Tomography Analysis of Compacted Soil Using Electrical Conductivity

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ABSTRACT

This paper reveals the soil compaction monitoring with tomography analysis as a determination of soil properties such as soil resistivity, soil moisture and angle of repose through Electrical Conductivity (EC). Estimation of soil compaction with electrical signal is becoming increasingly viable as commercial and technological solution in the construction of highway embankments, earth dams and many other engineering structures. To estimate the soil compaction in conventional soil monitoring technique is very tedious and costly with gathering a lot of sample of compacted soil for laboratory testing in geotechnical engineering. In this paper, the new idea is established to include 2-D tomography analysis with soil compaction monitoring using EC measurement system. Precision digital Multimeter and microcontroller handles the data acquisition, signal processing, control, and communication in this soil compaction measurement system. The performance of newly developed soil compaction measurement through EC system is estimated as reliable and robust with arrangement of tomography analysis in soil investigations. The importance of our research is to establish the reliable, faster and cost-effective soil compaction monitoring system with EC measurements in geotechnical site investigations.

Keywords: Soil resistivity, soil compaction, tomography analysis, Electrical conductivity.

I. INTRODUCTION

Electrical resistivity measurement of the compacted soil is important to be used as a proxy for the spatial variability of other soil physical properties like structure [2], water content or fluid composition. Soil compaction monitoring through EC system shows the important role in the construction of highway embankments, structural engineering and many other geotechnical engineering [10].The basic mechanism of the soil EC measurement system [11] for compacted soil is that when a constant voltage is applied to one of the two probes placed in the soil the current that flows between the probes is inversely proportional to the resistance of the soil [2,3,7]. Conventionally, the compaction of soil is measured through bulk density, dry density and moisture contents of the soil investigations [1,8]. The laboratory test is generally performed to reveal the maximum dry density versus the optimum moisture contents in soil compaction monitoring.

In addition, very limited work has been done so far on the technologies to demonstrate soil resistivity data of compacted soil as 2-D tomography in soil site investigations.

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Islam and Chik [6] shows multichannel analysis of surface wave method (MASW) method 2-D tomography to provide a robust and relatively straightforward method of examining the shallow subsurface. The tomography analysis in Digital Image Processing (DIP) system is embedded with the soil EC measurement system in this paper where real time data of the soil compaction and other soil properties are revealed clearly in geotechnical engineering. The advancement in soil compaction monitoring and Digital Signal Processing (DSP) is very significant due to the robust performance with running of a feasible precision in geotechnical framework. Emerging tomography analysis [6] with soil EC measurements for compacted soil are very consistent for the low power needs in civil and environmental engineering.

Collecting a lot of shots with shifting the electrodes of digital multimeter yields images representing the spatial variation of soil resistivity with dimensions. Array technique of computer programming is implemented to gather multiple 1-D soil resistivity outcomes to expose 2-D tomography of compacted soil. For the combination of multiple 1-D inversion outcomes, the characteristics for a particular site are revealed comprehensively with the consideration of depth and distance versus soil resistivity outcomes. Several key characteristics of soil resistivity data and 2-D tomography are capable to reveal better performance in geotechnical investigations, where other geophysical tools have failed or provided inadequate result. The aim of this research is to obtain a robust, cost-effective, faster and reliable soil EC measurement system with tomography analysis for compacted soil monitoring in geo-environmental engineering.

II. METHODOLOGY

The research study on the soil compaction monitoring measurement is conducted at University Kebangsaan Malaysia with the cooperation of Ministry of Science, Technology and Innovation of Malaysia. The data collection for soil compaction identification with soil resistivity is carried on at University Kebangsaan Malaysia (UKM) in Bangi, Selangor, Malaysia shown in Figure 1. The study of tomography analysis with soil EC measurement system is done and the analysis is performed using MATLAB 7.1 in Geotechnical Laboratory, Faculty of Engineering and Built Environment, University Kebangsaan Malaysia (UKM).

Conventionally, Soil compaction is estimated through the measurement of dry density of compacted soil with different percentage of water contents [5]. More dry density shows the reduction of water contents of soil more which increases the resistivity of surface soil in geotechnical field.

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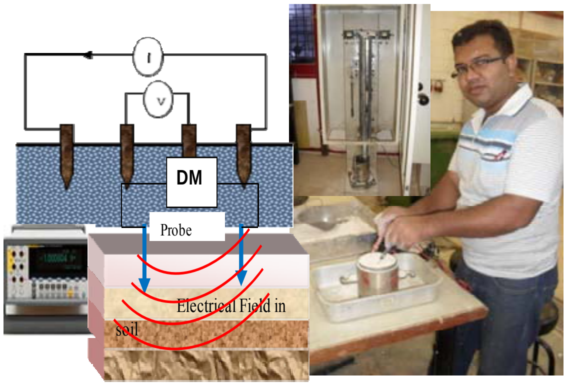

FIGURE 1 Soil EC measurement for compacted soil

Thus, the relation of soil water content with dry density and soil resistivity at the time of measurement clearly are major factors contributing to soil EC surveys. The resistance, R in unit of Ohm(Ω) of an electrical elements is defined through the Ohm's law.

$$R = \frac{V}{I} \quad (1)$$

Where, V is the potential difference in volt (V) and I is the current conduction (A) of electrical measurements. The resistivity, ρ of compacted soil is defined from the measured resistance of the soil as,

$$\rho = \frac{R \times A}{l} \quad (2)$$

where, R is the Resistance (Ω) of the conductor material, l is the Length of the conductor (m), and A is the Cross sectional Area (m^2).

Signal is generated through the electronics circuit of pulse generator and conducted to the probes situated in the soil. The electrical signal generated from V-Pulse generator of fixed peak to peak amplitude is transmitted through the probes in the soil. This propagated electric current in the soil between the two steel probes makes an electric field for electrical signal propagation. The current at the other end of the electrode is converted to a suitable voltage for soil EC measurements. The analog electrical data is then converted into a digital value for measuring purposes using a built in Analog to Digital Converter (ADC) inside the microcontroller.

The soil resistivity measurements of compacted soil are done in this work using precison digital Multimeter of Fluke Company with accurate measurements and Mega-Ohm scale for easier reading. The specifications and functions of insulation tester for soil resistivity calculations include measuring 100 μA to 10 A current range, with up to 100 pA resolution. High resistance meter with digital and analog configurations are used in our research to measure soil resistance with consistency.

III. RESULT AND DISCUSSION

Soil compaction monitoring with tomography analysis is developed in this research work. Recent advancement in electronics and signal processing have improved the ability to collect, process of data to manifest subsurface soil properties of compacted soil with EC system in geotechnical engineering [4,9]. To maximize the effectiveness of soil compaction measurement through EC system features of DSP and DIP is embedded in this system for geotechnical characterizations.

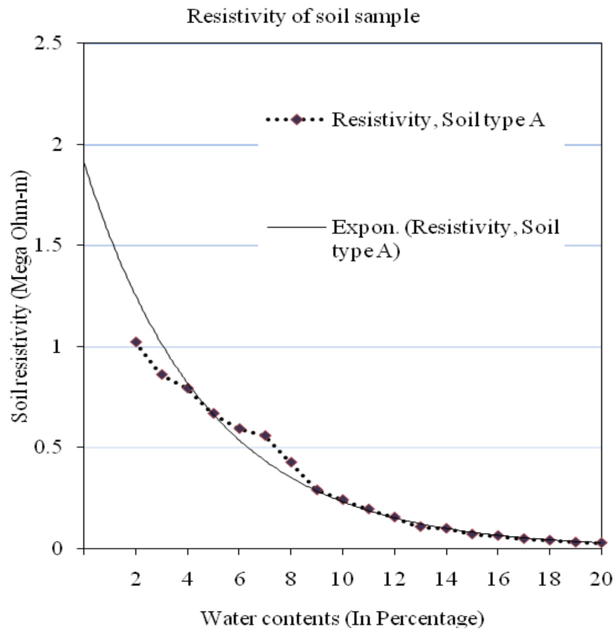

FIGURE 2 Representation of soil resistivity data for different water contents

In the soil compaction measurement through EC system, soil resistivity is measured according to the different percentage of water contents shown in Figure 2. Maximum dry density of the compacted soil is obtained with laboratory testing to obtain the mathematical relationship with soil resistivity in soil investigations. The soil resistivity as well as corresponding moisture contents data is stored in computer for soil compaction estimation.

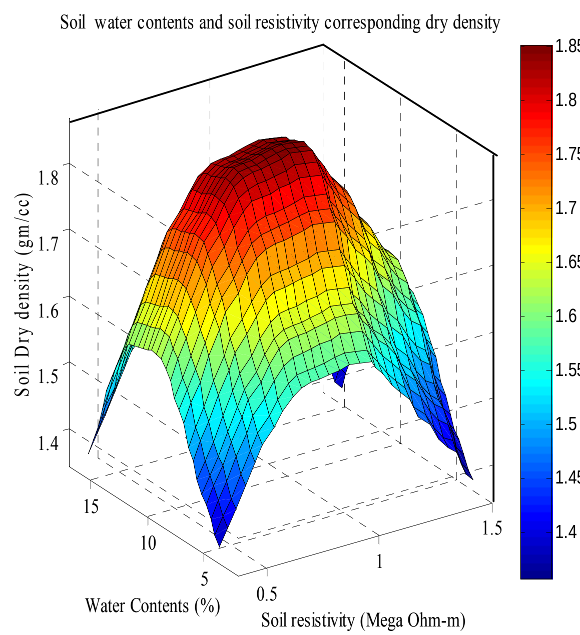

FIGURE 3 Soil dry density estimation from water contents and soil resistivity

Figure 3 shows dry density outcomes of compacted soil corresponding to the water percentage of soil and soil resistivity data in soil characterizations. As an example, for ten percent water contents with the soil resistivity as 0.45 Mega Ohm-m, the dry density of soil is demonstrated 1.65 gm/cc in soil resistivity measurement of compacted soil.

The 2-D tomography with soil resistivity profile is the advanced technique in geotechnical investigations to investigate the characteristics of compacted soil [6]. This technique is able to represent the depth and distance versus soil resistivity for near-surface soil profile. A 2-D soil layer profile is developed by gathering multiple 1-D resistivity outcomes shown in Figure 4, where data is stored using array declaration of DIP through computer programming language.

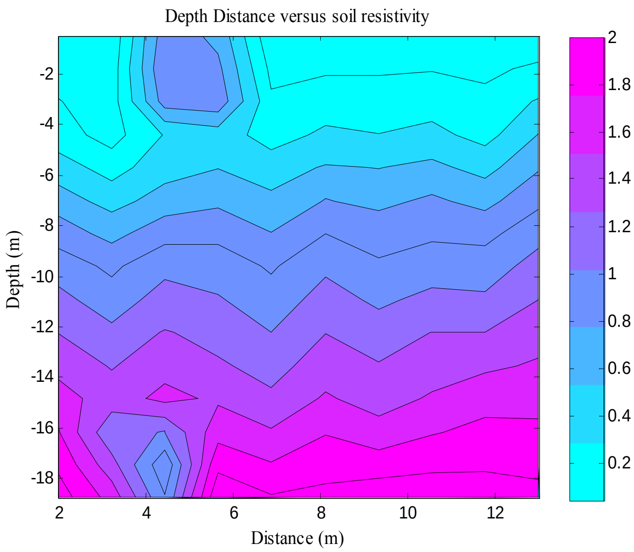

FIGURE 4 2-D tomography of soil resistivity profile

Usually, data has been taken from soil site to obtain the comprehensive information for soil compaction monitoring through laboratory test which is labor intensive, and expensive for soil investigations. Including tomography with soil EC measurement in our research work is also robust and cost-effective system for commercial and technological solutions with few test verifications in surface soil investigation. The filtering technique in this system is competent to reduce the noise of electrical signal collected through EC sensor in soil monitoring technique.

IV. CONCLUSION

A robust soil compaction measurement system is developed with the aim of achieving low cost, reliable and faster outcomes in geotechnical investigations. To obtain the better performance in soil site investigations, the 2-D tomography technique is embedded with soil EC measurement system in the research work. The design, block diagram, and the performance of tomography analysis are obtained for soil compaction monitoring in geotechnical and geo-environmental engineering. The developed relation of soil compaction with electrical resistivity is cost-effective including demonstration of depth and distance versus soil resistivity profile. The analysis used in this study would incorporate soil EC measurement system with other characteristics of soil and plot graphs for providing immediate information on the level of spatial variation of soil profile.

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