Gutane Migiru town to Fincha sugar factory, Oromiya, Ethiopia. *SN Applied Sciences*, 3(2). <https://doi.org/10.1007/s42452-020-04026-w>
- [8] Syahirah, A., Ishak, A., Jelani, J., Mohd, S., Syed Mohd Dardin, F., Rashid, Z., & Suif, Z. (2023). Concept Development of Inclinator for Real- Time Data Collection in Slope Movement Detection. *Journal of Engineering Science and Technology ICIST2022*, 18(1), 132–144. https://jestec.taylors.edu.my/Special%20Issue%20ICIST%202022_1/ICIST_1_12.pdf
- [9] Azman, A. G. (2000). The Western Belt granite of Peninsular Malaysia: some emergent problems on granite classification and its implication. *Geosciences Journal*, 4(4), 283–293. <https://doi.org/10.1007/bf02914037>
- [10] Ghani, A. A., Hazad, F. I., Jamil, A., Xiang, Q. L., Atiqah Wan Ismail, W. N., Chung, S.-L., Lai, Y.-M., Roselee, M. H., Islami, N., Nyein, K. K., Amir Hassan, M. H., Abu Bakar, M. F., & Umor, M. R. (2014). Permian ultrafelsic A-type granite from Besar Islands group, Johor, peninsular Malaysia. *Journal of Earth System Science*, 123(8), 1857–1878. <https://doi.org/10.1007/s12040-014-0501-5>
- [11] Zangerl, C., Koppensteiner, M., & Strauhel, T. (2022). Semiautomated Statistical Discontinuity Analyses from Scanline Data of Fractured Rock Masses. *Applied Sciences*, 12(19), 9622. <https://doi.org/10.3390/app12199622>
- [12] American. (2017). Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force. <https://doi.org/10.1520/d5607-16>
- [13] Mohammed. (2023). Geostatistical assessment of unconfined compressive strength of rocks in Northeast Jeddah, Saudi Arabia. *International Journal of ADVANCED and APPLIED SCIENCES*, 10(9), 92–100. <https://doi.org/10.21833/ijaas.2023.09.011>
- [14] Wang, M., & Wan, W. (2019). A new empirical formula for evaluating uniaxial compressive strength using the Schmidt hammer test. *International Journal of Rock Mechanics and Mining Sciences*, 123, 104094. <https://doi.org/10.1016/j.ijrmmms.2019.104094>
- [15] Woo, I., Fleurisson, J.-A., & Park, H.-J. (2010). Influence of weathering on shear strength of joints in a porphyritic granite rock mass in Jechon area, South Korea. *Geosciences Journal*, 14(3), 289–299. <https://doi.org/10.1007/s12303-010-0026-0>
- [16] John Kuna Raj. (2022). Drained Shear Strength Parameters of Saprock from A Weathering Profile Over Porphyritic Biotite Granite at KM 31 Of The Kuala Lumpur - Karak Highway, Peninsular Malaysia. *Bulletin of the Geological Society of Malaysia*, 74(1), 43–53. <https://doi.org/10.7186/bgsm74202203>
- [17] Bolla, A., & Paronuzzi, P. (2021). UCS field estimation of intact rock using the Schmidt hammer: A new empirical approach. *IOP Conference Series: Earth and Environmental Science*, 833(1), 012014. <https://doi.org/10.1088/1755-1315/833/1/012014>
- [18] Aftab Ur Rahman, Zhang, G., AlQahtani, S. A., Hammad Tariq Janjuhah, Hussain, I., Habib Ur Rehman, & Liaqat Ali Shah. (2023). Geotechnical Assessment of Rock Slope Stability Using Kinematic and Limit Equilibrium Analysis for Safety Evaluation. *Water*, 15(10), 1924–1924. <https://doi.org/10.3390/w15101924>
- [19] Kuna Raj, J. (2023). Physical characterization of the weathering profile over a sheared, biotite-muscovite granite in Peninsular Malaysia. *Bulletin of the Geological Society of Malaysia*, 75, 25–36. <https://doi.org/10.7186/bgsm75202304>

- [20] Mohammed Al-Bared, M. A., Abdullah, R. A., Mohd Yunus, N. Z., Mohd Amin, M. F., & Awang, H. (2015). Rock Slope Assessment Using Kinematic and Numerical Analyses. *Jurnal Teknologi*, 77(11). <https://doi.org/10.11113/jt.v77.6421>
- [21] Abdul Rahim, A. F., Rafek, A. G., Serasa, A. S., Abdullah, R. A., Rahim, A., Wan Harun, W. S., Foong, S. Y., Muslim, A., Lee, K. E., Nguyen, X. H., Tran, V. X., & Goh, T. L. (2022). Application of a Comprehensive Rock Slope Stability Assessment Approach for Selected Malaysian Granitic Rock Slopes. *Sains Malaysiana*, 51(2), 421–436. <https://doi.org/10.17576/ism-2022-5102-08>