

A hazard assessment of a granite cut-slope in a hillside development off Jalan Kuari Cheras, Selangor

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Abstract: One example of a hillside residential development that is of concern to the authorities is a rock slope off Jalan Kuari in Cheras. The rock slope was identified as being potentially unstable. The stability of this particular slope was critical because it was located immediately across the backlane behind a row of newly completed terrace houses. A study was undertaken to analyze the stability of the rock slope and to recommend suitable protection and/or stabilization measures, to ensure the long term stability of the rock slopes and the safety of the existing properties and human activities in the newly developed residential area. From this study, it was concluded that the rock slope behind the newly completed terrace houses is generally stable. Although all the joint planes are potential slip surfaces, no signs of major instability were found except for some localized small-scale unstable elements. Suitable protection measures and monitoring and maintenance programme were suggested to ensure the long term stability of the cut-slope.

Abstrak: Salah satu contoh pembangunan lereng bukit yang mendapat perhatian daripada pihak berkuasa ialah satu cerun potongan di Jalan Kuari Cheras. Cerun potongan ini dikenal pasti mempunyai potensi untuk mengalami kegagalan. Kestabilan cerun potongan ini penting kerana ia terletak di belakang satu barisan rumah teres setingkat. Satu kajian kestabilan cerun itu telah dijalankan untuk mencadangkan langkah-langkah pemuliharaan cerun bagi menjamin keselamatan harta benda dan nyawa penduduk di situ. Dari kajian ini didapati batuan pada cerun berkenaan pada umumnya adalah stabil. Walaupun kesemua satah-satah ketakselajaran yang terdapat mempunyai potensi menjadi satah-satah gelinciran, tiada tanda-tanda ketakstabilan major didapati kecuali unsur-unsur ketastabilan minor dan bersifat setempat. Beberapa langkah penjagaan dan pemantauan telah dicadangkan untuk memastikan kestabilan cerun potongan tersebut.

INTRODUCTION

From the early 1990s a series of landslides occurred in the Hulu Kelang area. These slides caused some loss of life and a significant amount of property damage. Consequently, extensive reviews were carried out on the stability of soil and rock slopes in the area and the authorities are concerned about new residential developments on hillside areas.

One example of a hillside residential development that is of concern to the authorities is a rock slope off Jalan Kuari in Cheras. The rock slope was identified as being potentially unstable. The stability of this particular slope was critical because it was located immediately across the backlane behind a row of newly completed terrace houses. Figure 1 gives a general view, showing the steep rock slopes on the left and the row of terrace houses on the right.

The main objectives of this study are to analyze the stability of the rock slope and to recommend suitable protection and/or stabilization measures, to ensure the long term stability of the rock slopes and the safety of the existing properties and human activities in the newly developed residential area.

HAZARD ASSESSMENT OF THE SITE

The rock slope under consideration is situated along the back lane of a row of terrace houses. The rock slope cutting is about 160 m in length and about 20 m high. The bench slope angle is nearly subvertical ($>85^\circ$), but the overall (global) rock slope angle measured about 75° . The

exposed granite is generally fresh (grade I) to slightly weathered (grade II) below the second bench, but at the top of the slope it grades into moderately to completely weathered (grade III-V) and residual soils (grade VI). The cut slope in soils is generally well treated and protected with turfing and drainage system. Discontinuities in the rock slope are mainly found in the form of joints (Figure 1 and Figure 2). The joints are generally widely spaced and thus give rise to tabular and blocky nature of the rock mass. Water seepage commonly occurs along the major joint planes.

The stability of the cut slope is controlled by several geologic factors. The granite bedrock is strong enough in places to form steep sided slopes, so that the cut slope is very steep. The frequency and orientation of joints, and other discontinuities as well as their properties affect the quality or strength of the rock mass, which influences the stability of the rock mass. The frequent presence of water in discontinuities or infilling of weak materials in the discontinuities creates local zones of weakness. The infiltration of water along the joints plays some part in destabilizing the rock mass. Depending upon the orientation of the joints, different discontinuities pose potential stability problems. The steepness of the cut slope cut by various joints makes it possible for rock falls and sliding to occur.

In general, very hard rock such as the coarse grained granite in this area, the potential mode of failure can either be one or combination of the following modes of failure, namely circular, planar, wedge or toppling (Hoek & Bray, 1981). Planar, wedge and toppling can introduce rock falls

if the unstable blocks are overhanging in a very steep or vertical slope face.

METHOD OF STUDY

The first phase involves preliminary evaluations of available geologic data. During this preliminary study, we identify the parts of the slope, which are obviously stable, and those in which there are some risks of failure.

In the second phase of the study, the slope which was identified as crucial was studied in detail. The rock slope face was marked with red spray paint at 10 meter intervals, starting from the right end of the slope cut. Orientation (strike and dip) for almost every joint or discontinuity planes were measured and their physical characteristics were studied and recorded. During the survey, the slope face was also checked for any occurrence of localized unstable blocks and/or rock overhangs.

To assess the stability and potential for failure along the cut slope, a graphical stereonet analysis was undertaken. A graphical stereonet analysis (Markland, 1972, Hoek & Bray, 1981) allows the orientations of the joints and fractures to be analyzed on-site and hence discontinuities which are potential failure surfaces may be demarcated. The method of analysis evaluates the orientations of the slopes as well as the discontinuities and the internal angle of friction (frictional component of shear strength) of the rock.

DISCONTINUITIES

The prominent joint sets were commonly closely spaced and filled with clay, indicating the regular passage of groundwater through the joints. At most stations along the slope cut there are from 3 to 5 differently oriented discontinuities of varying persistence, aperture, smoothness, roughness and infilling. For the purpose of analysis, all measurements taken within this relatively short stretch of slope were used although not every discontinuity was found at each measurement station.

Based on the discontinuity survey (Figure 2), 4 major joint sets (namely J1, J2, J3, J4) plus one set of minor joint (J5) and a set of sheet joint (J6) were identified. The northwesterly trending sub vertical major joint sets (J3 and J4), are striking nearly parallel to the slope face, while the northeasterly trending sub vertical joints (J1 and J2) transect the slope surface almost at right angle. The sheet joint dips gently (20-25°) to the NW (314°) into the slope and thus are not likely to pose instability problems to the rock slope.

ROCK SLOPE STABILITY ASSESSMENT

The slope stability assessment adopted in this study is to highlight any potential danger and the possible mode of rock slope failure that might be imposed on the existing slopes behind the terrace houses. Therefore, the visual

inspection method was used in conjunction with the stereoplots. All possible unstable sections of the slopes, especially the potential sliding planes and overhangs were identified. After the collection of discontinuity data, the graphical method or kinematics slope stability of discontinuity was used to assess the slope stability (Hoek & Bray, 1981).

Results of the kinematics stability analysis of the slope are given in Figure 2. The shaded region (area bounded by the friction circle and slope face) in the stereoplot is the considered a critical area. Results of the analysis (Figure 2) indicated that:

- The overall (global) rock slope is generally stable. No sign of major instability was detected on the slopes. The orientations of the major joint sets is generally favourable to the slope orientation with the exception of the sub-vertical J4 joint set that may give rise to toppling.
- However, potential localized small-scale wedge failures are possible on the berm slopes due to the intersections of joints sets J1xJ3 and J2xJ3. Details of these localised unstable elements and the recommended methods of stabilization/protection are summarized in Table 1.

EVALUATION FOR LONG TERM REMEDIAL ACTION

From this study, it can be concluded that the rock slope behind the newly completed terrace houses is generally stable. No signs of major instability were found except that for some localized small-scale unstable elements (Figure 3) as summarized in Table 1. These unstable elements could be easily removed from the slope or protected with the protection/stabilization measures recommended in Table 1. A qualified geotechnical engineer or engineering geologist should be engaged to supervise the slope stabilization/protection works.

After the remedial actions were taken the slope was further inspected and monitored. It was found that dilations

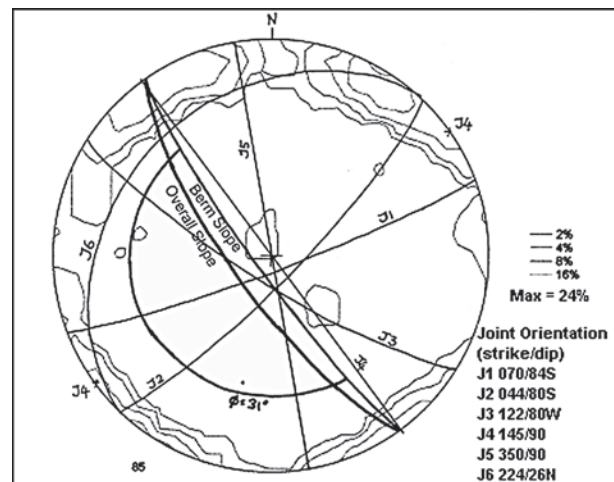


Figure 2. Kinematics stability analysis of the rock slope.

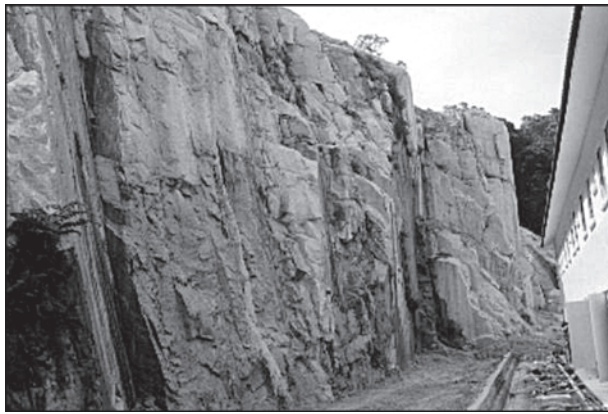


Figure 1. View of part of the steep granite cut slope behind existing row of terrace houses.

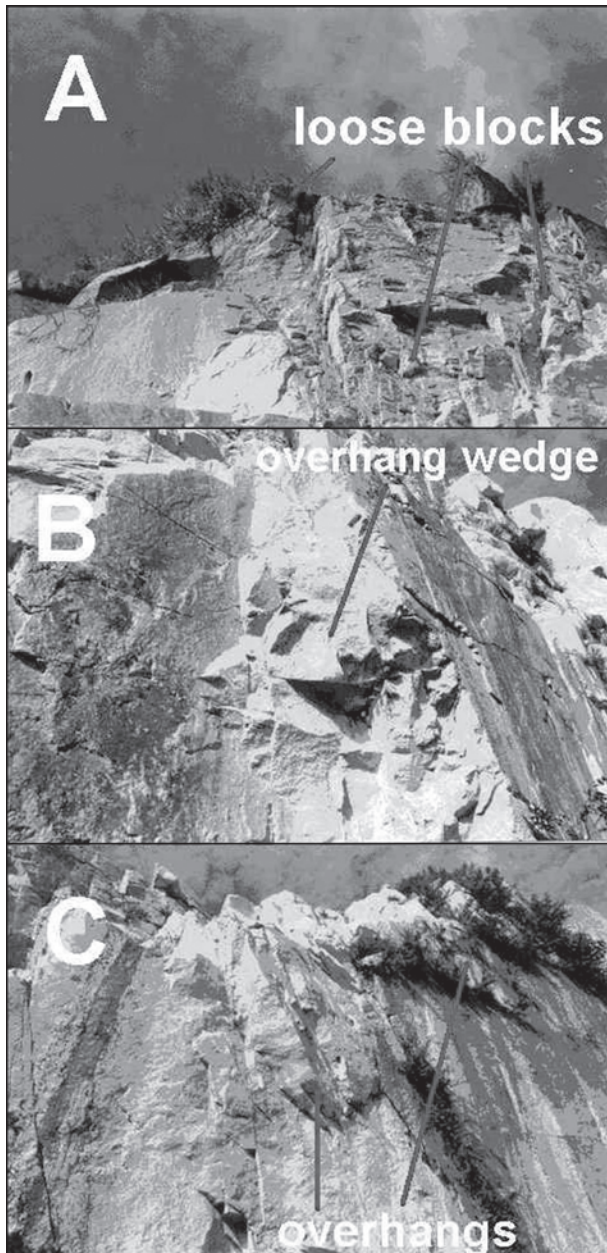


Figure 3. Examples of unstable elements on the cut slope before remedial works were undertaken. A) Loose blocks on top of the slope; B) overhang wedges; and C) overhang blocks.

Table 1: Summary of localised unstable elements in the rock slope and the recommended remedial measures.

Nos	Chainage (Refer to red marker at the foot slope face)	Unstable Elements	Estimate Size	Recommended Stabilisation/Protection Measures
1.	17m – 20m (lower berm)	Overhanging slab	3m x 4m x (0.5 – 1.0)m	Rock dowel
2.	22m – 24m (lower berm)	Overhanging wedge	1.5m x 2m x (0.3 – 1.0)m	Scale off
3.	22m – 24m (upper berm)	Overhanging wedge	Small (<1.0m ³)	Scale off
4.	39m (lower berm)	Overhanging wedge,	Small (<0.5m ³)	Scale off
5.	39m (upper berm)	Loose, heavily fractured rock	2m x 2m x 1m	Wire mesh + shotcrete (area: 5mx 3m)
6.	60m (upper berm)	Overhanging wedge/block, on a daylighting, wet joint	3m x 2.5m x 3m	Rock bolt + concrete dentition
7.	75m – 79m (lower berm)	Overhanging wedge, bounded by wet joints	6m x 4m x 3m	Rock bolt
8.	90m – 91m (upper berm)	Overhanging slab, daylighting	0.5m x 1.5 x 0.4m	Scale off
9.	103m – 106m	Daylighting wedge, wet, daylighting open joints	1.5m x 1.5 x 1m	Concrete dentition to support the overhanging wedge.

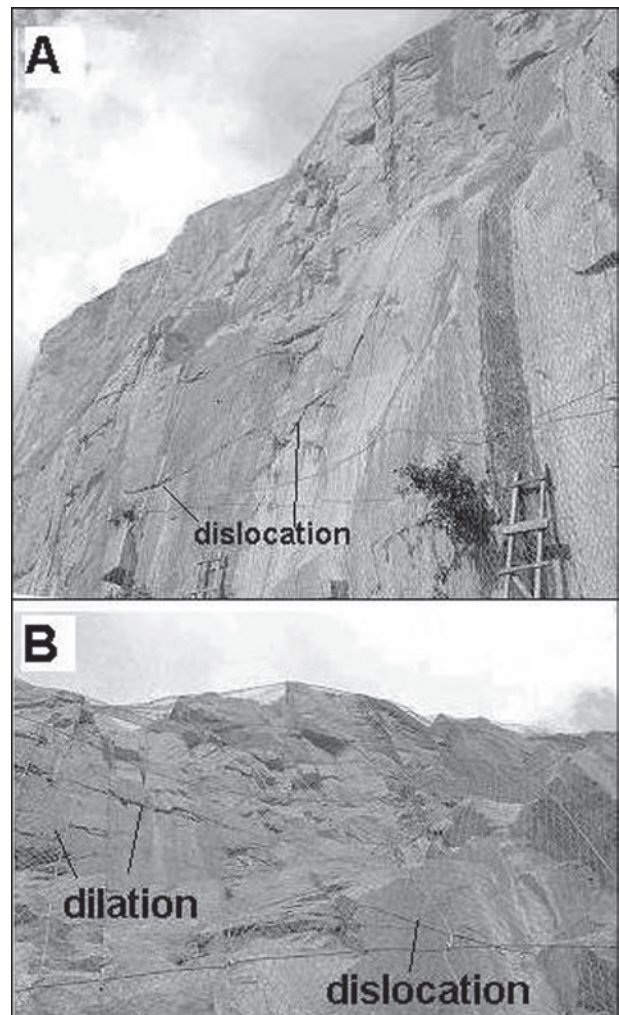


Figure 4. Examples of instabilities created after the stabilization works.

and other signs of displacement had occurred along some joints in certain blocks developed during and after the stabilization works (Figure 4). Further remedial works should be undertaken to ensure the long-term stability of the slope and in the meanwhile the slope should be monitored regularly for signs of instability.

Monitoring slopes of concern is commonly an interim, precautionary measure while other action is being taken to remedy the cause of concern so as to make the slope safe over the long term. After the completion of the additional remedial works, monitoring is no longer necessary but instead regular maintenance should be carried out.

CONCLUDING REMARKS - PLANNING CONSIDERATIONS

In any hillside development, the stability of cut slope should be maintained to prevent undesirable landslides

hazards. This study illustrated the concern of the authorities on the stability of cut slopes on hills where excavation has been carved out for the construction of roads and houses. With adequate cut slope design, and implementation of stabilization and protective measures on the cut slopes, including regular maintenance and monitoring, failures on cut slopes may be mitigated and subsequently, the need for costly rehabilitation and remediation measures may be avoided.

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