Discontinuity Mapping using Terrestrial Laser Scanner and Kinematic Method

Rasyikin Roslan, Rohayu Che Omar, Intan Nor Zuliana Baharuddin, Warishah Abdul Wahab, Faten Syaira Buslima

Abstract: ***This study presents the results of discontinuity mapping using terrestrial laser scanning (TLS) survey and the kinematic method. The results provide the current site and slope condition of comprehensive geological study using terrestrial laser scanning and discontinuity survey at Simpang Pulai, Perak. From the results obtained, it can be concluded that the major potential failures in this area are wedge and plane failures, but there are some area had the potential of toppling failure. This study, however, constitutes a preliminary design consideration and not intended for use in final design or construction. The final design shall be made by the engineer based on the further detail site investigation (S.I.) and other design factors to be used in the actual design of the project.***

Keywords: Discontinuity Mapping, Slope Stability Analysis, Rock, Terrestrial Laser Scanner, Kinematic Method

I. INTRODUCTION

Discontinuity mapping can be defined as a process to identify the failure planes and to evaluate slope stability [1]. There are various rock discontinuities such as bedding, foliation, cleavages, crack, joint, fault, and unconformity planes that are capable of behaving as the sliding plane in some mass movement occurrences stability of slopes composed by rocks, stability is affected by the shear strength of the rock and influenced by the presence of geological structures [2]. In general, discontinuity used to define the structural weakness plane where movement can take place. Four basic mechanisms of slope failures are a circular failure, plane failure, wedge failure and toppling failure [1].

The stability of rock slopes, both natural and engineered, is highly controlled by discontinuities. Quantification of their characteristics consequently represents a major initial step instability analysis [3]. Recent developments in terrestrial remote sensing techniques such as terrestrial laser scanning (TLS) have allowed the user to obtain high-precision profiles of distant landscapes and objects including detailed slope information for three-dimensional (3D) slope stability analysis [4] and data of inaccessible outcrops [5].

The kinematic method is one of the stability analysis techniques. This method is based on the principle of kinematics which deals with the geometric condition that is required for the movement of the rock block over the discontinuity plane, without considering any forces responsible for the sliding [6]. Kinematic analysis often used to investigate and determine the probability of structurally controlled failures [plane sliding, wedge sliding, and toppling [7].

Scope and Limitations

The purpose of this study is to provide the current site and slope condition of comprehensive geological study using terrestrial laser scanning and discontinuity survey at Simpang Pulai, Perak.

Study Area

The survey area was located in Simpang Pulai, Perak situated at 4°31'44.15"N latitude and 101°9'21.37"E as shown in Figure 1. The geology map in Figure 2 indicates the Kinta Limestone. This area has the existence of massive limestone bodies that are heavily jointed and fractured.

Fig. 1 Site location of survey works for comprehensive geological study at Simpang Pulai, Perak

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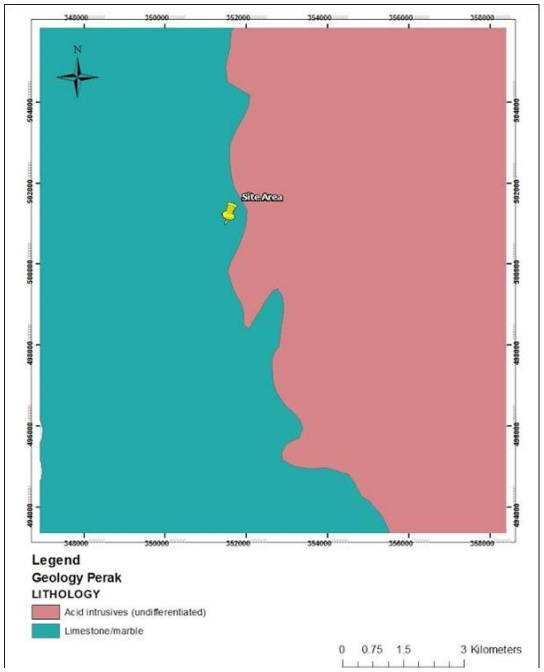


Fig. 2 Geological map of the site area

II. METHODOLOGY

Two steps involve in this study including terrestrial laser scanning (TLS) survey and discontinuity mapping.

Terrestrial Laser Scanning (TLS) Survey

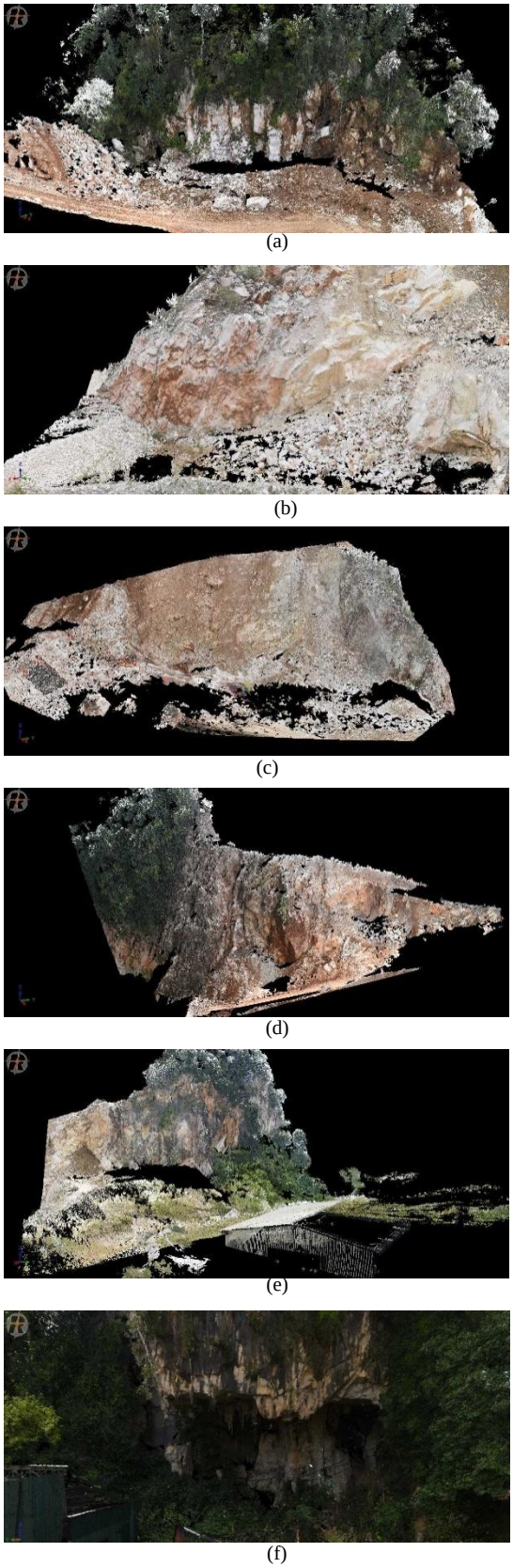
The survey was performed using a RIEGL VZ-400i terrestrial laser scanner. Basically, the setup of the scanner position depends on the field of view of the scanner. The position of the scanner is set at in front of the slope face and can detect approximately 600-meter distance from the scanner.

A reflector was re-setup every time a new scan position was established. The function of scanning the reflector is to use back sighting method when registering all the scan position afterward. Various resolutions were used during scanning the area i.e Panorama_50 was used when scanning regularly (open area) while Panorama_20 was used for the fine scan (dense area). Besides that, scanning range was set to 450-meter and 1400-meter depending on the coverage distance between the scanner and the area of interest. The time duration for each scan setting is as follow:

i) Panorama_50 + 450 meter range + image = approx. 2 minutes

ii) Panorama_20 + 250 meter range + image = approx. 4 minutes

The data captured by laser scanning (raw data) is transferred to the software program called RiSCAN PRO software for analysis. The data obtained from this survey are divided into six (6) sub-areas indicated in Fig. 3 (a) to (f). All the data will be compiled in an external hard disk



(a) (b) (c) (d) (e) (f)

Fig. 3 Terrestrial Laser Scanning (TLS) survey for (a) Area 1, (b) Area 2, (c) Area 3,(d) Area 4, (e) Area 5, (f) Area 6

Discontinuity Mapping

The site mapping from discontinuity survey and slope stability assessments (using TLS) was carried out on the site. The slope stability assessment adopted in this research is aimed at highlighting any potential risk which may give rise to the instability of slopes and to analyse the probable mode of failures. The kinematic stability is analysed using ShapeMetrix 3D and Dips software. These software programs used to analyse the potential for the various modes of rock slope failure (i.e plane, wedge and toppling failure). The failure occurs due to the presence of unfavourably oriented discontinuities.

III. RESULTS AND ANALYSIS

Kinematic analysis has been performed to all six areas (Area 1, Area 2, Area 3, Area 4, Area 5 and Area 6). The results of the analyses were discussed in sub-section 3.1 to 3.6.

Kinematic Analysis for Area 1

Fig. 4. Red arrows show the direction of the discontinuity. The kinematic analysis for Area 1 is shown in Fig. 5. There are ten (10) sets of major discontinuities with slope face ($145^o/62^o$) in Area 1.

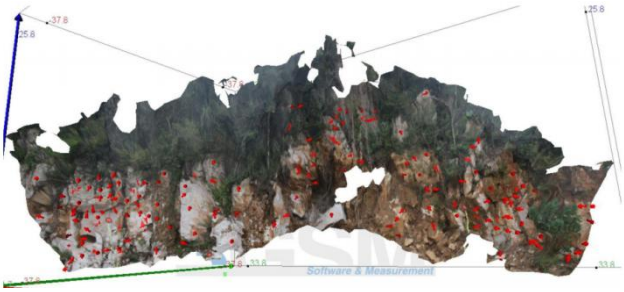


Fig. 4 3D image for Area 1

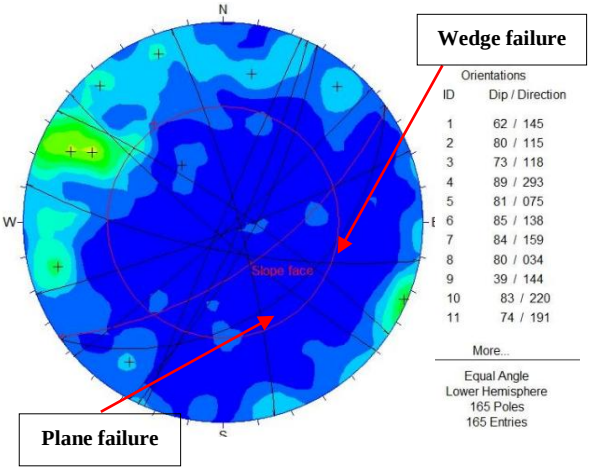


Fig. 5 Kinematic analysis for Area 1

From Fig. 5, it can be seen that there are 165 readings of discontinuity surveys along this area. The potential failures in this area are plane and wedge failures.

Kinematic Analysis for Area 2

The 3D image for Area 2 is shown in Fig. 6. In this area, there are eight (8) sets of major discontinuities with slope face ($035^o/70^o$) were identified as shown in Fig. 7.

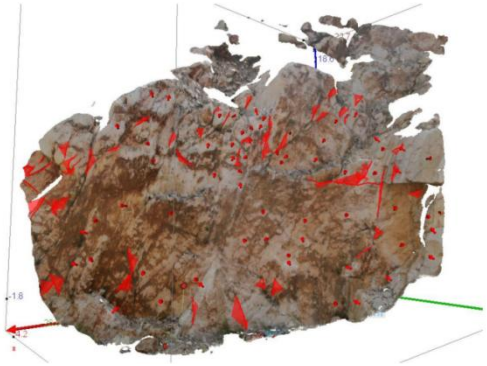


Fig. 6 3D image of Area 2

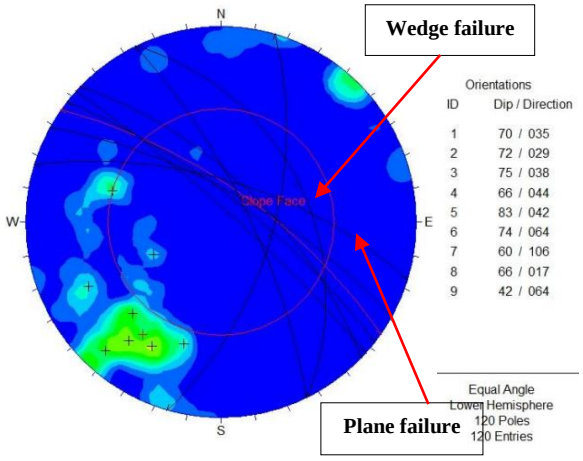


Fig. 7 Kinematic analysis for Area 2

Fig. 7 shows the kinematic analysis for Area 2. This analysis came from 120 readings of the discontinuity survey along this area. There are two potential failures identified in this area which are plane and wedge failures.

Kinematic Analysis for Area 3

In Area 3, as shown in Fig. 8, there are five (5) sets of major discontinuities with slope face ($146^o/55^o$) were identified. This result came from 100 readings of discontinuity survey along this area as shown in Fig. 9.

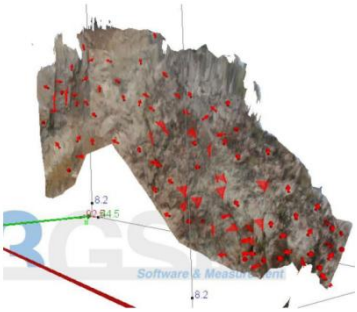


Fig. 8 3D image of Area 3

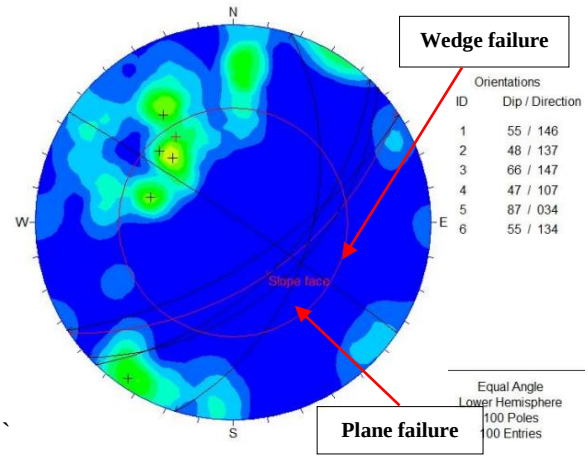


Fig. 9 Kinematic analysis for Area 3

Fig. 9 shows the results of the kinematic analysis for Area 3. In this area, the potential failures that have been identified are plane and wedge failures.

Kinematic Analysis for Area 4

As shown in Fig. 10, there are five (5) sets of major discontinuities with slope face (107°/52°) in Area 5. The red, yellow and green arrows differentiate the direction of discontinuities in Area 4.

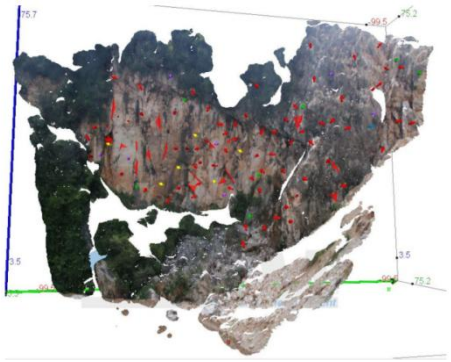


Fig. 10 3D image of Area 4

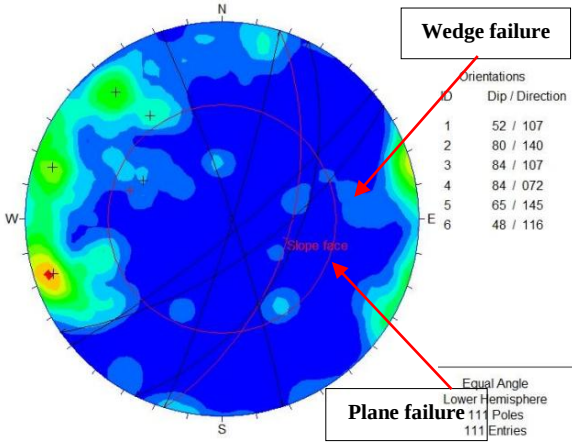


Fig. 11 Kinematic analysis for Area 4

Fig. 11 shows the kinematic analysis results for Area 4. These results came from 111 readings of the discontinuity survey along this area. Based on the results, it can be seen that the potential failures in this section are plane and wedge failures.

Kinematic Analysis for Area 5

There are seven (7) sets of major discontinuities with slope face (022°/77°) at Area 6 as shown in Fig. 12. The results came from 141 readings of discontinuity survey along this area as stated in Fig. 13.

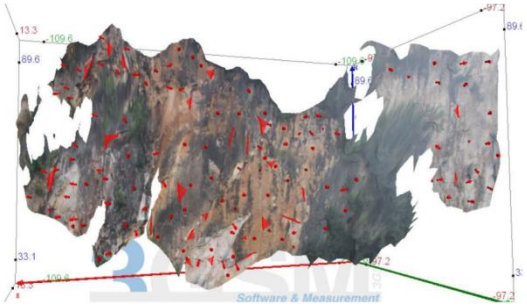


Fig. 12 3D image of Area 5

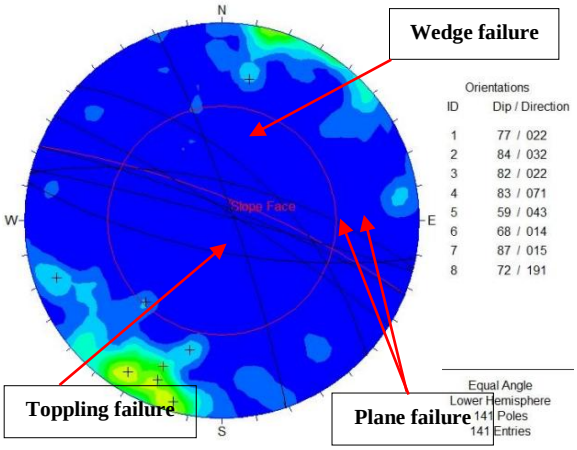


Fig. 13 Kinematic analysis for Area 5

Kinematic analysis for Area 5 is shown in Fig. 13. Based on the figure, three types of potential failures were identified in this area which is plane, wedge and toppling failures.

Kinematic Analysis for Area 6

In Area 6, as shown in Fig. 14, there are eight (8) sets of major discontinuities with slope face (298°/77°) that were detected based on 139 readings of discontinuity survey along this area.

Fig. 14 3D image of Area 6

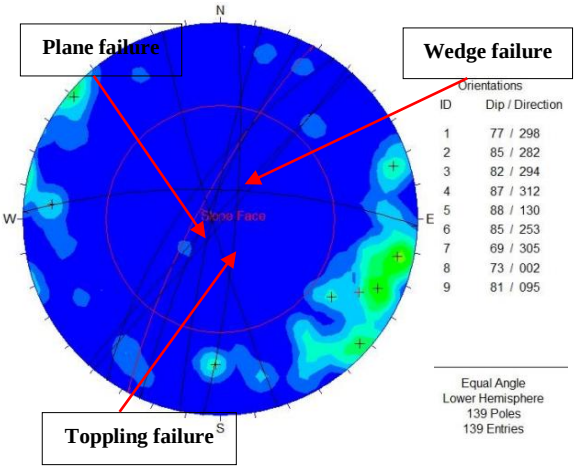


Fig. 15 Kinematic analysis for Area 6

Fig. 15 represents the kinematic analysis results for Area 6. The potential failures that were identified in this section are plane, wedge and toppling failures.

IV. CONCLUDING REMARKS

This study is mainly focused onthe current site and slope condition of comprehensive geological study using terrestrial laser scanning and discontinuity survey at Simpang Pulai, Perak. The following conclusions can be drawn from this survey:

a) Current Digital Terrain Model (DTM) and Digital Surface Model (DSM) has been generated from the terrestrial laser scanning.

b) The major potential failures in this area are wedge and plane failures, but there are some areas had the potential of toppling failure.

This study, however, constitutes a preliminary design consideration and not intended for use in final design or construction. The final design shall be made by the engineer based on the further detail S.I investigation and other design factor to be used in the actual design of the project.

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REFERENCES

1. Madun and H. Omar, “Influence of discontinuity sets on slope failures at Pos Selim Highway, Malaysia.” Geological Society of Malaysia Annual Geological Conference 2001.
2. N. K. Citrabhuwana, and S. B. K. Purwanto, ”Geology and Slope Stability Analysis using Markland Method on Road Segment of Piyungan – Patuk, Sleman and Gunungkidul Regencies, Yogyakarta.” Special Int. J. Econ. Environ. Geol. Vol:7(1) 42-52, 2016.
3. M. Sturzenegger, “Multi-Scale Characterization of Rock Mass Discontinuities and Rock Slope Geometry Using Terrestrial Remote Sensing Techniques.” PhD THESES. Simon Fraser University. 2010.
4. M. Wang, K. Liu, G. Yang and J Xie, “Three-dimensional slope stability analysis using laser scanning and numerical simulation.” Geomatics, Natural Hazards and Risk Journal, Volume 8, 2017 - Issue 2.
5. H. T. Nguyen , T. M. Fernandez-Steeger , T. Wiatr , D. Rodrigues , and R. Azzam, “Use of Terrestrial Laser Scanning For Engineering Geological Applications On Volcanic Rock Slopes – An Example From Madeira Island (Portugal).” Nat. Hazards Earth Syst. Sci., 11, 807–817, 2011.
6. T. K. Raghuvanshi, “Plane failure in rock slopes – A review on stability analysis techniques.” Journal of King Saud University - Science, Volume 31, Issue 1, January 2019, Pages 101-109.
7. T. Singh and K.S. Rao “Kinematic stability analysis of multi-faced rock slopes in the Himalayas.” Recent Advances in Rock Engineering (RARE 2016).