Application of Photogrammetric Technique in Determination of Rock Slope Stability of Quarry

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Abstract. Identify the characterization and orientation of the discontinuities such as joint, bedding and fault is a requirement in rock slope stability analysis because discontinuities control the type of failure. Until today, geologist still practices the classical method to determine the dip and strike of discontinuities which is by using Brunton compass at the field. It is difficult to measure at the inaccessible area, dangerous when having physical contact with the steep, fractured slope and time consuming to cover a large area are limitations of this method. A recent development in remote sensing has introduced Terrestrial Laser Scanner (TLS) as an indirect method in mapping the rock slopes by using the point cloud data. TLS allows for extremely rapid acquisition of large amounts of 3D coordinates of objects’ surfaces, with high precision measurement. The aim of this paper is to apply Terrestrial Laser Scanner (TLS) in determine the dip and strikes of the joints and compare the value with the hand measurement at a granite quarry in Ulu Choh, Johor. Analysis of the data shows the TLS method able to obtain the data for the joints and show almost the same trend. Thus, TLS is an efficient technology in geological practice.

1. Introduction

Rock slope failures are a natural disaster that has a lot of attention in these three decades because they cause severe loss of property and human life worldwide. In rock slope study, it is very important to identify the characterization and orientation of the discontinuities such as joints, bedding and fault [1][2]. Duncan (2017) highlighted that the orientation of geological features, dip and dip direction is required in rock slope stability analysis [3]. This is because the geological condition will contribute to the type of failures and instability in the rocky slope. Planar sliding, wedge, toppling and circular failure are a type of failures that can occur at the slope and the failure are controlled by the joints[17]. Currently, the traditional method of geological mapping is still applied by the geologist. The instrument used for measuring the dip and strike is Brunton compass and Schmidt hammer.

Geological survey mapping required the person to walk through all over the site, identify the numbers of the joint set, measure the dip and strike of each joint and gather the information in the notebook. Taking photos with the location of the photo is also required for the documentation. However, this method has limitations and challenges. Difficulties to access, using traditional tools to measure features at large distance and limited possibilities of recognition and localization are the challenges when doing geological mapping [4]. In addition, geological mapping is also dangerous and may affect the safety of a person in charge when the rock slope is steep and very high as it required physical contact with the slope. Besides, geological survey mapping is also time-consuming since

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A geologist need to cover the whole study area during the fieldwork, followed by the analysis and data processing [5]. Therefore, digital geological mapping technology is needed to overcome the problems. Digital capture of the geological data at the field is more efficient and can improve the workflow [6]. Capturing a high resolution of point cloud data can produce a detailed mapping of geological features and the geological structure can be analysed digitally. This is particularly useful for data collection in locations with limited human access. In recent years, remote sensing technology is widely applied in many fields of investigation.

Amongst the new methods for accurate rock slope surface, ground-based technologies using terrestrial laser scanning (TLS) [7], [8] have been increasingly used as efficient remote surveying techniques for the characterization and mapping of rock slopes. TLS is used to measure features of inaccessible rock boulder, study on the geomorphological evolution of the rock face and frequency of rockfall and also to detect displacement of millimetric magnitude prior to failure [9] [10] [11]. The advantage of TLS is it able to get an accurate measurement at large area, can determine the type of rock at a distance and visualize subject in 3 dimensional [12]. The prior research is focused on the analysis of the discontinuity in the rock by using a compass and compared with the TLS data. Three points, planar regression and moment of inertia analysis are also applied to process the point cloud and the result show that Light Detection and Ranging (LIDAR) survey can provide a realistic result of planar geological settings [13]. Thus, this paper will review and study on the application of terrestrial laser scanning as a tool for the rock slope stability analysis at a granite quarry.

2.0 Study Area

The study was conducted in Malaysian Rock Products Sdn Bhd (IJM) quarry at Ulu Choh in Johor state, Western Belt of Peninsular Malaysia. The rock slope is sited at a latitude of 1.537666 and longitude of 103.546389 in the Southern Province of Malaysia. Figure 1 shows the location of the rock slope. Based on the geological map, the lithology of the study area is a massive granitic rock, specifically medium-grained leucogranite. In the quarry, the granitic rock has a large range of weathering grade which is from fresh granite to very weathered granite. However, the study focus on the small area in the quarry and the weathering grade of the area is fresh granite to slightly weathered (III) granite. The rock slope has 7 meter height. Due to blasting activities, the granitic rocks are highly fractured. It has natural joints and manmade joints.

Figure 1: Location and geological map of the study area (Jabatan Mineral dan Geosains Malaysia).
3.0 Methodology

Terrestrial Laser Scanner (TLS)

Terrestrial Laser Scanner (TLS) is a remote sensing system that can define the distance to an object by analysing a laser light return on an object’s surface. TLS mounted on a tripod captures the relative position of objects’ surfaces in its line of sight as a 3 Dimensional (3D) point cloud consisting of millions of (xyz) points and their respective intensity value (i) [14]. TLS surveys were carried out from reachable points. 2 scan view positions have been performed at the site, and points cloud data were collected. One is nearer to the slope and another one is far from the slope. Multiple overlapping point cloud ensures the rock surface scanning cover the occlusion rock surface [15]. TLS data acquisition were carry-out using traverse techniques. TLS was set up over a known Ground Control Point (GCP) and back-sight to a known Cloud Combination Probe (CCP). Point cloud density was recorded using high-speed mode at 12mm@10 meter and panoramic images of scanning area were recorded using TLS internal camera with a resolution of 5 megapixels (Figure 2). All information such as setting parameters used, occupied station, backsight target, scanned point cloud and scanned images were recorded in TLS memory.

The objective of TLS was to build 3D surface models of the whole rock slopes to be investigated. Raw point clouds resolution for each scan position was set by choosing the best arrangement between the number of points (to avoid large and too heavy datasets) and the distance between contiguous points on the rocky slopes, which must be related to the minimum dimension of the features to be extracted (i.e., discontinuity surfaces and digital elevation model (DEM) resolution). The scans point clouds from different locations are combined within the same coordinate system in post-processing. For the georeferencing of the TLS point cloud, TLS is applied with Global Positioning System (GPS) [16]. Figure 3 shows the application of Real Time Kinematic (RTK) GPS in the field to establish TLS GCPs. The computed coordinates were used for the geo-reference processed to rectification the 3D model from the TLS point cloud. This operation is required to georeference the point cloud on a chosen reference coordinate system and to merge two or more scans of the same object realized from different points of view. Figure 4 shows the TLS point cloud at the quarry.

![Figure 2: Image using TLS internal camera.](image)

Upon completion TLS field data acquisition, the following data such as occupied station info, backsight station info, instrument height, the height of backsight target, digit images of the scan area, scan point clouds and scanning setting parameters were stored in one job. The job folder name based on TLS occupied the station. All job folders then transfer to personal computer for data processing using ScanMaster software. In ScanMaster software, a new project database was created. Then all TLS data (job folder for each occupied station) were import into job created in ScanMaster database. The point cloud is processed in the software.
Field observation and discontinuity survey have been conducted in order to collect the discontinuity data and to compare with the data from the terrestrial laser scanner. Data that has been collected are the dip, dip direction of the joints, the strength of the rock slope, presence of seepage and other details of the discontinuities. Brunton Compass is used for the calculation of the strike and dip of Geological features. The strike is measured by levelling with the bull’s eye level. The compass along the plane being measured. The dip is taken by laying the side of the compass perpendicular to the strike measurement and rotating horizontal level until the bubble is stable and the reading has been made.

4.0 Result and Analysis

After processing the point cloud, joints are identified from the rock slope (Figure 5) in Scan Master Software. In 100m length of the slope, dip and strike of the joints obtained from the terrestrial laser scanner are compared with the measurement of dip and strike took from the Brunton compass at the field. Figure 6 shows joints that have been chosen in 100m length of the slope. Table 2 shows the orientation value get from the TLS and direct contact measurement by using the geological compass.

![Figure 3: Concept of RTK GPS Surveying technique.](image1)

![Figure 4: TLS point cloud](image2)
Comparison of the result data of terrestrial laser scanner and the geological compass can be seen through stereonet form in Dips software as shown in Figure 7. Both of the stereonet from the TLS data and compass data show that the area consists of 3 joint sets which are j1, j2 and j3. However, the major joint set is j1 and j2. Most dominant discontinuities are dipping toward South West. Mean of the trend value is , while the mean of the dip value.

![Figure 5: Joint identified from Terrestrial Laser Scanner (TLS)](image1)

![Figure 6: Orientation of joint obtained from the TLS](image2)

| Terrestrial Laser Scanner (TLS) | Hand Measurement |
|-------------------------------|------------------|
| Dip Strike                    | Dip Strike       |
| 75 173                        | 80 177           |
| 69 103                        | 79 175           |
| 70 123                        | 75 170           |
| 66 176                        | 70 105           |
| 74 160                        | 58 150           |
| 70 114                        | 50 145           |
| 51 147                        | 68 103           |

Table 2: Dip and strike from TLS and hand measurement by using Brunton compass.
Figure 7: Contour plot and mean discontinuity plane for a) Terrestrial Laser Scanner b) Hand Measurement.

5.0 Conclusion

Terrestrial Laser Scanner provides precise measurement and rapid acquisition method of 3D slope surface. TLS help to obtain data from a remote and inaccessible area. Result shows that the TLS data produce almost the same trend as taken directly from the site. This practice can avoid dangerous things to happen and can consume time in data collection. The experimental work presented in this article was performed at University Technology Malaysia (UTM) with funding from Ministry of Higher Education through research grant number Q.J130000.2422.03G76 (THE INFLUENCE OF PLANT DIVERSITY ON SLOPE STABILITY).

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