Evaluation of Rock Mass Quality using Unmanned Aerial Vehicle Survey for Slope instability Assessment

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ABSTRACT: Rock mass quality (RQD) is the fundamental way of evaluation of rock mass quality in mining and geotechnical investigation. However, the estimation of RQD in morphological complex areas is difficult to obtain. In this research work, an unmanned aerial vehicle (UAV) survey was adopted to estimate the RQD at various locations along the slope using volumetric joint counts (Jv). At the centre of the slope, 72% of the data points represent fair rock, while 28% shows poor rock. In contrast, the 20 data point obtained towards the west included 90% of data points for fair rock while 10 % for good rock. Thus, based on his study it is concluded that UAV survey is an efficient way of characterization of rock mass quality.

Keywords: Slope stability, UAV, RQD, characterization, rock mass evaluation.

1 INTRODUCTION

Rock quality designation (RQD) is a fundamental way of evaluating rock mass quality based on the RQD index by estimating the degree of jointing of the rock mass *(Deere et al., 1967; Khurshid et al., 2022; Tsang et al., 2022)*. Due to its simplicity, the RQD is a widely applied technique for slope instability assessment. The conventional way of estimating of RQD is coring and scanline mapping by manual technique *(Zheng et al., 2018)*. However, the traditional way of measuring RQD in morphological complex areas is not easy. The aforementioned limitations of the conventional way of estimating RQD are successfully overcome by Unmanned Aerial Vehicle (UAV) survey. The technological advancement in the UAV survey in recent decades has made it easy and rapid to extract the data regarding discontinuity spacing from 3D point cloud.

The primary advantage of a UAV survey is that no direct access to the desired area is required. This makes UAV the most widely applied technique for geotechnical and rock engineering applications (Dandois et al., 2015; Guisado-Pintado et al., 2019; Gül et al., 2020; Ji et al., 2019; Junaid et al., 2022; Karimi et al., 2021; Kim et al., 2022; Mesas-Carrascosa et al., 2015; Park et al., 2022; Roşca et al., 2018; Son et al., 2020; Song et al., 2022; Wingtra, 2021; Xiang et al., 2018; Zhang et al., 2022). Furthermore, the ability of UAV surveys to obtain accurate 3D models also favors it’s application for slope stability assessment a lot. The primary requirement for estimation of RQD is the joint spacing, and the UAV survey can determine the joint spacing more accurately compared to the traditional technique.

This study majorly focuses the determination of RQD along the rock slope using UAV survey. The paper aims to perform a UAV survey along the desired study and obtain a denser 3D point cloud. The 3D point cloud is then further utilized to extract the spacing between the joints. Finally, the quality of the rock mass was assessed along the rock slope.

2 STUDY AREA

The desire study area is in Pengerang, Johor, Malaysia. The slope exists along a newly established highway in Johor, Malaysia, nearby to industrial zone shown in Figure 1(b).

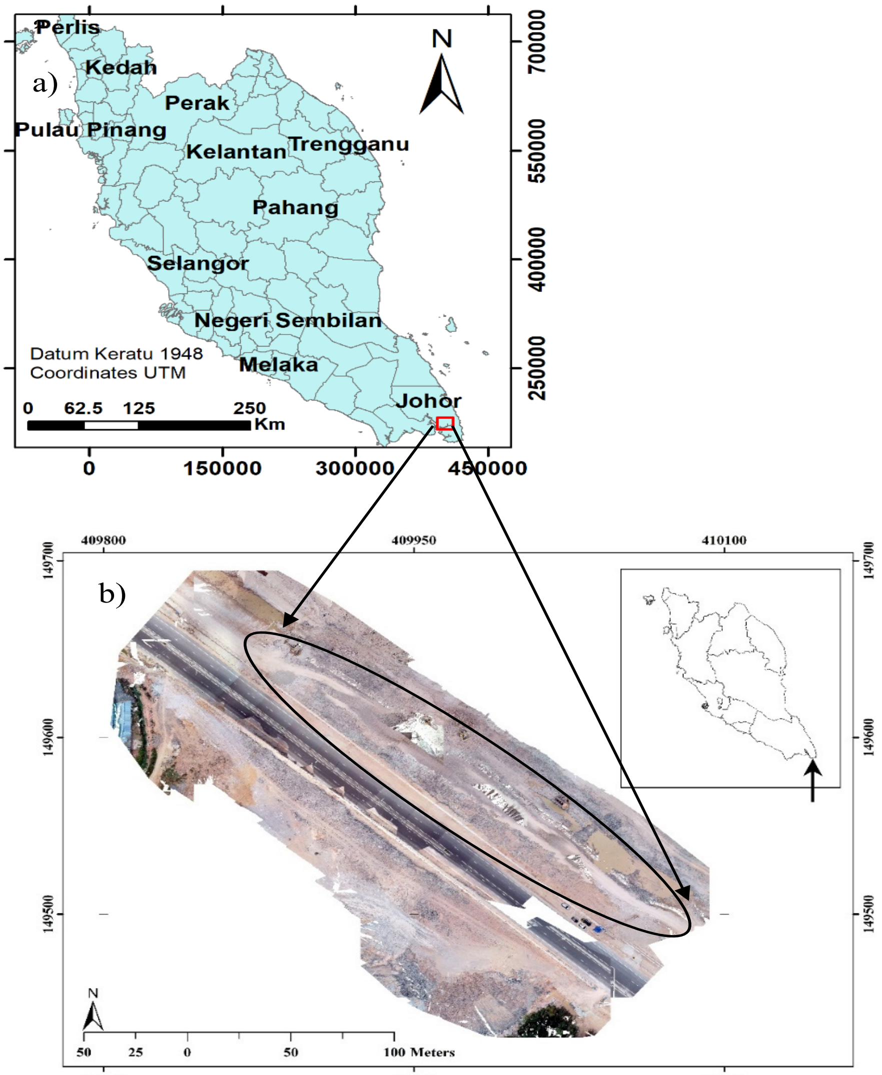

Figure 1. Desired Study Area.

3 METHODOLOGY

The flowchart of the data collection, processing and interpretation is provided in Figure 2. The field works in this research study involves the ground control positioning (GCP), UAV survey, and estimation of RQD.

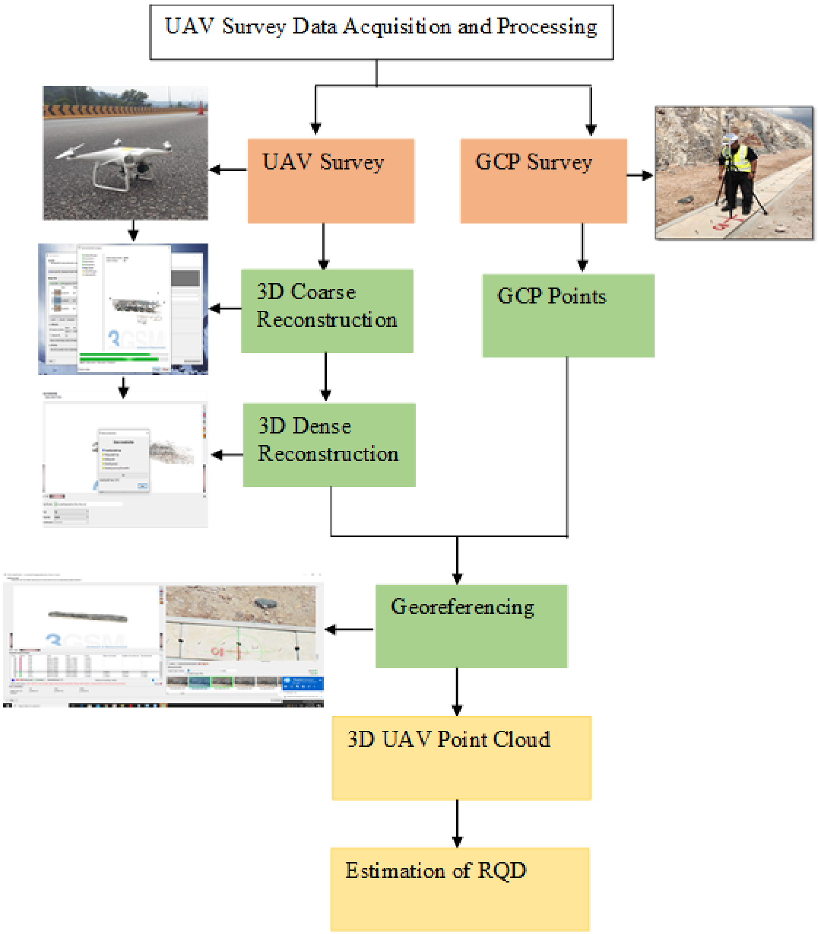

Figure 2. Flow chart of Methodology.

3.1 *GCP Survey*

The GCP point at the study area was obtained using Real-Time Kinematic Global Navigation Satellite System (RTK GNSS) with SOUTH G1 GNSS system provided in Figure 3(a). In this study a total of 10 GCP at slope toe were utilized for the georeferencing of the model schematized in Figure 4.

3.2 *UAV Survey*

In this research work the aerial images of the rock slope were captured at a height of approximately 5-30 m from the rock surface using DJI Phantom 4 v2.0 delineated in Figure. 3(b). Around 246 images were obtained that were deployed to reconstruct the 3D point cloud in ShapeMetriX (SMX) UAV software.

3.3 *Estimation of RQD*

To evaluate the quality of the rock mass the RQD were measured using Jv at various locations from 1* 1 m block as schematized in Figure 3(c). The joints were traced in each block and the spacing between them were measured and the RQD was calculated using equation 1(Alameda-Hernández et al., 2019; Khanna et al., 2021; Nanda et al., 2020; Singh et al., 2020).

$$RQD - 115 - 3.3Jv \qquad (1)$$

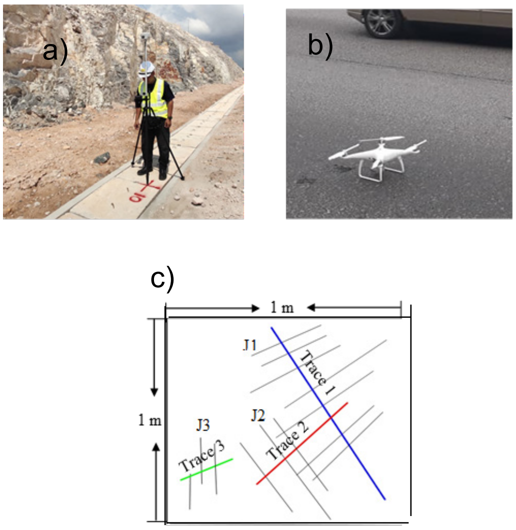

Figure 3. a) GCP survey b) UAV survey c) 1*1 m block.

4 RESULTS

4.1 3D Point Cloud

The 3D point cloud was constructed by capturing images from 104 positions as shown in Figure 4. A total of 197314 spare points were used by SMX UAV software to reconstruct 3D dense point clouds.

Figure 4. 3D point Cloud of Study area with GCP Points.

4.2 Obtained RQD Values

The rock slope was divided into three sections represent by green, yellow, and red in Figure 5. The area enclosed in green section was covered with loose material, therefore, no RQD value was obtained from this section. At the centre section 46 values of RQD were obtained, while the area shown in red colour provided 20 RQD values. These RQD values shown various quality of the rock mass at the area.

Figure 5. 3D point Cloud showing various locations of RQD.

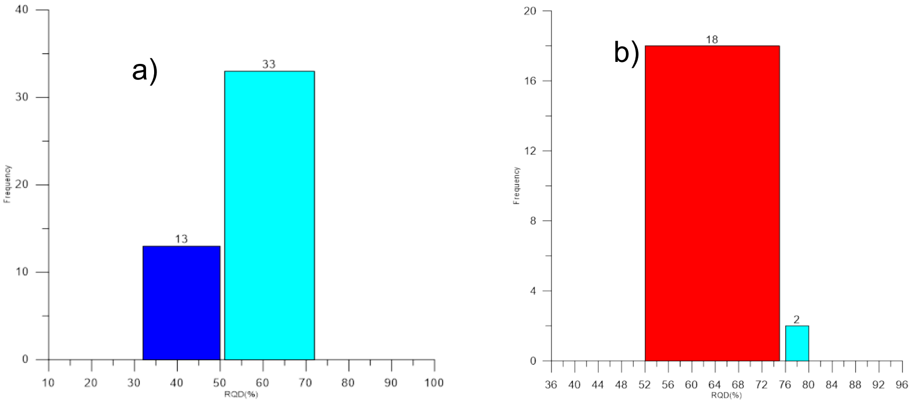

Figure 6. Histogram of RQD values a) Center of Slope b) Western part.

5 DISCUSSION AND CONCLUSION

The RQD and Jv comprehensively reflects three significant geometry parameters such as the number of joint sets, joint persistence and spacing between the joints. Since the rock mass is composed of many joints, therefore the rock mass properties are more complicated compared to the intact rock. Consequently, proper zoning of the cut slopes based on the rock mass quality is utmost important for reliable geotechnical design. For this purpose, in this research work the rock mass evaluation along the slope were performed estimating a total of 66 data points for RQD at various locations.

At the centre of the slope based on the recorded 46 data points, 72% of the data points represent fair rock, while 28% shows poor rock. In contrast, the 20 data point obtained towards the west included 90% of data points for fair rock while 10 % for good rock. These shows that the rock mass quality at the desired study area is categorized in three type of quality such as poor rock, fair rock and good rock. Although, the statistics shows that the rock mass quality along the rock slope is in good compromised with safety limits. However, considerable portion of the rock mass at centre is poor rock. This is alarming and hence sign for regular monitoring of this portion of the slope.

Towards the eastern section of the rock mass no data points for RQD were recorded, hence unbale to characterize the rock mass quality at this portion. This is due to the east portion of the rock slope was covered with loose material; hence no data point was recorded at this portion. These shows the limitation of the UAV survey that it is unable to analyse the portion that is highly vegetated or covered with loose material. Thus, this research work allow us to argue that the primary advantage of UAV survey over conventional technique is its accessibility to complex terrain. The research work presented in this article allows us to conclude that UAV survey is an expeditious and efficient technique for rock mass quality assessment that is helpful in slope instabilities assessment.

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