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Slope Monitoring Study Using Time-Lapse Resistivity Tomography and Engineering Soil's Characterization Methods

Andy A. Bery

Geophysics Section, School of Physics, Universiti Sains Malaysia, 11800 Penang, Malaysia

Abstract: This paper present the integration of time-lapse resistivity tomography and engineering soil's characterization in slope monitoring study in Penang Island, Malaysia. This study was conducted at very low cost and this integration was able to gives important information about the slope subsurface during monitoring period. The time-lapse resistivity tomography by merging data levels for two optimized arrays of wenner-schlumberger and pole-dipole arrays. The total number of datum points for wenner-schlumberger array is 665 meanwhile for pole-dipole array is 1387. The total number of data points used in this study is 2052 data points. From the resistivity time-lapse resistivity results, the results were successful in imaged the percentage changes of model resistivity at the slope subsurface. This percentage change of resistivity is related to the subsurface change which due to water present at different time. This percentage changes in model resistivity is also indicate the location of weak zones and unsaturated zones at the subsurface. Thus, in this research, we studied the empirical correlation about related engineering parameter such as grain-size distribution, moisture content, atterberg limits and soil's index properties at the slope area.

Key words: Time-lapse resistivity · Slope monitoring · Low cost · Engineering

INTRODUCTION

Slope stability has been an important matter discussed in geotechnical engineering area. The slope monitoring is the main method used for information-based construction. The study of slope stability using slope monitoring become more important to geoscientists and civil engineers in order to prevent lost of lost and structure failure. Thus the combination of non-constructive geophysical method such as electrical resistivity and soil's engineering study is necessary to understand the Earth subsurface characteristic at certain duration. Recently slope monitoring study has been conducted by [1-4]. [5] declared that: "because of the unpredictability of slope behaviour, slope monitoring programs can be of value in managing slope hazards and they provide information that is useful for the design of remedial work".

Geophysical methods such as electrical resistivity and seismic refraction are the common use to study the slope stability study. Recently in environmental study, the synthetic modelling application in high resolution seismic refraction tomography was studied by [6]. Integration of engineering parameters with the seismic refraction velocities has been studied by [7]. Electrical resistivity tomography has been used to determine the actual dimension of the buried bunkers [8]. Geoelectric resistivity survey was conducted by [9] for investigating two industrial sites to the east of Matruh city, northwestern coast of Egypt. The process of site investigation is controlled by the occurrence of groundwater, nature of bedrock and presence of shale or clays as prerequisite information for any developmental project. [10] have used application of pole-pole array for the detection of shallow structures. Stability of slope and seepage analysis in earth fills dams using numerical models have been studied by [11]. High resolution time-lapse resistivity tomography with merging data levels by two different optimized resistivity arrays for slope monitoring study was studied by [12].

MATERIALS AND METHODS

This study was conducted at Penang Island, Malaysia. Penang Island has no sedimentary rock. Penang Island is underlain by igneous rocks which are granites in

Corresponding Author: Andy A. Bery, Geophysics Section, School of Physics, Universiti Sains Malaysia, 11800 Penang, Malaysia.

Table 1: Engineering laboratory analysis results

Sample No.	Resistivity ρ(Ω.m)	Soil's Cohesion C'(kN/m²)	Friction Angle Ø'(Deg.)	Moisture Content W(%)	Void Ratio e (%)	Porosity n(%)	Saturation Degree S(%)	Liquid Limit W_L(%)	Plastic Limit Wp(%)	Plasticity Index PI(%)	Liquidity Index LI(%)
1	275.119	7.35	36.22	59.175	82.500	45.210	87.635	66	45.318	20.683	69.999
2	319.869	8.07	37.28	47.231	100.00	50.000	84.311	55	37.735	17.265	55.003
3	411.589	9.05	40.47	33.233	66.670	40.001	83.687	38	27.637	10.363	53.996
4	230.677	6.01	51.47	75.937	94.440	48.571	88.307	82	57.57	24.43	75.182
5	756.463	14.27	35.08	27.15	50.000	33.333	50.620	35	25.476	9.524	17.575
6	849.853	16.11	10.24	21.245	57.143	36.364	48.933	31	17.143	13.857	29.618
7	585.191	6.87	31.21	62.157	97.636	50.598	75.123	71	55.541	15.359	42.425
8	703.878	10.60	21.40	65.775	90.589	52.469	87.475	68	64.488	3.512	36.646
9	510.298	12.44	25.99	44.175	66.959	40.105	80.770	50	37.607	12.393	52.997
10	724.743	15.27	25.95	45.239	67.102	40.156	79.186	52	38.698	13.302	49.172
11	587.216	15.18	28.00	42.049	76.471	56.667	75.379	56	37.381	18.619	25.0712

Fig. 1: The resistivity survey line is layout during the slope monitoring study

the IUGS or Streckeisen classification. The total length of the study line is 40 m with 1 m electrode spacing (Figure 1). This study was conducted from November 2013 until February 2014 along the same survey line at different time. There two different optimized arrays used in this study; Wenner-Schlumberger array with total datum points of 665 and pole-dipole array with total datum points of 1387 as shown in Figure 2. These two arrays were chosen in this study because the merging data levels of the two different arrays are reasonable all-around alternative if both signal strength and resolution are needed. Moreover, the depth of investigation is more acceptable than other arrays.

In geotechnical laboratory, the engineering parameters are obtained using several engineering tests such as moisture content, grain-size distribution (GSD), direct shear test, index properties of soils and atterberg limits. These engineering parameters is examined and correlated with the in-field geophysical survey. Thus, all the gather information would able to give the characterization of the slope subsurface condition.

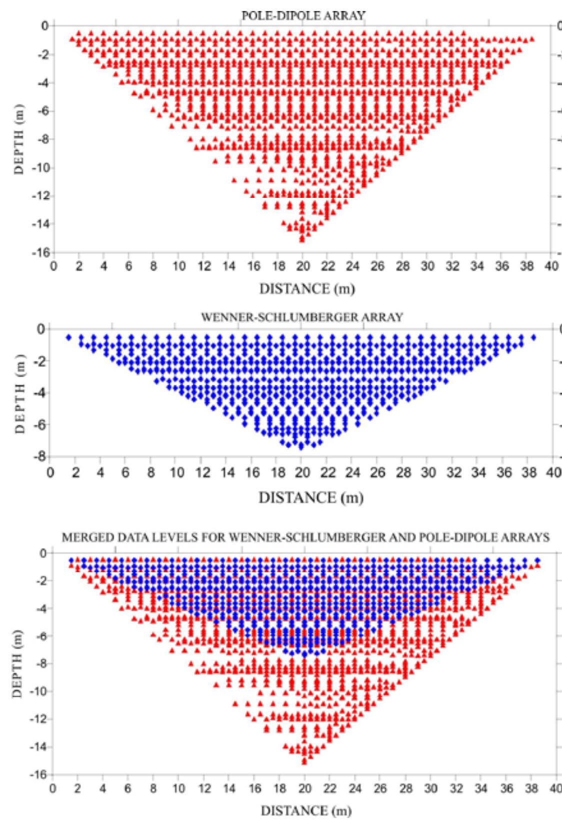

Fig. 2: The merging data levels for two different optimized arrays used in this study

RESULTS AND DISCUSSION

The infield results for electrical tomography are shows that the electrical resistivity tomography method is able in monitoring the slope subsurface over the same survey line at different time as shown in Figure 3 and Figure 4. The results for electrical resistivity are shown during December 2013 infield study and February 2014. The electrical resistivity tomography for December 2013 shows that there is moist zone (70-100 ohm.m) at distance 24m to 32 m with depth range value from 20m to27 m. Near

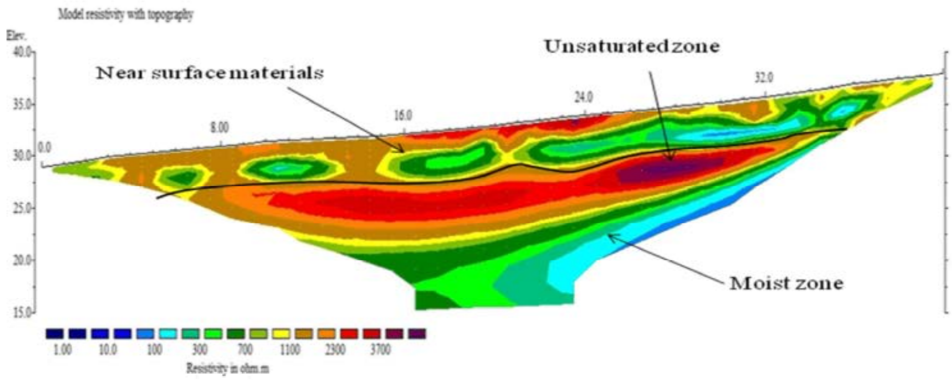

Fig. 3: Merging data levels for December 2013 infield survey

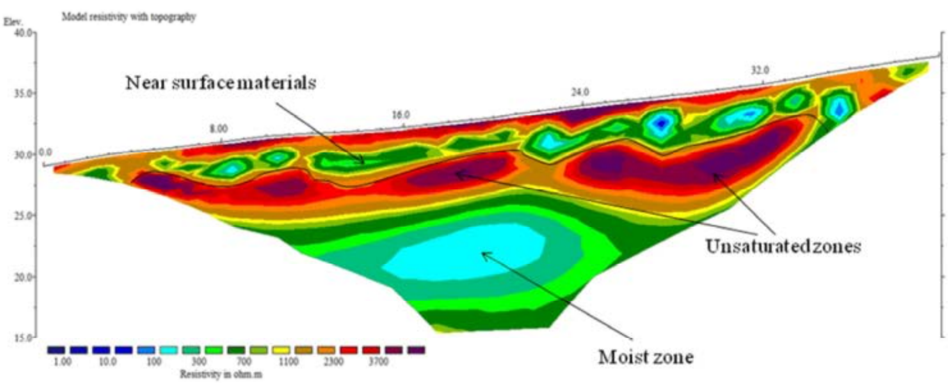

Fig. 4: Merging data levels for February 2014 infield survey

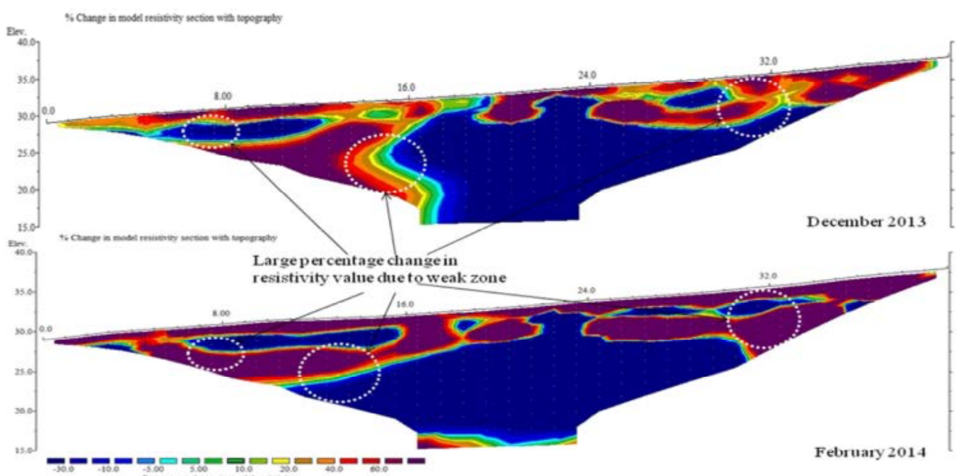

Fig. 5: The time-lapse resistivity tomography results for December 2013 (above) and February 2014 (below) show the percentage change in model resistivity at slope subsurface.

surface material (1 - 9 m) from the surface was identified as reddish clay with some gravel with resistivity value range (300 - 1100 ohm.m).

In this study, we have used time-lapse resistivity tomography method to study the percentage change in resistivity distribution at slope subsurface. This will able give detail about the changes in resistivity which close related to water present at the subsurface. The results for December 2013 and February 2014 infield survey are shown in Figure 5. There are large changes in resistivity value at certain area. This large change in resistivity value is indicated by their changes up to

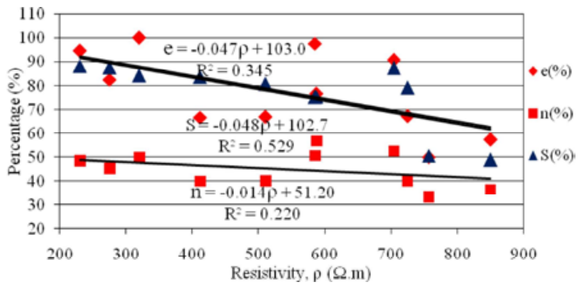

Fig. 6: The empirical correlation of void ratio (e), porosity (n) and degree of saturation (S) with resistivity (ρ) of soil samples.

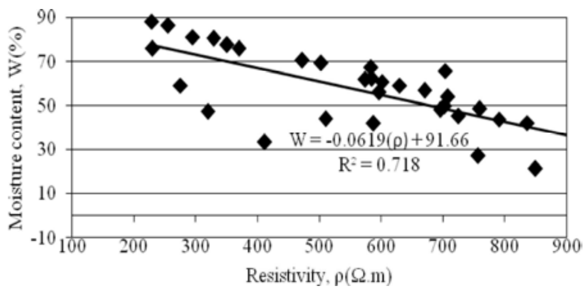

Fig. 7: The empirical correlation between resistivity, (ρ) and moisture content (W) of 32 soil samples.

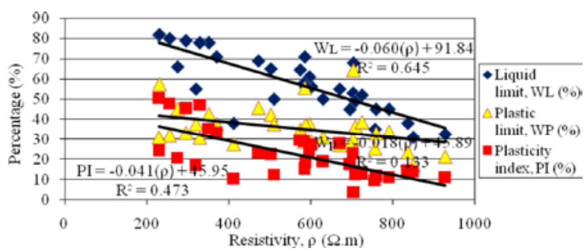

Fig. 8: The empirical correlation between liquid limit (WL), plastic limit (Wp) and plasticity index (PI) with resistivity (ρ) of 32 soil samples.

60 percent. This could be due to changes in water at the area and this indicates that this area is a weak zone at the slope subsurface.

In this section, the empirical correlation and their regression coefficient between selected engineering parameters for collected soil is discussed. The graph of index properties of soils (void ration, porosity and saturation degree) versus resistivity is shown in Figure 6 below. The empirical correlation for these three engineering parameters with electrical resistivity is successful indentified.

Another 21 soil sample collected from the field study area. The graph of moisture content (W) with resistivity is shown in Figure 7 below. The empirical correlation with its regression coefficient is shown below. The graph shows that the moisture content is inversely proportional to resistivity for the collected soil samples.

The empirical correlation between atterberg limits (liquid limit, plastic limit and plasticity index) with resistivity is shown in Figure 8. From the distribution of these engineering parameters, it shows that the relationship of these engineering parameters is inversely proportional to resistivity. Thus, this shows that the water content inside the soil samples is a main factor influence the resistivity value.

CONCLUSION

The slope subsurface is successful imaged by the geophysical method of electrical resistivity along the same survey line at different time during slope monitoring period. The time-lapse resistivity tomography was successful correlated with water present at the slope subsurface. Thus integration of geophysical method and engineering study is a useful tool in study the environmental because this study was conducted at low cost but it able to gives important information about the slope subsurface.

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