APPLICATION OF ELECTRICAL RESISTIVITY IMAGING TECHNIQUE IN THE STUDY OF SLOPE STABILITY IN BANDING ISLAND, PERAK

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Introduction

Landslides are a serious geologic hazard and cause many damages in the world. There are many factors contributing to the instability of slopes, but the main controlling factors are the nature of the underlying bedrock and soil, the configuration of the slope, the geometry of the slope, and groundwater conditions (Huat *et al*, 2008). Landslides are typically associated with periods of heavy rainfall. This condition is very much so for Malaysian situation which has an equatorial type of climate and receives rainfall throughout the year with high temperature. The location of Peninsular Malaysia is subjected to both South-West and North-East monsoons causing high annual precipitation. Mean annual precipitation for Malaysia ranges from 1750 mm to 2500 mm. In highland interior, mean annual rainfall raises to 3000 mm and can reached 3500 mm in some wet years. With heavy and intensive rainfall coupled with grounds being composed of residual soils derived from the weathering of rocks which are mostly sandy or silty in texture, erosion and slope instability problems are sometimes chronic in Malaysia (Hengchaovanich, 2005). The stability of sloping land and the potential for failure would have an effect on the safety of people, property and the value of the area. One of the focus areas with frequent landslides are in East – West Highway between Grik and Jeli. Banding Island is located approximately in the middle between Grik and Jeli. Within this island, two main facies were observed; namely the Argillaceous Facie constituting the eastern portion of the island and the Arenaceous Facie on the western part of the island. The Argillaceous subfacies are grouped together and called Meta-argillites and Arenaceous Facie grouped called Meta-arenites Landslides were observed to occur frequently in the Argillaceous Facies. In this study the geophysical method Electrical Resistivity Imaging (ERI) was used to obtain the ground conditions. The results indicate variations and anomalies that can be correlated with different types of rock in Banding Island. Besides geophysical aspect, the important method in landslide study is in geotechnical part. Fortunately, there have been recent efforts from both geophysicists and geotechnical engineers to employ geophysical techniques as an advanced soil testing tool (Giao *et al*, 2003). The ERI method is relatively economical and can cover a wide area for ground surface either is two dimensions or three dimensions. The relationship between electrical resistivity of earth materials to its strength parameters will be established in Banding Island soil. The main factor that trigger slope failure is water and it also exert a very strong influence on the electrical resistivity and shear strength of earth materials. Besides trying to show the reliability and accuracy of electrical resistivity method in determining soil strength parameters, this work also illustrate a cost-effective way of assessing soil strength (Lau, 2005).

Objective

Field investigation and laboratory test are a necessary part of determining an appropriate remediation for a landslide. Thus, the main objective in this research is to determine the subsurface characteristics different types of rock in Banding Island based upon electrical resistivity. The laboratory testing method for shear strength using shear box test is to correlate between the strength of soil to the electrical properties of the ground. Besides, the soil classification test will be conducted to understand how these parameters influences the electrical resistivity and shear strength parameters of the soil sample. These study also asses the slope stability of Banding Island in general.

Research Methodology

Study site is located at Banding Island. Banding Island is a man-made island, created out of hill tops and being surrounded by Tasik Temenggor reservoir. The island is elongated approximately in north-south direction. The distance between the northern and southern tip of the island is about 4.0 km while the broadest east-west part of the island is approximately 1.0 km. The central part of the island is a ridge trending in a north-south direction. The highest point is 436 meter above mean sea level while the island shore line is at an elevation of approximately 220 meter above mean sea level. The research include fieldwork, laboratory work and data interpretation. For the first objective thirteen lines of ERI was conducted in the study area which cover eastern part and western part of the island. These profiling measured using ABEM Terrameter SAS4000 to get the electrical resistivity distribution of the subsurface between different types of rocks. This non destructive method is based on measuring the electrical potential which results from an applied direct electrical current flowing in to the ground (Turesson, 2006). Wenner array protocol was chosen as arrangement of the electrodes. During the fieldwork soil sample had been taken in seven ERI line and has two to four sampling points in every line. Undisturbed soil samples were collected for testing shear strength in a standard 60-mm shear box and electrical resistivity using A.C Terrameter. Disturb samples were also taken for shear strength and electrical resistivity measurements using the same tools while parts of these samples were used for soil classification test included determination of soil grain-size distributions, porosity and Atterberg Limits. The mesurements are following British Standard procedures (BS 1377, 1990) and Methods of soil analysis (Black *et al*, 1965). The method use in the present investigation is illustrates in Table 1.

Table 1: The geophysical and geotechnical methods for this study

Procedures		
Fieldwork	Laboratory Work	Desk study and data interpretation
1. Geophysical mesurement - Electrical resistivity 2. Soil Sampling	1. Geophysical measurement - Electrical resistivity 2. Geotechnical (shear strength) - Shear Box Tests 3. Geotechnical (classification tests) - Grain size distribution - Sieve Analysis - Hydrometer test - Porosity - Specific Gravity (SG) - Bulk Density - Alterburg Limit - Liquid Limit (LL) - Plastic Limit (PL) - Plasticity Index (PI)	1. Processing GIS data for landslide mapping 2. Interpretation field electrical resistivity values using Res2Dinversion software

Results and Discussion

The first objective had been achieved to determine the subsurface characteristics different types of rock In Banding Island based on electrical resistivity. The eastern part of the island is underline by Meta-argillites type of rock which is weak and many have scarp failure here. While the western part of the island is underline by Meta-arenites type of rock. This side is high resistance from the landslide occurrences. Six electrical resistivity profiles had been conducted in eastern side of the island which tree line spanning landslide area and the others in origin soil condition. In the western part, four resistivity profiling was carried out. Here two example of electrical resistivity profiling situated in northern part of the island from both types of rocks will discussed.

The electrical resistivity image of Line 1 (Figure 1) portrayed the electrical resistivity distribution of subsurface in the vicinity of the slope failure of skid trail. Ground in elevation 224 m is the edge of the lake and it is good calibration to proof the zone is water saturated. Along the survey line the soil is very loose and has many small pool of water on the ground. This clue indicates that the water saturated is very close to the ground surface which give the resistivity value lower than 500 ohm-m. The loose soil here causes wide landslide and damaged the skid trail. ERI measurements of Lines 2 (Figure 2) were conducted on grounds underlain by Meta-arenites. From the image it is noted that grounds with resistivity value 4,000 ohm-m or more occurred either on or very near to the surface of the ground. This indicate that the ground is not highly saturated

with water and not having a lot of electrically conducting minerals, such as clays. Besides it can predict as boulder which close to the ground surface.

From all this resistivity profiling that had been caries out it can be conclude that resistivity of the rock in Meta-argillites here are around 500 ohm-m to 10 ohm-m. This is very different with the western part underline by Meta-arenites which has electrical resistivity range 500 ohm-m to 30000 ohm-m. The eastern part is composed of meta-argillite and it is thinly foliated and highly fractured. This shows the ground in the vicinity slope failure in most eastern part, easily weathered and prone to failure. Some parts in Meta Argellites are still free from scarp failure but are prone to landslide if we do any constructions. In the western part of the island, field evidence show the Meta arenites are thickly bedded or foliated and sometimes massive. Hence it can be concluded that areas in the vicinity Meta arenites are much stronger than Meta Argellite which already have many scarp slope. Field observations also indicated that the surface to the hard layer and that of to the top of bed-rock occur quit near to the ground surface.

Electrical current in soils is mainly electrolytic, i.e. based on the displacement of ions in pore-water, and is therefore greater with the presence of dissolved salts. Thus, electrical current in soils depends on the amount of water in the pores and on its quality. (Samouelian *et al*, 2005). Figure 3 shows the relationship between electrical resistivity and water content in five ERI profiling. The electrical resistivity decreases when the water content increases. It can also be seen that for water content <15%, the electrical resistivity rapidly decreases with increasing water content.

All the soil samples are collected in depth 200 cm in several points along the ERI profiling. The result from grain size analysis for soil classification shows the type of soil sample is gravel which is more than 50 percent coarse fraction of gravel size. The correlation shear strength parameters (cohesion and angel of friction) with electrical resistivity have been conducted using direct shear test measurement. The direct shear test is a simple and widely used test for determining the shear strength of soil. Since the soil type is gravel there are no relationship between cohesion and electrical resistivity as shown in Figure 4. Cohesion parameters are suitable for cohesive soil which have high clay portion. Figure 5 shows a relationship between angel of friction and electrical reissitivity. The relationship in liner series with y=0.005x +19.700 and the R^2 is 0.336.

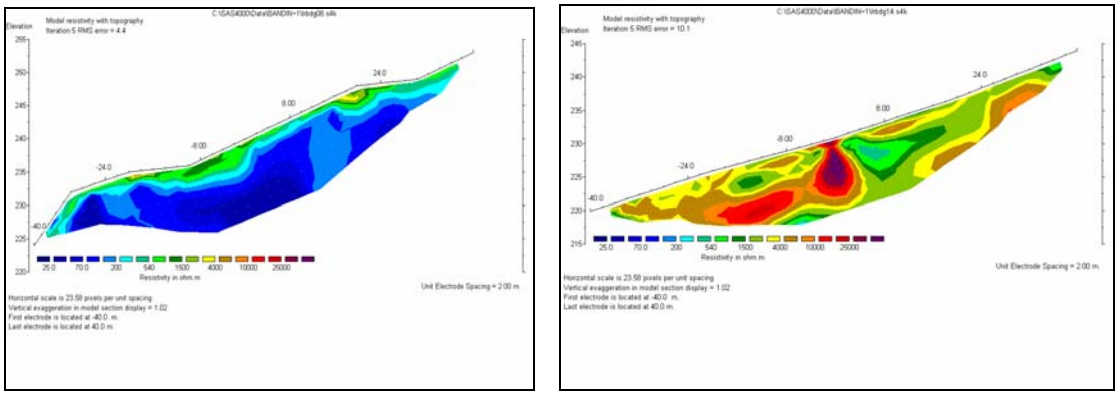

Figure 1: Electrical resistivity image of Line 1 located in slope failure of skid

Figure 2: Electrical resistivity image of Line 4 on the western side approximately opposite to Line 1.

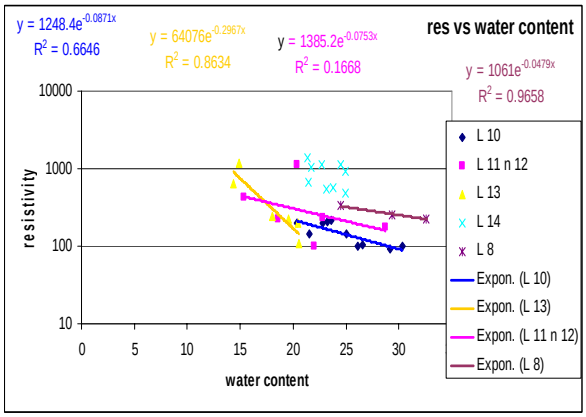

Figure 3: Relationship between electrical resistivity and water content for different ERI profiling

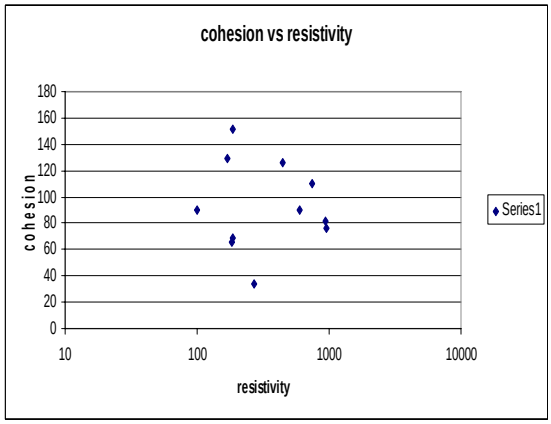

Figure 4: Relationship between cohesion and resistivity

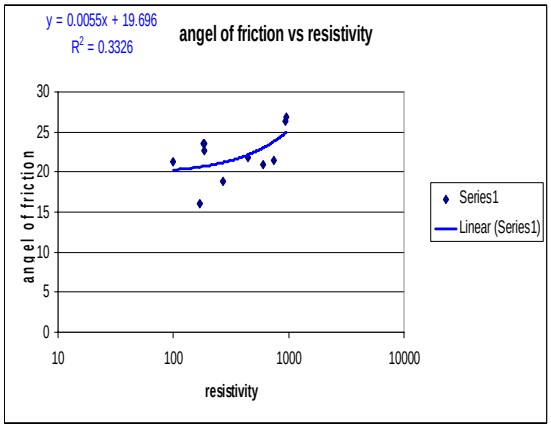

Figure 5: Relationship between angel of friction and resistivity

Significance of Findings

The present work attempts to establish empirical relationship between strength parameter of residual soil between Meta-argillites and Meta-arenites types of rock in Banding Island. The shear strength parameters will be correlate with the electrical resistivity of the same sample through out of this study area. The establish relationship will be applied to the field and actual electrical resistivity to obtain the general distribution of the strength parameters of soil in Banding Island.

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