The Influence of Soil Moisture Content and Grain Size Characteristics on its Field Electrical Resistivity

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ABSTRACT

Electrical resistivity method (ERM) is increasingly and favourably adopted in geotechnical engineering due to a variety of reasons. In the past, ERM was popularly used in engineering, environmental and archaeological purposes. Its reliability depended entirely on the expert interpretation skills of a geophysicist. However, by virtue of the indirectness in measurement, ERM data must needs be strongly verified during the interpretation stage in order to produce results that are sufficiently reliable for use by geotechnical engineer in design and construction stages. Hence, this study presents such a demonstration of the influence of soil moisture content and grain size characteristics to field resistivity data as much desired for ERM verification. 2D ERM was performed using a set of ABEM (SAS) 4000 based on pole-dipole array. Three soil samples from locations lying along a survey line were collected immediately for moisture content and particle size distribution test according to BS 1377 (1990). Laboratory geotechnical tests strongly indicated that the electrical resistivity data can varied with the moisture content and grain size character. Soil electrical resistivity values decreased with increasing moisture content and fines content. The correlations established between the above parameters in this study, help to strongly ratify the field ERM data and thus contribute to a meaningful ERM interpretation.

KEYWORDS: Electrical resistivity; Moisture content; Grain Size; Field resistivity data; Geotechnical data

INTRODUCTION

Geotechnical site investigation (SI) process was basically related to the exploration, sampling and laboratory testing. According to Whitlow (2001), site investigation was performed to evaluate the general suitability tor environment, and to design economic structures with reference to both temporary and permanent structures in the project. It was also necessary to adopt the best construction method, efficient in terms of time, cost and quality and to allow for problems arising with the changes in ground and environmental condition which may be natural or caused either by manmade activities. It also included advising on the relative suitability of different sites such as for alternative techniques or solutions. Conventional geotechnical exploration equipment used for site investigation consisted of big, heavy and bulky machine such as rotary wash boring, cone penetration test, etc. Nowadays, construction projects are mostly carried out on sites with difficult accessibility such as in rural and mountainous area due to the accent on land use other constraints. As a consequence, the time and cost of the project was affected due to the mobilization and operation of those bulky conventional SI machine. However, current development of alternative SI techniques from another discipline such as geophysical method is proving to be a successful and worthwhile tools that are applicable for most of geotechnical works.

The basis of geophysics is the study of earth using a quantitative physical scence approach. Some of the physical properties used were electrical resistance, density, velocity, magnetic susceptibility, etc. Geophysical techniques are an indirect or surface method which consists of electrical resistivity, seismic, ground penetrating radar, gravity, magnetic, electromagnetic. In the Malaysian construction context, resistivity and seismic method are the most practical geophysical methods used due to the successful contrast outcome. The technology is easily mobilized and time saving. Common geophysical practices are often adopted in engineering, environment and archeological studies such as to locate boulders, bedrock, overburden materials, earth work related to the rippability, leachate migration, groundwater sources and contamination, cavity, sinkhole, etc. As reported by Benson et al., (2003), it is important to understand the physical properties associated with the target of interest in order to select the most suitable geophysical method. According to Clayton et al., (1995), geophysical techniques offer the chance to overcome some of the problem inherent in more conventional ground investigation techniques. Furthermore, this technology is less expensive, less invasive and less time consuming (Abidin, 2011; Liu and Evett, 2008 and Lee, 2002). Geophysical methods use an indirect method to measure the physical properties from the surface during data acquisition in order to map the subsurface profile by anomaly outcome. The raw observation data is processed using utility software and proceed for the interpretation which is traditionally verified using geological description of borehole. Nevertheless, according to Fraiha and Silva (1994) and Benson et al., (2003), geophysical methods are insufficient to stand alone in order to provide solutions to any particular problems.

In the past, major problem in geophysical data interpretation was often a result arising from ambiguous data. Data acquisition, processing and interpretation, is still exposed to noise which may come from the equipment, geological, environment and operator or human factor culminating in the geophysical data ambiguity. Conventional reference tables of geomaterials used for anomaly interpretation also sometimes was difficult to decide due to its wide range of variation and overlapping values. As a result, a strong verification is vital to support the interpretation outcome which otherwise have been traditionally interpreted based on a qualitative approach depending on the experience of the expert. It is important to integrate the geophysical input with other design criteria such as laboratory geotechnical data. The success at any site investigation works was based on the integration of method (Benson et al., 2003). Hence, this study embarked on the investigation of the influence of soil moisture content and grain size analysis on electrical resistivity data in quantitative perspectives so that it can contribute to verify and enhanced a level of confidence among the related parties during the results interpretations stage used in the subsequent stages of design and construction.

METHODOLOGY

This study was conducted in two stages viz; field electrical resistivity tomography and selected laboratory soil classification test.

2–D Electrical Resistivity Field Tomography

A single leveled line of electrical resistivity survey was performed using the suite of ABEM SAS (4000) equipment available at Universiti Sains Malaysia, Engineering Campus. Small (150 mm long) steel electrodes placed at equal spacings of 17 cm was used for a total of 41 electrodes, connected to the two resistivity multicore cable by 41 numbers of jump cables. The field resistivity data (apparent resistivity) was recorded using Terramater SAS (4000) data logger. Data acquisition was performed using pole-dipole array which require a single infinity electrode. After the data acquisition stage, the raw data was transferred from data logger to the computer and was processed and analyzed using RES2DINV software.

Soil Sampling, Moisture Content and Particle Size Distribution Test

Three disturbed soil samples (A, B and C) obtained from locations in the line of the 2D electrical resistivity survey was taken to the laboratory for moisture content and grading test. Disturbed soil samples were taken using hand auger down to a depth of 24 cm. Soil sample A (at the end of the West-East direction) and C (at the end of the East-West direction) was taken form side of the line while the soil sample B was taken at the center of the line as illustrated in Figure 1.

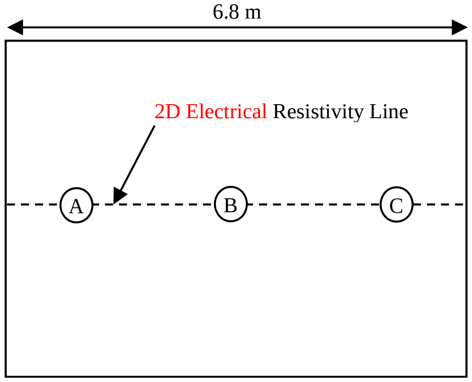

Figure 1: Schematic diagram (Plan view) of the position of soil sampling and resistivity line alignment

All soil samples obtained from the sites were taken to the laboratory immediately for moisture content and particle size distribution test. Moisture content or water content is the method to quantify the amount of water contained in material such as soil, rock, wood, etc. Soil moisture content remains an important and crucial parameter throughout geotechnical engineering practice both in the laboratory and field. Dry and wet sieve test was performed for grading characteristics determination due to its fine soil condition. Dry sieve was conducted using mechanical sieve shaker while the hydrometer test was used to quantify the fine soil which passes through a 63 µm test sieve size. Based on Friedel et al., (2006), soil parameters determined in grain size analysis could replicate the variety of resistivities obtained on the site very well. Aspects of the detailed experiments were in accordance with BS 1377-2 (1990).

RESULTS AND DISCUSSION

The electrical resistivity result as given in Figure 1 displayed a cross section of 6.8 meter length with a maximum depth of 2.72 meter. This very shallow profile was produced with the small electrode spacing adopted in order to determine a soil resistivity value at a very shallow depth of interest. Resistivity values referred to in this study area as reported by previous researchers are given in Table 1. Generally, the profile displayed an anomaly representing an alluvium due to the resistivity values that varied from 10 – 800 Ωm. Resistivity value from points A, B and C was extracted using the RES2DINV software and is as tabulated in Table 2 for detailed study while the laboratory soil test results are given in Tables 3 and 4 respectively.

Table 1: Typical values of electrical resistivity constants for some of the earth materials

Description	Resistivity, ρ (Ωm)
Alluvium (Telford and Geldart 1976)	10 – 800
Clays (Telford et al., 1990)	1 – 100
Clay and saturated silt (Peck et al., 1974)	0 – 100
Dry clay and silt (Sowers, 1979)	100 – 500
Sand (Peck et al., 1974)	500 - 1500
Surface waters (sediments) (Telford et al., 1976)	10 – 100

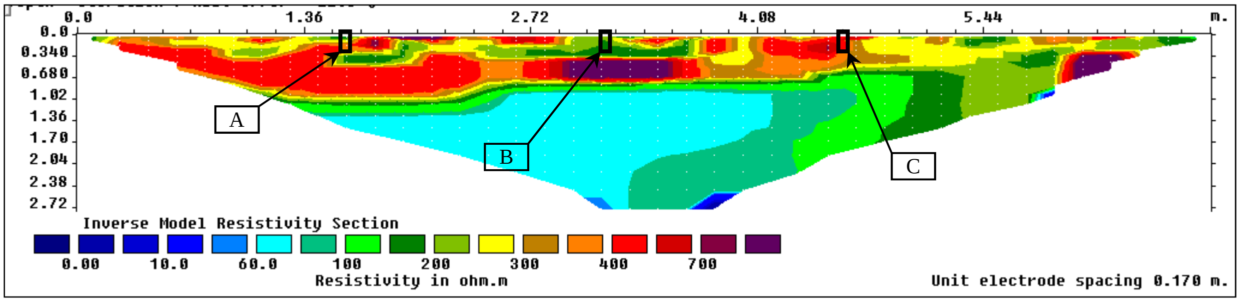

Figure 1: Global 2D Electrical resistivity tomography results and localize selected point (A, B and C) used for further detail study

Table 2: Electrical resistivity values for soils located at point A, B and C

Soil sample	**A**	**B**	**C**
Resistivity value, ρ (Ωm)	395	263	289

Table 3: Moisture content at points A, B and C

Soil specimen	1a	1b	1c
Moisture content, w (%)	35.52	48.68	40.12

Table 4: Moisture contents at points A, B and C

Soil specimen	Material	Quantity, %	Quantity, %
A	Gravel	7.85	34.19
	Sand	16.34	
	Silt	46.22	75.81
	Clay	29.59	
B	Gravel	6.85	20.51
	Sand	13.66	
	Silt	43.12	79.49
	Clay	36.37	
C	Gravel	5.12	22.86
	Sand	17.74	
	Silt	47.58	77.14
	Clay	29.56	

Three soil samples were obtained from locations at points A-C to determine the influence of resistivity data due to changes in the moisture content and grain size. According to results presented in Table 2, it can be noted that the soil resistivity value was highest at point A (395 Ωm) followed by point C (289 Ωm) and then B (263 Ωm). From the laboratory soil test results, it was noted that the moisture content value was highest at point B (48.68 %) compared to the other points while the lowest moisture content value was at point A (35.52 %). The quantity of soil grain also contributes to the inconsistency of resistivity value. Generally, soil can be in form of both granular and fine particle which also influences the resistivity value especially depending on its ability to contain water. Based on sieve analysis, it was found that the quantity of granular soil was highest at point A (34.19 %) compared to point B (20.51 %) and C (22.86 %). Moreover, the quantity of fine soil was recorded to be the highest at point B (79.49 %) and slightly less at point C (77.14 %) and B (75.81 %) respectively. According to Abidin et al., (2012), resistivity data exhibits a low value for a fine soil such as clayey and silty while the coarser soil such as sand and gravel will produce a higher resistivity value. Hence, this study was demonstrate that the highest resistivity value at point A was contributed by the lowest quantity of moisture content with highest quantity of coarse soil and lowest quantity of fine soil compared to soil at point B and C. The lowest resistivity was found to at point B since it contained highest moisture content and the highest proportion of fine soil and therefore the lowest proportion of coarse soil. According to Telford et al., (1990) and Griffiths and King, (1981), resistivity value is highly influenced by pore fluid and grain matrix of geomaterials. Furthermore as stated by Telford et al., (1990), electrical current may propagate in geomaterials via the process of electrolysis where the current is mobilised by ions at a comparatively slow rate. Overall results as presented in Figure 2 summarize the influence of resistivity data due to changes in the moisture content and particle size distribution of soil.

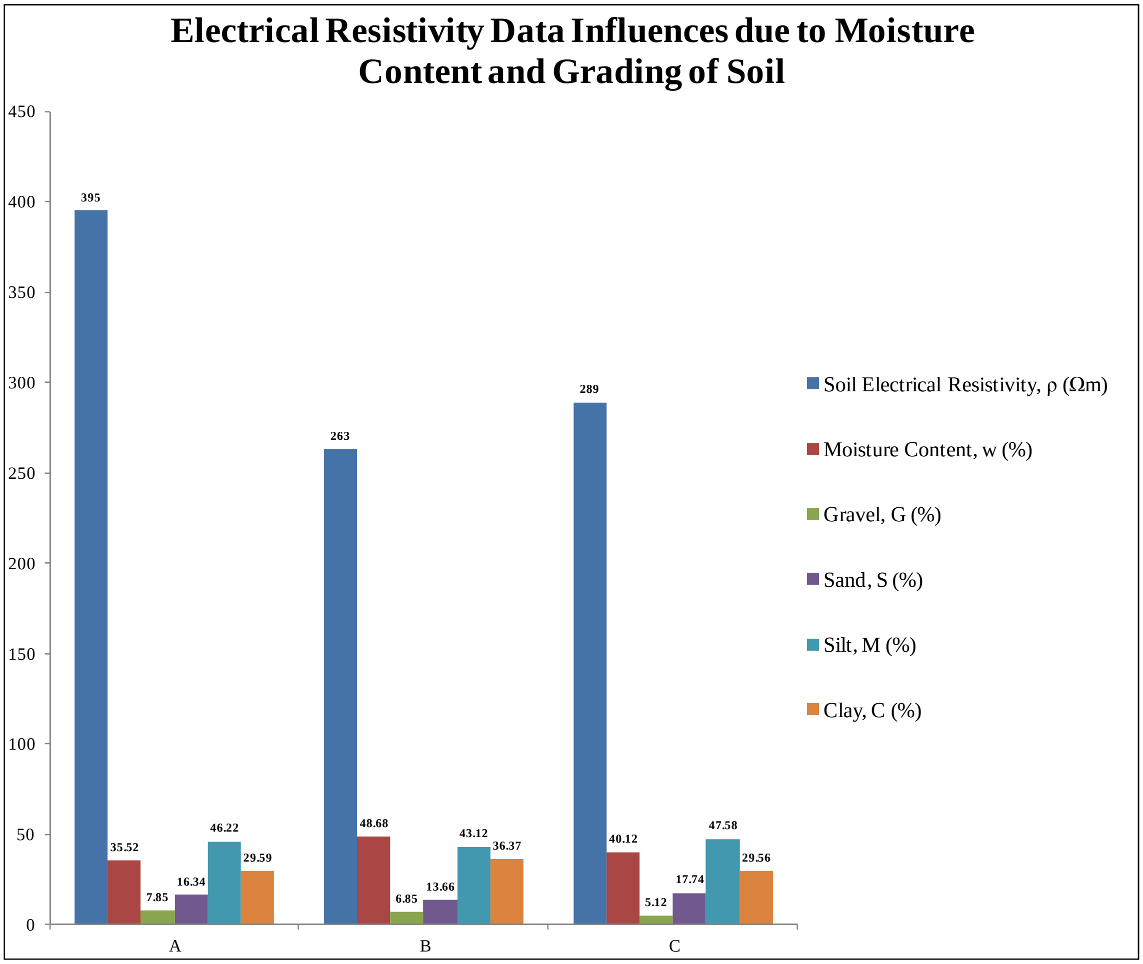

Figure 2: Overall results from field resistivity test and geotechnical lab test from point A, B and C

CONCLUSION

The influence on soil resistivity data due to changes in the moisture content and grain size was successfully and methodically studies and presented. The soil electrical resistivity data was observed to be very sensitive to the quantitative proportion of water and geomaterial particle fractions. The soil electrical resistivity data was successfully being verified using geotechnical laboratory moisture content and particle sizes distribution test. The integration of geophysical method such as field resistivity survey with laboratory geotechnical method provided a meaningful contribution to the geophysicist and geotechnical engineers since it applicable to minimize and explain some of the ambiguity during the data interpretation stage.

ACKNOWLEDGEMENT

First author wishes to acknowledge gratefully the interaction of the supervisors and research members, and for their tremendous guidance, assistance and cooperation.

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