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 presents 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 the integration was able to provide important information about the slope subsurface during the monitoring period. The time-lapse resistivity tomography by merging data levels for two optimized arrays of werner-schlumberger and pole-dipole arrays. The total number of datum points for werner-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 Matrihu 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
Table 1: Engineering laboratory analysis results

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Soil Resistivity (Ωm)</th>
<th>Soil's Cohesion C'(kN/m²)</th>
<th>Fricion Angle Ø'(Deg.)</th>
<th>Moisture Content W(%)</th>
<th>Void Ratio e (%)</th>
<th>Porosity n(%)</th>
<th>Saturation Degree S(%)</th>
<th>Liquid Limit Wl(%)</th>
<th>Plastic Limit Wp(%)</th>
<th>Plasticity Index PI(%)</th>
<th>Liquidity Index LI(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>275.119</td>
<td>7.35</td>
<td>36.22</td>
<td>59.175</td>
<td>82.500</td>
<td>45.210</td>
<td>87.635</td>
<td>66</td>
<td>45.18</td>
<td>20.683</td>
<td>69.99</td>
</tr>
<tr>
<td>2</td>
<td>319.869</td>
<td>8.07</td>
<td>37.28</td>
<td>47.231</td>
<td>100.00</td>
<td>50.000</td>
<td>84.311</td>
<td>55</td>
<td>37.75</td>
<td>17.265</td>
<td>55.003</td>
</tr>
<tr>
<td>3</td>
<td>411.589</td>
<td>9.05</td>
<td>40.47</td>
<td>33.233</td>
<td>66.760</td>
<td>40.001</td>
<td>83.687</td>
<td>38</td>
<td>27.637</td>
<td>10.363</td>
<td>53.996</td>
</tr>
<tr>
<td>4</td>
<td>230.677</td>
<td>6.01</td>
<td>51.47</td>
<td>75.937</td>
<td>94.440</td>
<td>48.571</td>
<td>88.307</td>
<td>82</td>
<td>57.57</td>
<td>24.43</td>
<td>75.182</td>
</tr>
<tr>
<td>5</td>
<td>756.463</td>
<td>14.27</td>
<td>35.08</td>
<td>27.15</td>
<td>50.000</td>
<td>33.333</td>
<td>50.620</td>
<td>35</td>
<td>25.476</td>
<td>9.524</td>
<td>17.575</td>
</tr>
<tr>
<td>7</td>
<td>585.191</td>
<td>6.87</td>
<td>31.21</td>
<td>62.157</td>
<td>97.636</td>
<td>50.598</td>
<td>75.123</td>
<td>71</td>
<td>53.541</td>
<td>15.359</td>
<td>42.425</td>
</tr>
<tr>
<td>8</td>
<td>703.878</td>
<td>10.40</td>
<td>21.40</td>
<td>65.775</td>
<td>90.589</td>
<td>52.469</td>
<td>87.475</td>
<td>68</td>
<td>64.488</td>
<td>3.512</td>
<td>36.646</td>
</tr>
<tr>
<td>9</td>
<td>510.298</td>
<td>12.44</td>
<td>25.99</td>
<td>44.175</td>
<td>66.959</td>
<td>40.105</td>
<td>80.770</td>
<td>50</td>
<td>37.607</td>
<td>12.393</td>
<td>52.997</td>
</tr>
<tr>
<td>10</td>
<td>724.743</td>
<td>15.27</td>
<td>25.95</td>
<td>45.239</td>
<td>67.102</td>
<td>40.156</td>
<td>79.186</td>
<td>52</td>
<td>38.698</td>
<td>13.302</td>
<td>49.172</td>
</tr>
<tr>
<td>11</td>
<td>587.216</td>
<td>15.18</td>
<td>28.00</td>
<td>42.049</td>
<td>76.471</td>
<td>56.667</td>
<td>75.379</td>
<td>56</td>
<td>37.381</td>
<td>18.619</td>
<td>25.0712</td>
</tr>
</tbody>
</table>

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

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.

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 to 27 m. Near
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
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 slope subsurface.

REFERENCES