ROCK CUT SLOPE STABILITY EVALUATION OF THE CROCKER FORMATION ALONG JALAN UMS, KOTA KINABALU, SABAH

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ABSTRACT. *The aim of this paper is to present the result of an evaluation of the cut rock slope stability of the Crocker Formation along Jalan UMS, Kota Kinabalu, Sabah. Geological mapping, discontinuity survey, and kinematic analysis have been conducted on ten (10) selected cut rock slopes in the study area. Result of kinematic analysis shows that wedge, toppling and planar failures are potential in five cut rock slopes. However, no potential modes of failure are identified in cut rock slopes numbers 2, 7, 8, 9 and 10. Flatten slope range from 30° to 55°, wire mesh and drainage ditches are proposed as mitigation measures for the cut rock slopes in the study area.*

KEYWORDS. Slope stability, crocker formation, Kota Kinabalu, mode of failure, optimum slope angle.

INTRODUCTION

Slope stability is often the most critical safety issue or feasibility component for quarries, residential developments and road construction in hill slope environments. Slope stability depends largely upon the geologic and geotechnical characteristics of the rock and soil that form the slopes. Not surprisingly, the strength of these materials also plays an important role in slope stability.

In rock slopes, often the most important factor of stability is the geologic structure of the rock. Geologic structure refers to the type, condition, orientation, and spacing of discontinuities within the rock mass. Failure usually initiates at and follows pre-existing discontinuities rather than breaking through intact rock. Thus it is the nature of discontinuities and not of the intact rock that governs the mechanical and hydrological behavior of the rock mass (Maerz, 2000).Unforeseen occurrences and damage also depend on the slope morphology and linear infrastructural features. A combination of these factors contribute to the large number of accidents during and after construction work, as well as loss of both material resources and lives (Uribe-Etxebarria *et al.,* 2005).

The occurrence of the more than a cubic meter (m^3) fallen rock block at the bottom of the cut rock slope at Jalan UMS (Figure 1) has become an issue for this study. To ensure the stability of cut rock slope in this area, an evaluation had to be undertaken. To evaluate the rock slope stability, 10 cut rock slopes along Jalan UMS have been selected and identified as Slope 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10. The locations of cut rock slopes in the study area are shown in Figure 2.

Generally, the study area is underlain by the Late Eocene to Early Miocene Crocker Formation which is a highly fractured and jointed rock mass. Intense jointing and shearing characterizes the rock mass into polygonal block shapes of various sizes from as small as several cm^3 to up to 10 m^3 (Ismail Abd. Rahim *et al.*, 2009). The rock block type can be classified as tabular rock block and intersection of the major joints gives rise to irregular block type (Ismail Abd. Rahim *et al*., 2006).

Figure 1. More than a cubic meter (m^3) fallen rock block at the bottom of cut rock at Slope 5.

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METHODOLOGY

Geological mapping, discontinuity survey, and kinematic analysis have been used to evaluate the stability of slope in this study area. Geological mapping includes lithological and structural identification, measurement and interpretation. For discontinuity survey, scan line method was conducted by following ISRM (1981). DIPS 5.0 software package (Rocscience, 2009) has been used to identify the discontinuity set or average orientations of discontinuity sets.

To assess the relative stability and potential for future rock failures in the study area, kinematic analysis (Markland, 1972) has been used. The Markland test is an extremely valuable tool for identifying those discontinuities that could lead to planar, wedge, or toppling failure modes in the rock mass. This Markland test also allows the orientation of joints, bedding planes and fractures to be analyzed at numerous stations to determine which discontinuities are likely to provide failure surfaces for future rock failures. This method compares the orientation of the slope with orientations of rock discontinuities and the internal angle of friction (frictional component of shear strength) of the rock mass.

Slope orientation, discontinuity sets orientation and friction angle of the Crocker Formation are the three main parameters required to perform the Markland test. Data of the strike and dip values of slopes and discontinuities have been obtained from a discontinuity survey and pole plot, respectively. The slope face is shown as a great circle and the friction angle is represented by an interior circle. The value of 30 degrees was selected for the friction angle along discontinuities in the Crocker Formation sandstone following Hoek & Bray (1981), Hoek & Brown (1997) and Ismail Abd Rahim *et al*. (2010). For this study, the basic proposals of Hoek & Bray (1981) were used for mode of failure.

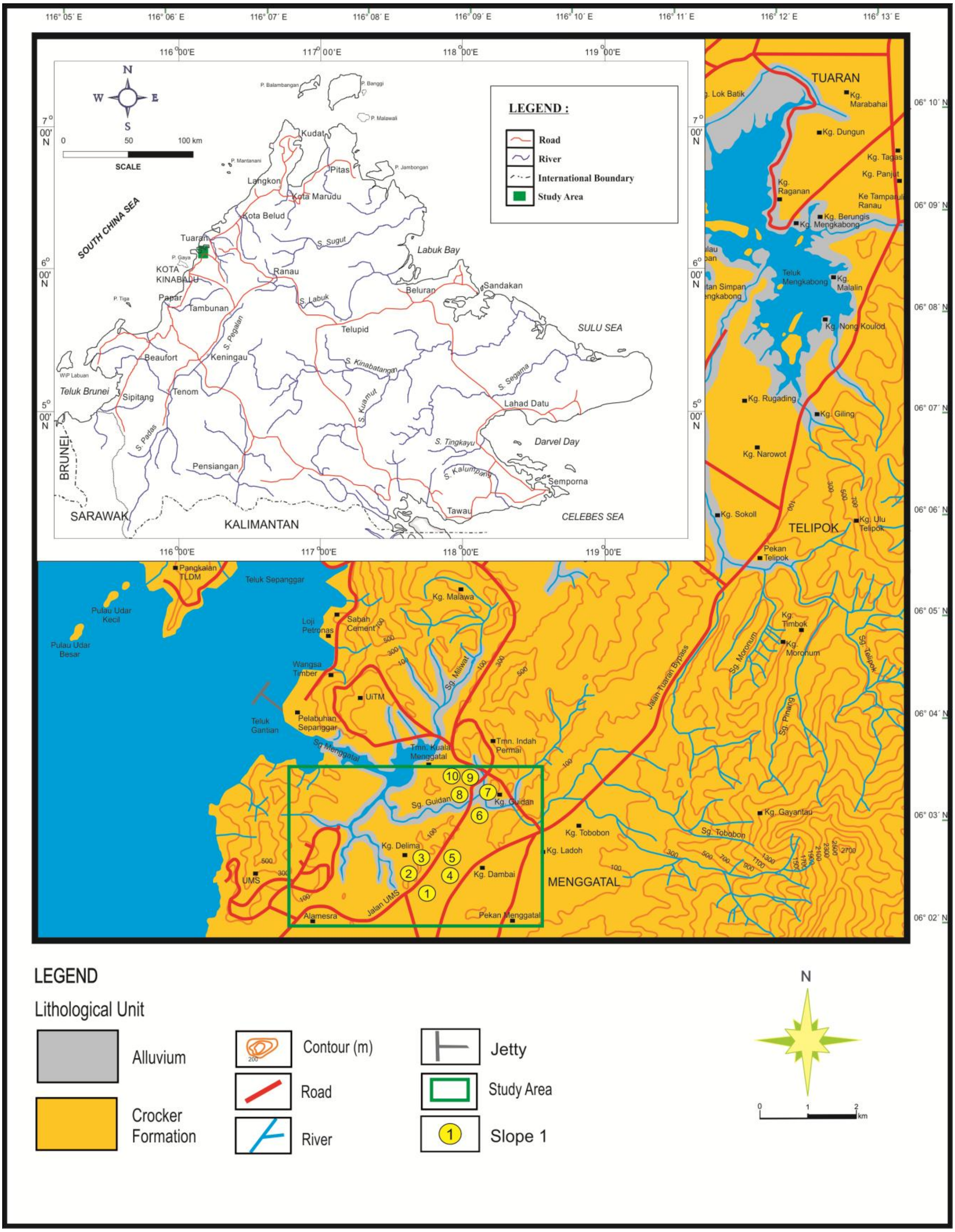
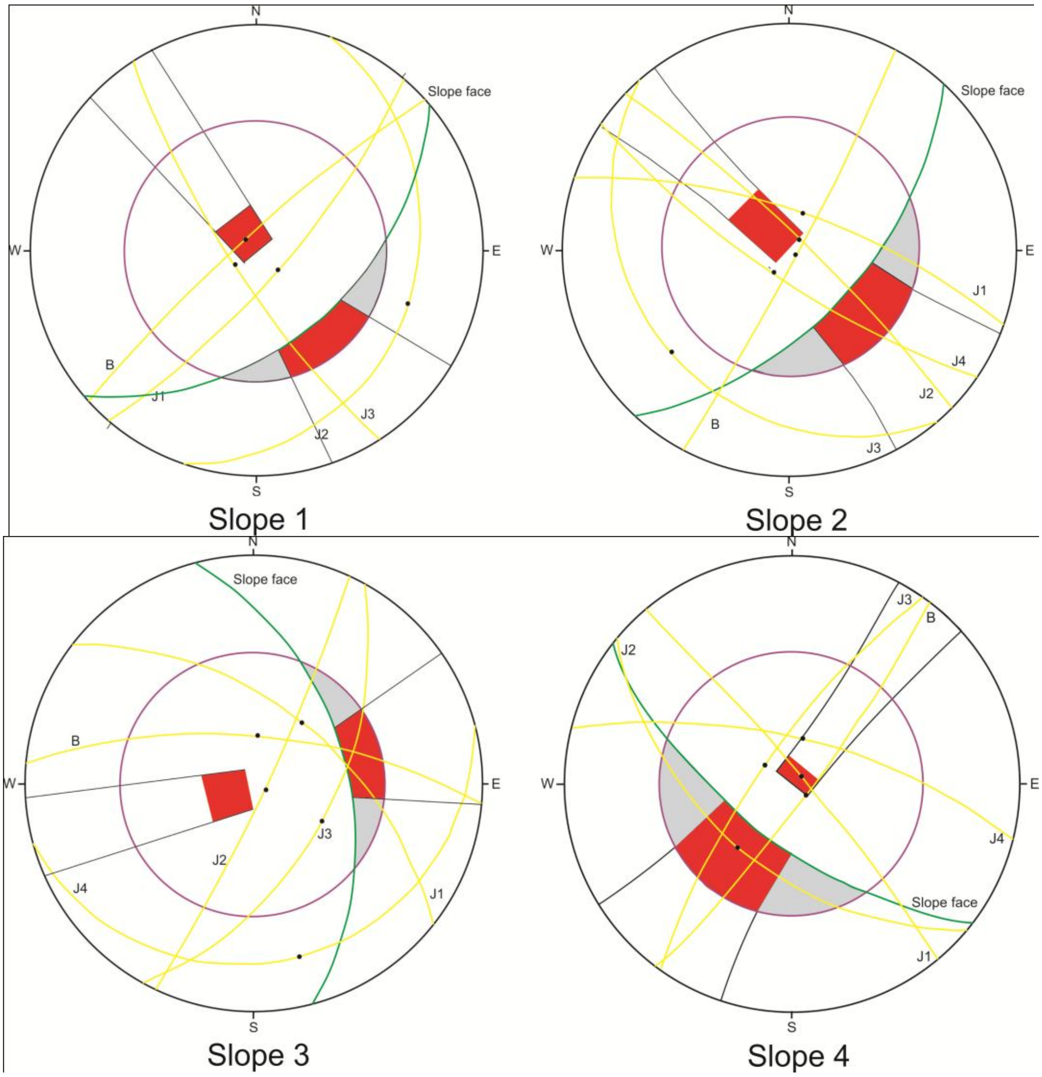


Figure 2. Location of cut rock slopes and geological map of the study area.

RESULTS

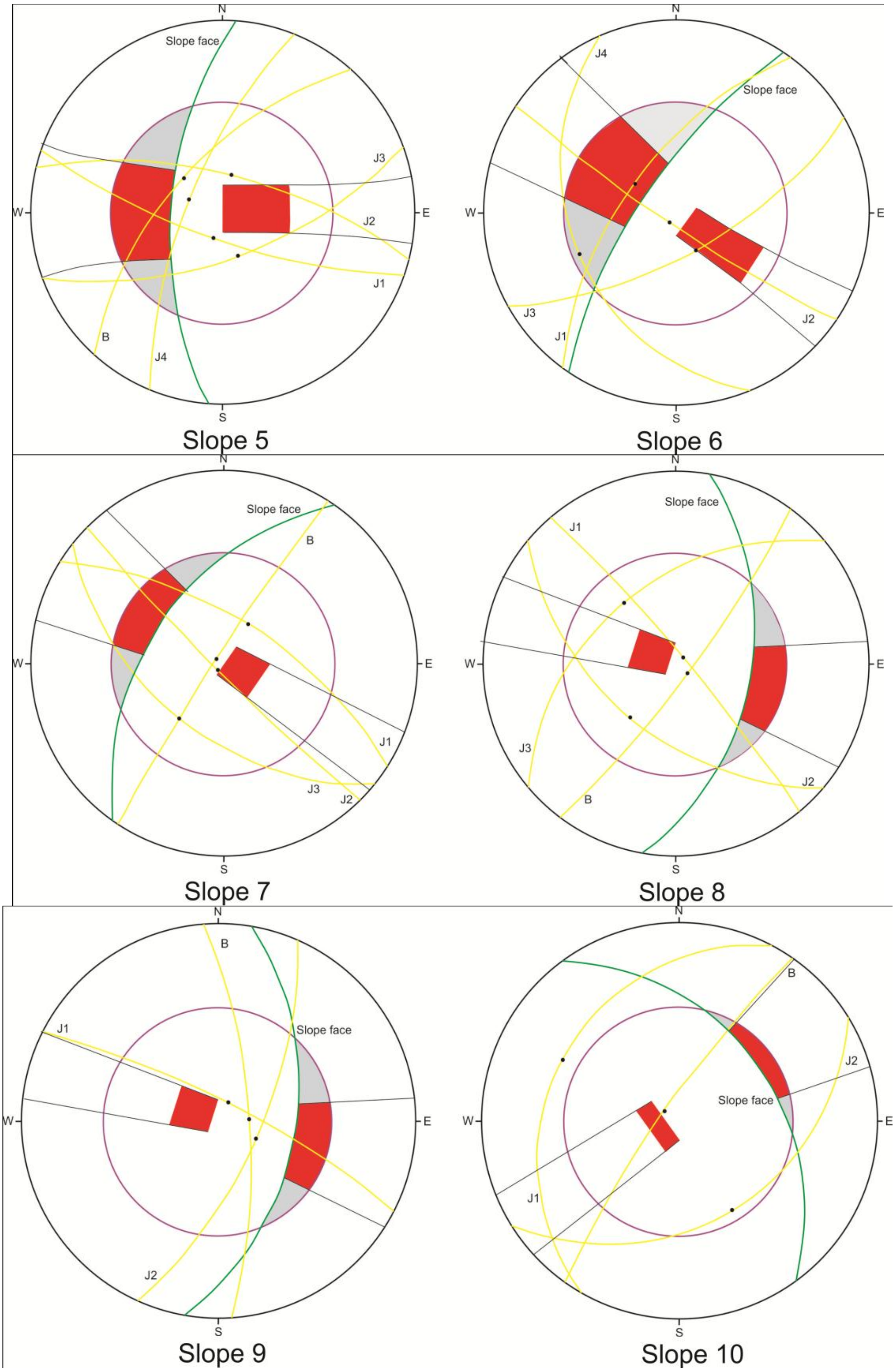
Evaluation of rock slope stability was performed by kinematic analyses. Kinematic refers to the motion of bodies without reference to the forces that cause them to move (Goodman, 1989). A kinematic analysis is very useful to investigate possible failure modes of rock masses which contain discontinuities (Jeongi-gi Um & Kulatilake, 2001).The results of kinematic analyses of each cut slope are shown in Figure 3 and Table 1.

From the kinematic analyses, the optimum slope angle for each cut slope was determined by considering the safest slope angle for any type of failure. The basic concepts related to estimation of optimum safe slope angles for the three basic modes of failure are discussed by Goodman (1989) and Ismail Abd Rahim *et al.,* (2006, 2010). Example of the identification of optimum slope angle for Slope 6 is shown in Figure 3. Other remedial measures for each cut slope were considered during the kinematic check and are shown in summary are in Table 2.



Slope 1 Slope 2 Slope 3 Slope 4

Figure 3. Kinematic analysis of the cut slope at Jalan UMS. Notes: red-potential failure zone; grey-possible failure zone; J1-joint 1; J2-joint 2; J3-joint 3; J4-joint 4; B-bedding.



Slope 5

Slope 6

Slope 7

Slope 8

Slope 9

Slope 10

Figure 3. Kinematic analysis of the cut slope at Jalan UMS. Note; red-potential for failure zone; grey-possible for failure zone; J1-joint 1; J2-joint 2; J3-joint 3; J4-joint 4; B-bedding (con't).

Table 1. Slope geometry, unfavourable discontinuity set and mode of failure for the cut rock slopes.

Slope			**Discontinuity/ bedding plane or intersection**	**Mode of Failure**	**Failure category**
Slope	**Orientation (^{o})**	**Angle (^{o})**			
1	50	45	B	T	Potential
2	43	55	-	-	-
3	354	45	BJ3 J1J3	W	Potential
4	128	63	J2 J2J3 BJ2	P W W	Potential
5	184	60	BJ1 J3J4	W W	Potential Possible
6	214	69	J1 J1J2 J4J1	P W W	Potential Potential Possible
7	215	48	-	-	-
8	37	81	-	-	-
9	37	81	-	-	-
10	215	80	-	-	-

Note : T-toppling; W-wedge; P-planar; J-joint; B-bedding

DISCUSSION

Ten cut rock slopes of the Crocker Formation were analyzed along Jalan UMS, Kota Kinabalu. The Crocker Formation has varies engineering geological properties and two to four joint sets including bedding planes.

Intersection of J3 with B and J1in Slope 3 contributes to the formation of wedge failures. J2 and J1 act as release planes for these wedge failures. In Slope 4, wedge failures are formed by the intersection of J2 with J3 and B planes. The release plane in these wedge failures is J1. Planar failure is also potential in this slope because J2 is day lighting on the slope face with the occurrence of J1 as a release plane.

The wedge failure is potential in Slope 5 by the intersection of B and J1 planes. J4 become a release plane for this wedge failure. Intersection of J1 and J2 are contribute to the formation of wedge failure in Slope 6. The release planes are J3 and J4.

Joint J1 is day lighting in Slope 1 face for toppling failure as well as the occurrence of J1 and J3 release planes. Kinematic analysis shows that there are no potential failure in slope2, 7, 8, 9 and 10 due to the intersection point and discontinuity planes are not daylight on the slope faces.

Slope flattening or optimum slope angle was determine by stereographic analysis and one of the example was done for Slope 6 are shown in Figure 4. The result of others slope optimum angle are shown in Table 2.The overall optimum slope angles vary between 30^{o}and 55^o.

Wire mesh and drainage ditch are also recommended remedial measures for the cut rock slopes in the study area (Table 2).

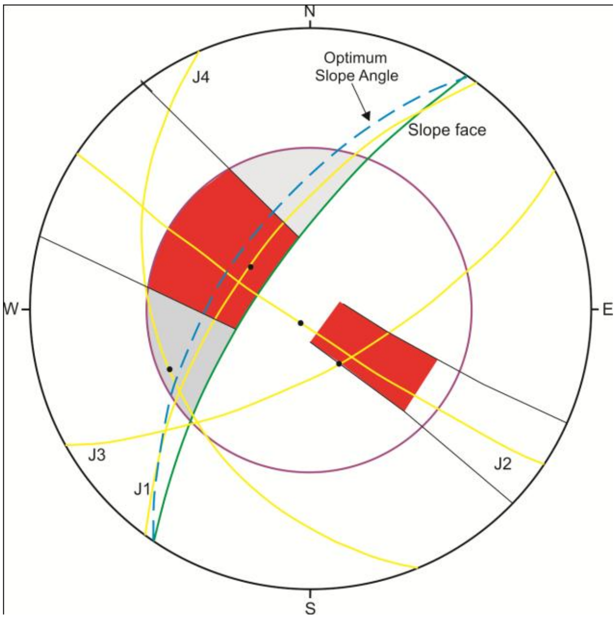


Figure 4. Optimum Slope Angle (example Slope 6).

Table 2. Recommended remedial measures for the cut rock slopes.

Rock Cut Slope	Remedial measures		
	Optimum Slope Angle (°)	Wire mesh	Ditch
Slope 1	30	-	/
Slope 2	-	-	-
Slope 3	40	/	/
Slope 4	46	/	/
Slope 5	47	/	/
Slope 6	55	/	/
Slope 7	-	-	-
Slope 8	-	-	-
Slope 9	-	-	-
Slope 10	-	-	-

CONCLUSION

Conclusions of this study are;

1. The potential modes are wedge, planar and toppling failures.
2. Cut rock slopes 2, 7, 8, 9 and 10 are stable.
3. The proposed optimum slope angle for the cut rock slope ranging from 30° to 55° depends on the orientation and density of discontinuities, planes and mode of failures.
4. Wire mesh and drainage ditches are proposed additional remedial measures for the slope in the study area.

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