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A Comparative Study of Two Landslide Events at Sultan Ahmad Shah Mosque, Jengka, Pahang

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ABSTRACT

Landslide has become a very serious problem in Malaysia lately. Landslides can be caused by a number of factors including slope geometry, soil types and properties, rainfall effects, infiltration, erosion and drainage system. In order to determine the landslide risk based on the soil physical properties, ROM scale method can be used. In this study, the slope at Sultan Ahmad Shah Mosque, Jengka, Pahang which consists of failure zones and un-failed zones next to the failure zones was selected to asses the relationship between the soil physical properties in term of particle size distribution and the slope failure using ROM scale method. Sieve analysis and hydrometer tests were conducted to determine the ROM values. From the research finding, all the soil samples taken from the failure zones were in the critical risk category and the soil samples taken from un-failed zones were in the moderate and high risk category.

Keywords: *landslide, ROM scale, soil erodibility*

Introduction

Cruden and Varnes (1996) stated that the term landslide refers to 'the movement of a mass of rock, debris or earth down a slope'. Varnes (1978) describes landslides as rock, earth, or debris flows on slopes due to gravity. Landslides are caused when the stability of a slope changes from a stable to an unstable condition. A change in the stability of a slope can be caused by a number of factors, acting together or alone. Carrara (1988) and Cruden and Varnes (1996) noted that landslides are caused by one or a combination of two or more of the following factors to include change in slope gradient, ground-water movement, removal or changing the type of vegetation covering slopes. Namuwaya (2006) listed landslide conditioning factors including slope gradient, slope direction (aspect), drainage flow accumulation, geology, soil (texture, depth and sub group) and land use/land cover. Swanson and Dyrness (1975) have observed that in addition to natural phenomena, human activities may increase the natural tendency for landslides to occur. Hussein (1999) explained that slope failure occurs when the slope becomes saturated caused by rise of groundwater level due to rain. Gue and Fong (2003), and Harun (1993) explained that erosion will cause slope failure due to improper drainage was provide on the slope. The soil erosion phenomenon is basically the function of the erosivity of the rainfall and the erodibility of the soil. Soil erodibility is defined as the susceptibility of a soil to the detachment and transportation of soil particles by erosive agents (Houghton and Charman, 1986). Morgan (1986) stated that the soil erodibility index causes slope failure. It is based on Bouyancos formula, as in Equation 1.

$$\text{Erodibility Index} = \frac{\%\ \text{Sand} + \%\ \text{Silt}}{\%\ \text{Clay}} \qquad (1)$$

Roslan and Mazidah (2001) stated that the soil physical properties (percentage of sand, slit and clay) have influence on the risk of slope failure. Based on the study conducted by Roslan and Mazidah (2001), the formula for soil erodibility index was modified, as in Equation 2.

$$\text{Erodibility Index}_{(ROM)} = \frac{\%\ \text{Sand} + \%\ \text{Silt}}{2 \times \%\ \text{Clay}} \qquad (2)$$

In this study, the soil samples taken from failure zones and at the un-failed zones next to the failure zones at the same slope were analysed by using the Erodibility Index $_{(ROM)}$ formula.

Problem Statement

This research was to study the relationship between the soil physical properties in term of particle size distribution and the slope failure risk for soil samples taken from failure zones and at the un-failed zones next to the failure zones at the same slope, which is failure zones and un-failed zones has almost similar aspects such as slope dimension, slope geometry, slope management and rainfall factor. Previous research in the establishment of 'ROM Scale' was carried out only in failure zones without the considering similarity of slope aspect and rainfall factor.

Objective

The objective of this study is to determine the ROM values of the failure zones and unfailed zones next to the failure zones at the same slope.

Scope of the Study

The study is conducted at the slope at the Sultan Ahmad Shah Mosque, Jengka, Pahang. Soil samples were taken at 300 mm below the existing ground level at the failure zones and at the un-failed zones next to the failure zones. The tests involved were sieve analysis and hydrometer tests conducted to determine the ROM values.

Research Methodology

The flow chart of research methodology is illustrated in Figure 1. The study area was the slope at the Sultan Ahmad Shah Mosque, Jengka, Pahang. The area was selected because of that particular slope has had a two failure zones and un-failed zone side by side. Another factor is the slope has almost similar aspects. Identification of the slope failure was conducted by looking at their physical conditions. Slope dimensions and geometries were measured using surveys equipments. Slope dimensions consist of slope length and slope height. Meanwhile slope geometries include slope steepness and elevation. Furthermore, landslide scar dimensions namely scar length, scar width, scar depth and scar size were measured using survey equipment. Slope management and landslide data were visually observed. Slope management concentrate on slope development, nature of slope, type of slope, landuse, vegetation, slope protection and drainage system, while landslide data focus on material, failure and position. Two soil samples were taken at depth of 300 mm from ground surface from each point which are point A (at head of slope) and point B (at toe of slope) for failure zone and un-failed zone (refer to Figure 2). Soil samples were collected using hand auger. The samples of soil were analysed by carrying out sieve analysis and hydrometer test.

Sieve analysis was conducted at the Soil Laboratory, UiTM Pahang while hydrometer tests were carried out at the IRCDIP laboratory, UiTM Malaysia. Soil test conducted on the soil sample was to identify the soil physical properties in terms of particle size distribution to obtain percentage fine sand, silt and clay of each sample. These values were used to estimate the soil erodibility using the ROM Scale method. The ROM value calculated by using Equation 2 and the scale and degree of soil erodibility for the soil samples based on Table 1. Table 1 shows the classification of soil erodibility scale using ROM Scale method.

Identify Slope Failure (Failure Zones and Un-failed Zones)

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Measure Slope Dimensions and Geometries

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Measure Landslide Scar Dimensions

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Observe Slope Management and Landslide Data

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Collect of Soil Samples

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Conduct Sieve Analysis and Hydrometer Tests

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Identify the 'ROM Scale'

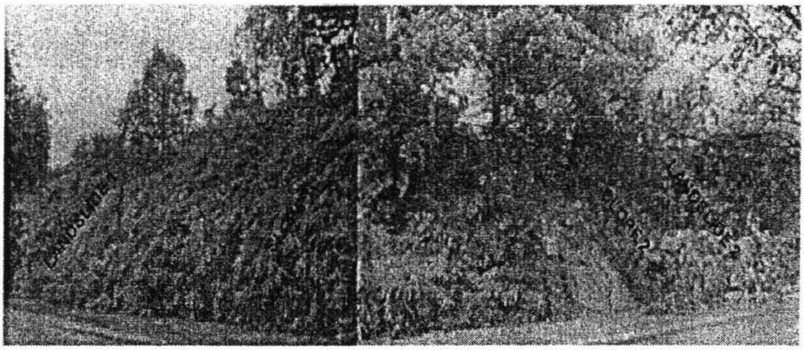
Figure 1: Flow Chart of Research Methodology

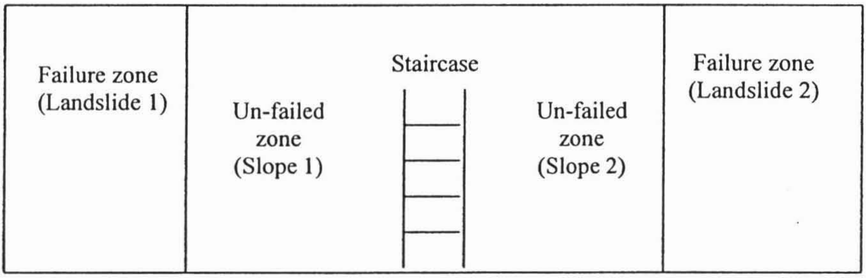
The study area was done on slope at Sultan Ahmad Shah Mosque, Jengka, Pahang. Slope at Sultan Ahmad Shah Mosque, Jengka, Pahang is selected because of that particular slope has a two failure zones and un-failed zone side by side. Another factor is slope has almost similar aspects. Identification of slope failure is conducted by looking at their physical condition. Slope dimensions and geometries are measured using surveys equipments. Slope dimensions consist of slope length and slope height. Meanwhile slope geometries include slope steepness and elevation. Furthermore, landslide scar dimensions namely scar length, scar width, scar depth and scar size are measured using surveys equipments. Based on visual observation, slope management and landslide data are observed. Slope management concentrate on slope development, nature of slope, type of slope, landuse, vegetation, slope protection and drainage system, while landslide data focus on material, failure and position. Two soil samples were taken at depth of 300 mm from ground surface from each point which are point A (at head of slope) and point B (at toe of slope) for failure zone and un-failed zone (refer Figure 2). Soil samples are collected using hand auger. The samples of soil were analyzed by carrying out sieve analysis and hydrometer test. Sieve analysis was conducted at soil laboratory, UiTM Pahang while hydrometer tests at IRCDIP laboratory, UiTM Malaysia. Soil test conducted on the soil sample was to identify the soil physical properties in term of particle size distribution to obtain percentage fine sand, silt and clay of each sample. These values were used to estimate the soil erodibility using the ROM Scale method. The ROM value calculated by using Equation 2 and the scale and degree of soil erodibility for the soil samples based on Table 1. Table 1 shows the classification of soil erodibility scale using ROM Scale method.

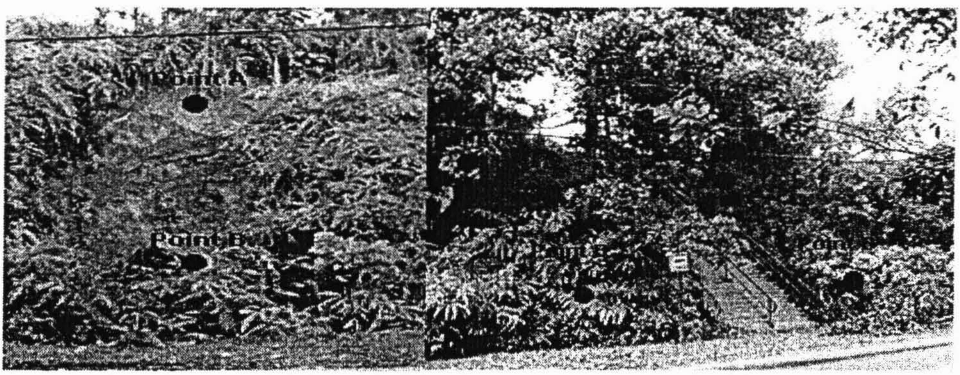
$$\text{Erodibility Index}_{(ROM)} = \frac{\%\ \text{Sand} + \%\ \text{Silt}}{2 \times \%\ \text{Clay}}$$

Table 1: Classification of Soil Erodibility Scale (Roslan and Mazidah, 2001)

ROM Scale	**Degree**
< 1.5	Low
1.5 – 4.0	Moderate
4.0 – 8.0	High
> 8.0	Critical







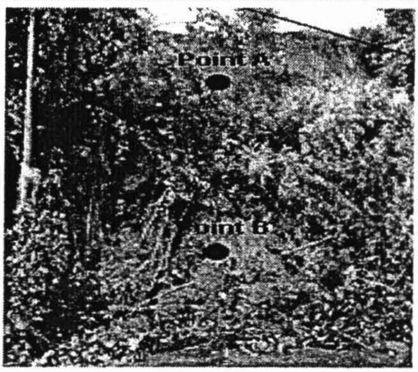


Figure 2: Location of Selected Soil Samples for Failure Zone and Un-failed Zone

Results and Discussion

Slope Features

The result of slope features is shown in Table 2. From the measurement, the elevation of slope is 55.0 m, slope height is 9.1 m and slope length is 10.5 m. With respect to slope steepness, the slopes have a gradient 60.0 degrees. The slope shows upslope development and is classified as convex slope. The observation shows that the slope is fill slope, impervious landuse and has shrubs. Terracing is applied as a slope protection at the Sultan Ahmad Shah Mosque, Jengka, Pahang slope and the slope areas are none containing drainage system.

Table 2: Slope Features

Parameter	Remarks
Elevation (m)	55.0
Slope height (m)	9.1
Slope length (m)	10.5
Slope steepness (°)	60.0
Slope development	Upslope
Nature of slope	Fill
Type of slope	Convex
Landuse	Impervious
Vegetation	Shrubs
Slope protection	Terracing
Drainage system	None

Landslide Features

The results for the landslide features are shown in Table 3. From the measurement, landslide event 2 was observed as a critical and risk of landslide occurrence compare with landslide event 1 since landslide event 2 having the higher landslide scar dimensions about scar width, scar depth, scar size and scar volume. From the visual observation, landslide event 1 and landslide event 2 have a similar landslide data in terms of material, failure and position.

Table 3: Landslide Features

Landslide event		1	2
Landslide scar	**Length (m)**	10.5	10.5
	Width (m)	6.8	17.0
	Depth (m)	1	4
	Size (m^2)	66.5	148.5
	Size category	Very small	Very small
	Volume (m^3)	66.5	594.0
	Volume category	Small	Medium
Material		Earth	Earth
Failure		Slide-rotational	Slide-rotational
Position		Upper, middle and lower	Upper, middle and lower

ROM Scale

The average ROM value of two soil samples and degree of soil erodibility for the soil samples are summarised in Table 4. It is based on Table 1 which shows the classification of soil erodibility scale using ROM Scale method. The failure zones (Landslide 1 and Landslide 2) are in the critical risk category because its ROM value is larger than 8.

The recommendations for achieving more accurate results are:

- In future, a study need to consider other factors such as rainfall and shear strength of soil to see its relationship with soil erodibility scale (ROM Scale).
- Small quantity of soil sample does not give satisfactory results. Therefore, it is advisable to add more quantity of soil samples to achieve consistency of results.
- Terracing is not suitable to be applied at Sultan Ahmad Shah Mosque, Jengka, Pahang slope since it cannot resist the landslide due to rainfall effect. Thus, other methods of slope protection need to be considered to be applied at certain zones at the Sultan Ahmad Shah Mosque area, Jengka, Pahang.

Table 4: ROM Value and Degree of Soil Erodibility using ROM Scale Method

Point	Landslide/ slope	Average ROM value	Degree
A	Landslide 1	8.8	Critical
	Slope 1	5.9	High
	Slope 2	7.1	High
	Landslide 2	10.1	Critical
B	Landslide 1	9.7	Critical
	Slope 1	3.4	Moderate
	Slope 2	5.5	High
	Landslide 2	13.4	Critical

Conclusion

Based on the ROM scale, slopes that are categorised in critical degree category have a high risk of being failure. From this study, the results show that both of the failure zones are under the category of critical risk. Meanwhile, for both of the un-failed zones, they are categorised as moderate and high.

The soil erodibility at toe of slope contributes more to the tendency of landslide to occur compared with soil erodibility at head of slope. This is proven where both of the failure zones occur at the toe of slope with high level of soil erodibility. Due to that, the sampling of soil for soil erodibility assessment should be done at the toe of slope. Soil sampling had been concentrated at the slope toe because:

- based on previous research, most of the landslide happened is due to the erosion that occurs at the slope toe.
- from this research, high level of soil erodibility occurs at slope toe compared to slope head, causing the landslide to happen.
- most of the landslide happened at the bottom of the slope compared with the middle and top of the slope.

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