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# THE IMPORTANCE OF FORMER QUARRY ROCK SLOPE ASSESSMENT FOR SUSTAINABLE INFASTRUCTURE DEVELOPMENT

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## ABSTRACT

Former quarry sites have become a privileged site for infrastructure development due to their restricted locations in hilly areas as they are isolated from the hectic urban life. Besides, the quarry floors are chosen for reclamation and earthworks because of the good transportation networks, relatively flat and sound bedrock of the quarry. However, rock slope face form during quarry operation has high potential for hazard because of instability issues. The nature of rock slopes which have overhangs, loose block, height, have poor accessibility, do not have any bench and do not have proper mitigation measures can cause problems. Rock slope stability assessment conducted showed that rock slopes have the potential for multiple failures either in planar, wedge, toppling or combination between these failures. Field mapping has verified this potential failure in the field. The classification of rock mass using rock mass classification (RMR) indicated that the rock mass can be categorised as fair.

**Keywords:** former quarry site, rock slope assessment, rock mass rating.

## INTRODUCTION

Blasting is a standard procedure in quarry operation to excavate rock aggregate. The uncontrolled blasting technique had produced unstable rock slope face [17]. Geo-environmental problems identified in the abandoned quarry sites are slope stability problems such as sliding, toppling [9] and the quality of rock mass. Due to improper blasting design, the excessive over-blasting has caused the widening of major joints, excessive over-breaks, unstable and loose overhanging blocks [1, 18]. This situation can pose a threat to the environment and a hazard to human because it is unfavourable to stability situations. The ex-quarry rock slope is categorised by the close proximity to steep, high and unstable rock slopes. In some cases, the un-engineered rock slopes are very problematic to stabilise because the slopes are too high up to 70-80 metres have poor accessibility and do not have any bench [8]. It is also difficult to ensure that these high risk slopes are satisfactorily rehabilitated and stabilised.

The abandoned quarry areas become valuable as land is getting scarce due to rapid development. Nevertheless, the former or abandoned quarries are unpleasant and may be a safety hazard. The former quarry sites and hill slopes are categorised as an Environmentally Sensitive Area (or KSAS-Kawasan Sensitif Alam Sekitar). Its status as a KSAS calls for the developers to submit the details of geological and geotechnical report to the local authority for the approval of their proposed development to ensure the issues of geohazard potential and mitigation measures are sufficiently addressed by the developer, through their appointed geologist or geotechnical consultants [8].

Building residential structures in areas close to unstable rock quarry slopes without prior appropriate investigation will lead to unsatisfactory setbacks, loss of lives and properties [14]. Over breaking from previous blasting work has caused instability of the rocks forming the slope in the area, hence it is essential and necessary to carry out an appropriate assessment prior to the development in such area [10].

## MATERIALS AND METHODS

### Study area

The selected sites in this study area were Taman Bukit Permai off Jalan Kuari in Cheras, Palm Walk in Bandar Sungai Long and Kajang Granite Quarry (Figure-1). These sites were previously abundant with quarries. Five slopes were selected for detailed scan line mapping to determine its rock mass quality using rock mass classification (RMR) as shown in Figure-2.

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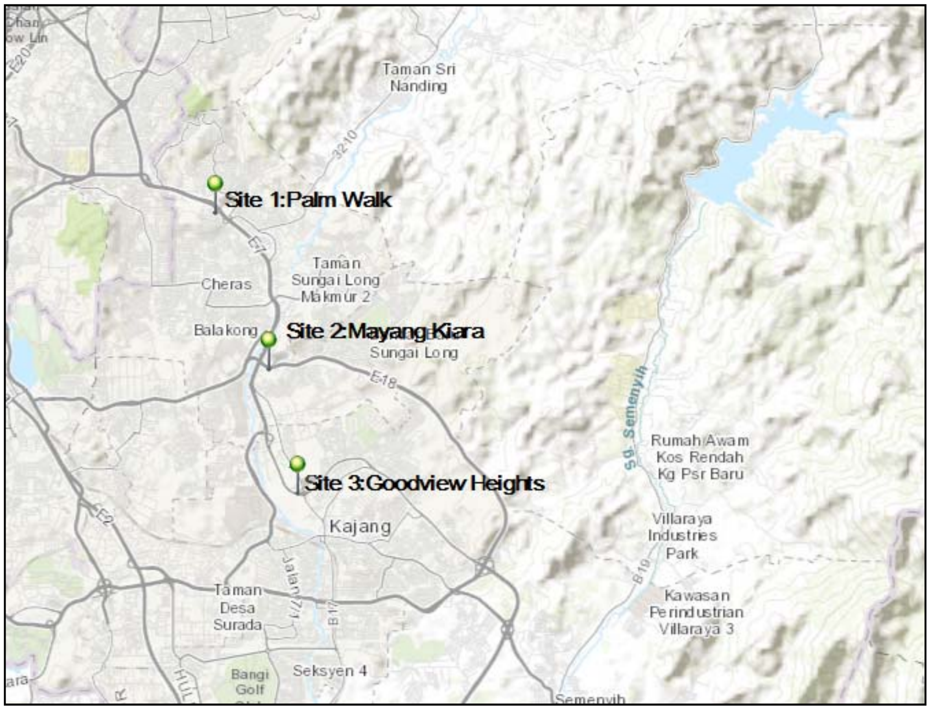


**Figure-1.** Location of study area. Mayang Kiara [Lat: 3° 6’30.71’’ N, Long: 101° 45’28.26’’ E], Palm Walk, Bandar Sungai Long [Lat: 3° 3’6.50’’ N, Long: 101° 48’42.36’’ E], Goodview Heights, Kajang [Lat: 3° 0’6.24’’ N, Long: 101° 49’33.52 E].

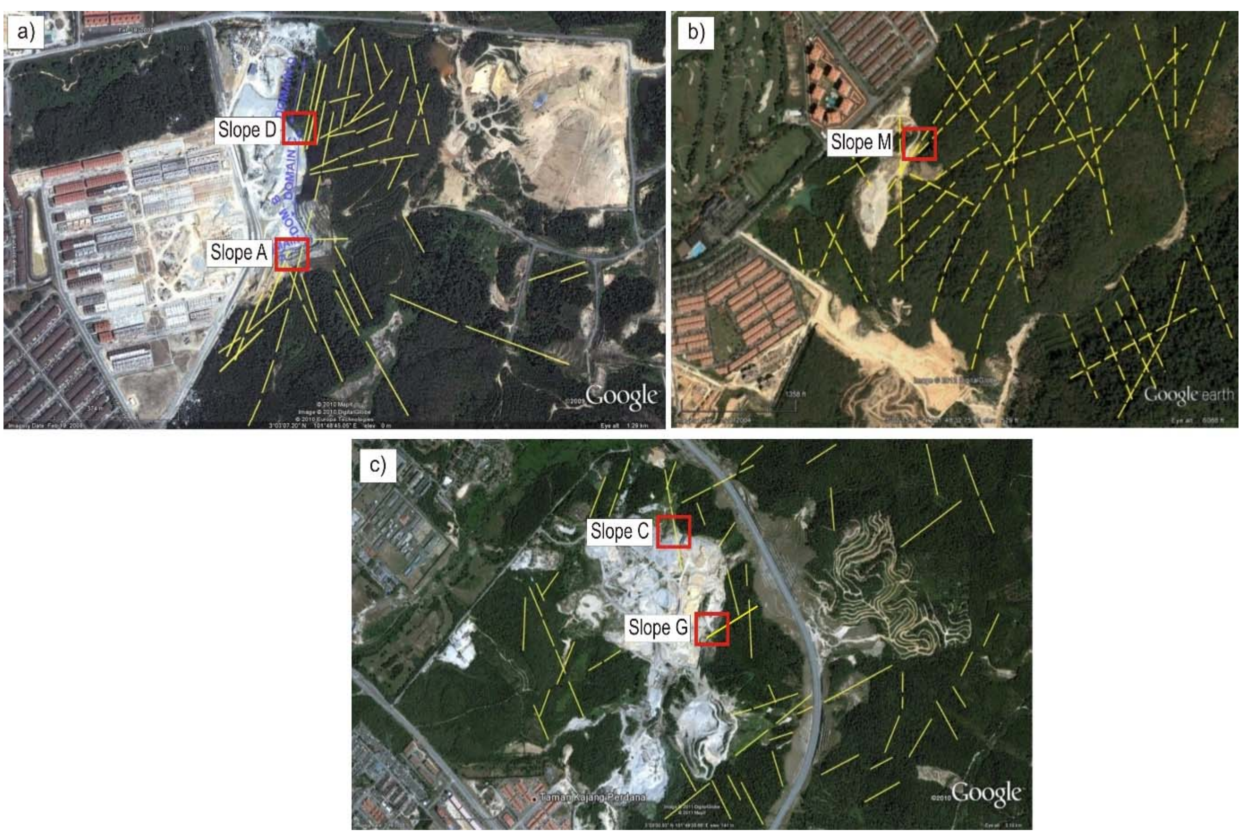


**Figure-2.** Location for scan line survey at three sites were conducted within the rectangular box areas; a) Palm walk, b) Mayang Kiara and c) Goodview heights

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**Geology and site condition**

The bedrock geology of the area is essentially consisting of granite, locally known as Kajang Granite and it is also part of the Kuala Lumpur Granite. The granite is composed mainly of medium to coarse-grained, equi granular to moderately porphyritic textured, light grey muscovite-biotite granite. The granite is consisting predominantly of quartz, plagioclase, K-feldspar with some amount of biotite and muscovite (Figure-3). The exposed rock masses vary in weathering grades from fresh (grade I) to slightly weathered (grade II), moderately weathered (grade III) and highly weathered (grade IV) rocks. These rock slopes were formerly rock quarry faces, thus forming steep high craggy rock slopes with numerous protruding overhangs and loose blocks resulted from past rock blasting activities (Figure-4).

**Figure-3.** Close-up view of the fresh granite.

**Figure-4.** Nature of a rock quarry face. Note the loose overhanging blocks and some of the fallen blocks on the floor.

**Method of study**

There are three stages in this research which were: field study (engineering geological mapping), lab analysis (rock material strength), data analysis and interpretation. In this study, engineering mapping was done using scan line method as suggested by [15, 16]. This method is well accepted worldwide to determine rock mass quality. The scan line survey was conducted 1.5 metres above the quarry floor. The purpose of the discontinuities survey was to determine the main discontinuities and its orientation (strike and dip) that could possibly affect the slope stability of the quarries, and to distinguish their types. A detailed scan line survey was conducted at five rock slopes. Five main discontinuity properties were measured during field study. There are i) discontinuity spacing, ii) discontinuity frequency, iii) width of apertures, iv) discontinuity persistence and v) first order asperity measurements. The importance of these aspects of discontinuities in rock slope stability has been discussed in detail by [7, 19]. Rock samples were collected from each site to determine its material strength. Ten irregular shaped rock samples were tested using point load test to determine their material strength using the method suggested by [4].

The structural data collected from the scan line survey were analysed using stereographic projection techniques to determine the slope stability. Stereographic methods are suitable in slope stability analysis, especially for identifying kinematically possible modes of failure which had been proven by numerous studies [5, 6, 7, 11, 20] since this stereographic projection technique was proposed by [12]. A stereonet of the discontinuities set at each quarry was drawn to determine the potential modes of failure. There are three modes of failures that can be identified from a stereogram, i.e., wedge failure, planar failure and toppling failure. All data from rock slope kinematic stability analysis, rock material testing and discontinuities survey were combined to determine the rock mass quality using rock mass rating by [3].

**RESULTS AND DISCUSSIONS**

**Kinematic stability analysis**

Kinematic stability assessment was done to five rock slopes. The analysis is shown in Figure-5. In general, rock slopes in this area had potential to fail in multiple modes either as one or combination of the following modes of failure:

- Circular failure-generally occurs on very heavily fractured rock mass, where there is no identifiable pattern of structures.
- Planar failure-the failure will take place on dominant discontinuity or highly ordered structure, parallel or near parallel to the slope face.
- Wedge failure-commonly occurs on two or more intersecting discontinuity planes.
- Toppling-can form columnar or blocky structures separated by steeply dipping discontinuities.

The most common potential failure is wedge failure because of the high number of discontinuities set present in the rock mass. The minimum number of failures that could potentially occur is three and the highest number is six. Both slopes at Kajang Granite Quarry have the potential to fail in wedge, planar or toppling failures

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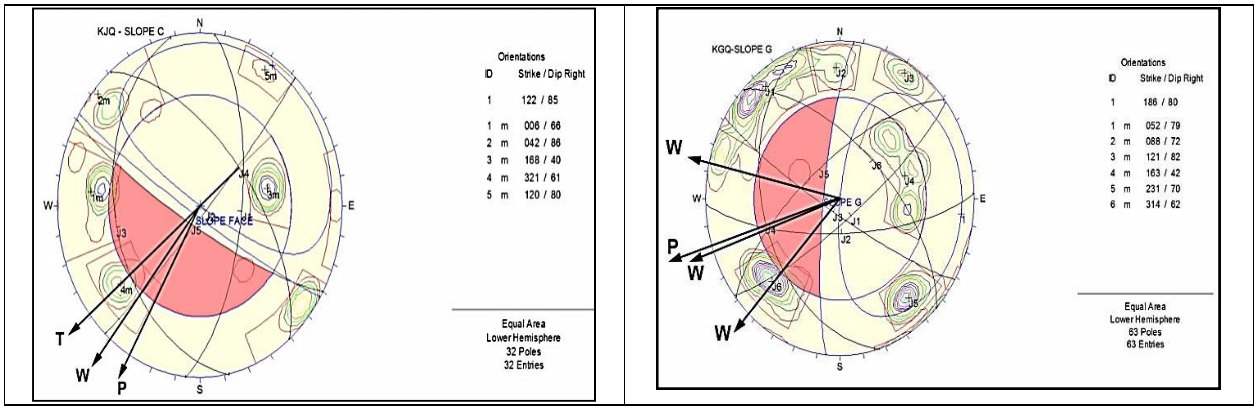
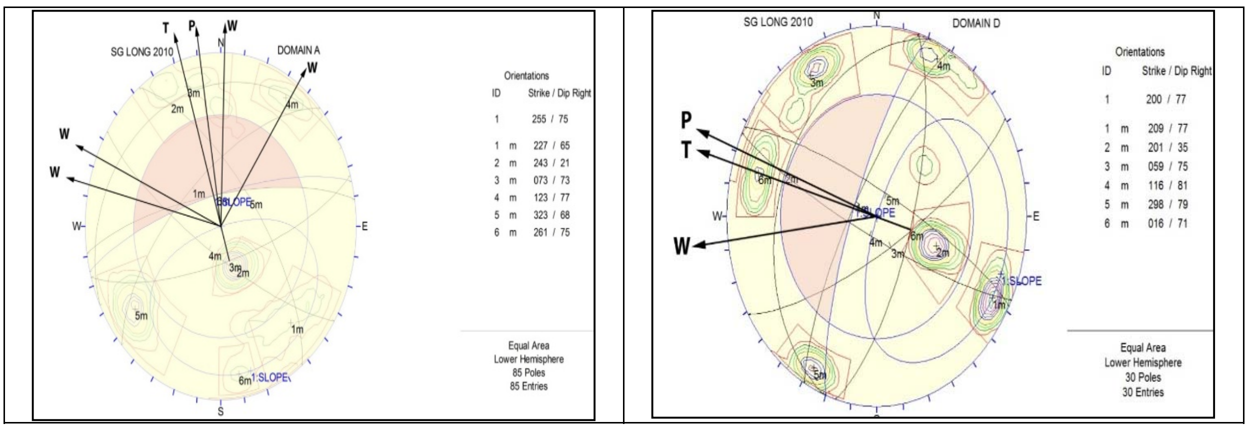
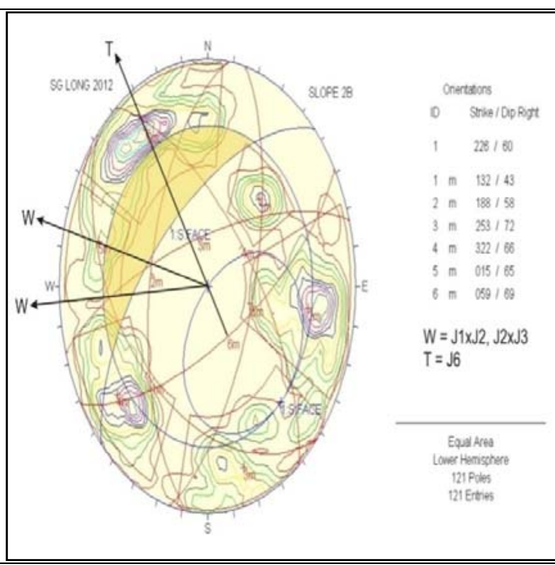
and it had been proven accurate based on field observations as shown in Figure-6. Similar conditions can also be seen for slopes at Palm Walk (Figure-7) and Mayang Kiara. This analysis concluded that all quarry cut slopes are unstable and have high potential for slope failures. These findings are comparable with previous research [2, 13, 18].




Kajang granite quarry




Palm walk




Note
W-Wedge failure
P-Planar failure
T-Toppling failure

Mayang Kiara

**Figure-5.** Result of kinematic stability analysis for three sites in this research.

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**Figure-6.** Side view of slope C at Kajang granite quarry. Note the highly persistent joint sets, and numerous loose, overhanging blocks, and the potential of toppling and wedge failures.


**Figure-7.** View of domain D slope at palm walk. The potential planar failure caused by day lighting joint set.

**Rock mass quality**

The result of rock mass quality assessment is shown in Table-1. The quality of quarry rock mass was classified as fair rock by which the rock mass rating value ranged from 49 to 54 with a difference in value of five. Slope M at Mayang Kiara has a lower value with 49, followed by the slopes at Kajang Granite Quarry (slope C and G) and lastly the slopes at Palm Walk (slope A and D). The discontinuities conditions between each slope are almost similar, with slight difference in discontinuities surface roughness. RQD value between slopes showed some difference with values ranging from 75.22% to 96.18%. The blasting during quarry operation has some effect on the degree of rock mass fracture. The value of rock material strength can be classified as strong material. It is suitable with the condition of rock material which is fresh and used for construction material.

**CONCLUSIONS**

The selection of former quarries for infrastructure development has increased recently because of the strong foundation, and flat space. However, the major problem at former quarry sites is slope stability because the nature of slope that was resulted from quarrying activity. The rock mass quality was categorised as fair rock, which means the rock mass can only stand stable in a short time if mitigation measures is not applied. Proper mitigation measures need to be applied at rock mass to ensure its stability for a longer time and minimise any potential hazard in the future. There are various techniques in rock slope mitigation. The most economical method of stabilising these existing unstable areas in the site is by the reduction of the slope height with the use of controlled blasting techniques.

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**Table-1.** Summary of rock mass rating (RMR).

| | | Palm Walk | | | | Mayang Kiara | | Kajang Granite Quarry | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Slope A | | Slope D | | Slope M | | Slope C | | Slope G | |
| | Parameters | | Rating | | Rating | | Rating | | Rating | | Rating |
| Rock material strength | Point load strength index | 7.60 MPa | 12 | 6.84 MPa | 12 | 7.98 MPa | 12 | 5.34 MPa | 12 | 8.02 MPa | 12 |
| | Drill core Quality RQD | 90.67 % | 20 | 96.18 % | 20 | 75.22 % | 17 | 82.39 % | 17 | 78.57 % | 17 |
| | Spacing of discontinuities | 0.63 m | 13 | 0.66 m | 13 | 0.51 m | 13 | 0.50 m | 13 | 0.73 m | 13 |
| Conditions of discontinuities | Number of set | 6 sets | 1 | 6 sets | 1 | 6 sets | 1 | 5 sets | 1 | 6 sets | 1 |
| | Persistence | Medium – high | 2 | Medium – high | 2 | Medium – high | 2 | Medium – high | 2 | Medium – high | 2 |
| | Separation | Tight | 4 | Tight | 4 | Tight | 4 | Tight | 4 | Tight | 4 |
| | Weathering | II – III | 2 | II – III | 2 | II – III | 2 | II – III | 2 | II – III | 2 |
| | Infilling | Cemented, others | 4 | Cemented, others | 4 | Cemented, others | 4 | Cemented, others | 4 | Cemented, others | 4 |
| | Roughness | Stepped | 3 | Wavy | 2 | Wavy | 2 | Wavy | 2 | Wavy | 2 |
| | Weathering of joint wall | Hard | 3 | Hard | 3 | Hard | 3 | Hard | 3 | Hard | 3 |
| | Groundwater | Dry | 10 | Dry | 10 | Dry | 10 | Dry | 10 | Dry | 10 |
| Total Rating | | | 74 | | 73 | | 69 | | 70 | | 70 |
| | Rating adjustment for discontinuity orientation | Wedge - (J1x J5),(J1x J6), (J4x J6), (J5x J6) Planar – J6 | -20 | Wedge - (J4x J1) Planar - J1, J2 (friction angle > 36° ) Toppling - J6 | -20 | Wedge - (J1x J2), (J2x J3) Toppling - J6 | -20 | Wedge - (J3x J5) Toppling – J4 joint set Planar – J5 | -20 | Wedge Toppling Planar | -20 |
| Total Rating | | | 54 | | 53 | | 49 | | 50 | | 50 |
| Rock mass class | | | Fair rock | | Fair rock | | Fair rock | | Fair rock | | Fair rock |

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