Int. J. Electrochem. Sci., 6 **(2011)** 6733 - 6740

International Journal of
ELECTROCHEMICAL
SCIENCE
www.electrochemsci.org

Study of Chemical Effects on Soil Compaction Characterizations Through Electrical Conductivity

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Received: 11 September 2011 / *Accepted:* 28 October 2011 / *Published:* 1 December 2011

This paper presents the influences of chemical characteristics on soil compaction measurements through electrical conductivity in geotechnical investigations. The particle shape of soils, soil moisture contents and presence of chemical properties influence electrical conductivity of soil. The presence of organic materials and waste materials in soil effects on the soil compaction characteristics. In this study, soil compaction estimation with electrical resistivity is shown including chemical characterizations in the soil of geotechnical engineering. In addition, soil resistivity measurements with moisture contents and conventional laboratory test of determining bulk density and dry density are conducted in this research. The pH value of soil sample is also taken to obtain the chemical characterizations of soil. The results of the study are shown as the experimental observations in soil compaction monitoring of chemical contaminated soil through electrical conductivity. The research is crucial for the study of soil compaction determination including chemical characterizations through electrical signal in geotechnical engineering.

Keywords: Compaction characteristics; soil electric resistivity; soil chemical characteristics

1. INTRODUCTION

The soil characterizations with electrical conductivity (EC) are very important to determine soil compaction in geotechnical characteristics [1]. Soil EC measurements can be influenced with the specific soil chemical properties including chemical contamination, salinity, porosity, integrity of chemical in soil, depth of top soil, temperature and cat ion exchange capability [11-14]. The particle shape of sediments, soils, and rocks, moisture contents have influences on important transport properties, such as electrical conductivity [2], dielectric permittivity [5], soil resistivity, thermal conductivity, and hydraulic conductivity. Soil electrical resistivity depends on soil water content as well as dry density of data fields [7]. Soil resistivity also depends on soil texture (especially content of clay), soil type and water holding capacity and the amount of dissolved ions in pore water [6-9]. More dry density reduces water content of soil which increases the resistivity of surface soil in geotechnical field.

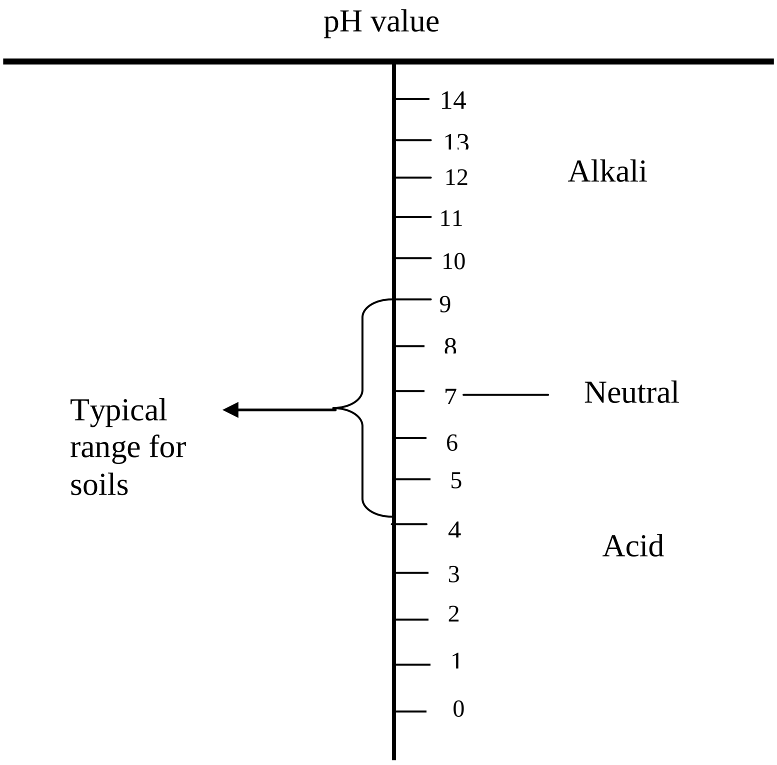

Figure 1. pH range of soil in geotechnical investigations

Soil has pH range to show the presence of acid or alkaline of soil. More acidic soil is serious corrosive to common constructions materials such as steel, cast iron and zinc coating [4]. Soil acidity is produced for mineral leaching, decomposition of acidic plant, industrial wastes, acid rains and certain form of microbiology activity. Alternatively, soil containing high sodium, potassium, magnesium and calcium are responsible to be alkali. Figure 1 shows the range of acidity and alkalinity of the soil based on their pH values.

The presence of chemical materials effects on soil compaction characteristics [3]. The presence of organic materials in a soil shows the effects on soil strength. Generally, the soil compaction characteristics have been taken with the identification of the soil bulk density, dry density and optimum moisture contents of the soil using a lot of testing in laboratory [3]. The example of dry density curve of soil is shown with changing of water contents in soil as Figure 2. Laboratory testing for estimation of bulk density, dry density and optimum moisture contents is also tedious and time consuming for collecting a lot of dry sample and compacted sample of soil. Now, researchers have concentrated to obtain bulk density and dry density of soil through measurements of soil electrical resistivity. There are very few investigations about soil compaction characteristics including presence of chemical properties through electrical resistivity in soil investigations.

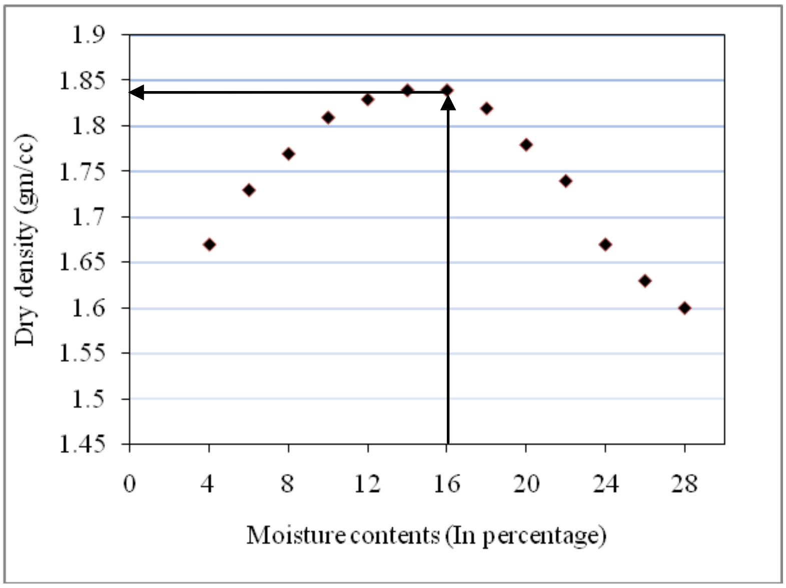

Figure 2. Dry density testing with changing of moisture contents in laboratory

In this research work, soil resistivity is obtained according to the four probes Wenner method in compacted soil measurements. The basic principle of taking soil resistivity 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 [10-11].

The laboratory tests of determining bulk density and dry density are considered to get the relations of soil compaction characteristics with electrical resistivity. The pH value of different soil sample is also measured to get the chemical characterizations for presence of organic and waste material in soil.

Considering the chemical characteristics in soil compaction monitoring with EC would be able to get idea for working with chemical contaminated soil in geotechnical engineering. The aim of the research is to show the observations of chemical influences on soil compaction measurements through electrical signal in geotechnical investigations.

2. METHODOLOGY

The research work on the soil compaction estimations through electrical resistivity is conducted at Geotechnical Laboratory, Faculty of Engineering and Built Environment in University Kebangsaan

Malaysia with the cooperation of Ministry of Science, Technology and Innovation of Malaysia. The data collection of pH value of different type of soil is carried out in this study. The study on the soil electrical resistivity and dry density of compacted soil is done and the analysis is performed using MATLAB 2009.

The soil resistivity measurements of compacted soil are done in this work using Fluke 8846A precision digital multimeter with Mega-Ohm scale for easier reading. Using four point arrangements of Fluke digital multimeter has increased the accuracy of resistivity measurements of compacted soil. The specifications and functions of precision multimeter for soil resistivity calculations are shown in Table 1.

Table 1. Specifications and function of multimeter used in soil resistance measurements

	Specifications	Functions		
Insulation Resistance Tester-Digital	Test Voltage	1000 V and 600 V		
	Measuring ohms Ranges	10 Ω to 1 GΩ with up to 10 μΩ resolution		
	Measuring current ranges	100 μA to 10 A current range, with up to 100 pA resolution		
	Measurement technique	2 x 4 ohms 4-wire		
Insulation Resistance Tester-Analog	Test Voltage	DC 1000 V	DC 500 V	DC 250V
	Measuring ohms ranges	0~400 MΩ	0~200 MΩ	0~100 MΩ
	Mid Scale Value	4 MΩ	2 MΩ	1 MΩ

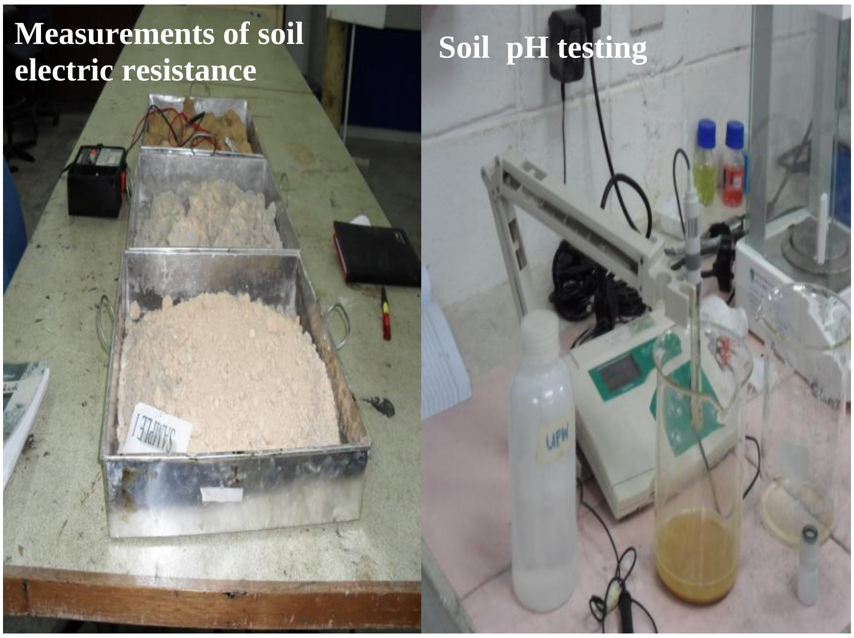

Figure 3. Measurements of soil electric resistance and pH value of soil

Various components of the instruments are configured, assembled, and tested as Figure 3 in this research work. Soil electrical resistivity and pH value of soil are obtained with small-scale measurements of different soil properties. Laboratory tests are performed involving soil physical properties such as water content, soil structure, ranges of soil particle sizes, soil bulk density in this study.

Soil electric resistivity is obtained with passing the electric currents using electric source. The electric current is passed in the soil between the two steel probes. The amount of current that flows in soil between the probes is directly proportional to the EC of the soil. The current is detected at the other end of the electrode and suitable voltage differences are considered to obtain resistance of soil.

3. RESULT AND DISCUSSION

Different types of soil are collected from different construction site to conduct the study. Standard Proctor compaction tests, ASTM D-698 (American Society for Testing and Materials) are carried out for different types of soil. Resistivity is measured for every compacted soil sample with changing of percentage of water contents in soil. Maximum dry density and soil resistivity are obtained at optimum moisture contents to get the compaction characteristics of soil.

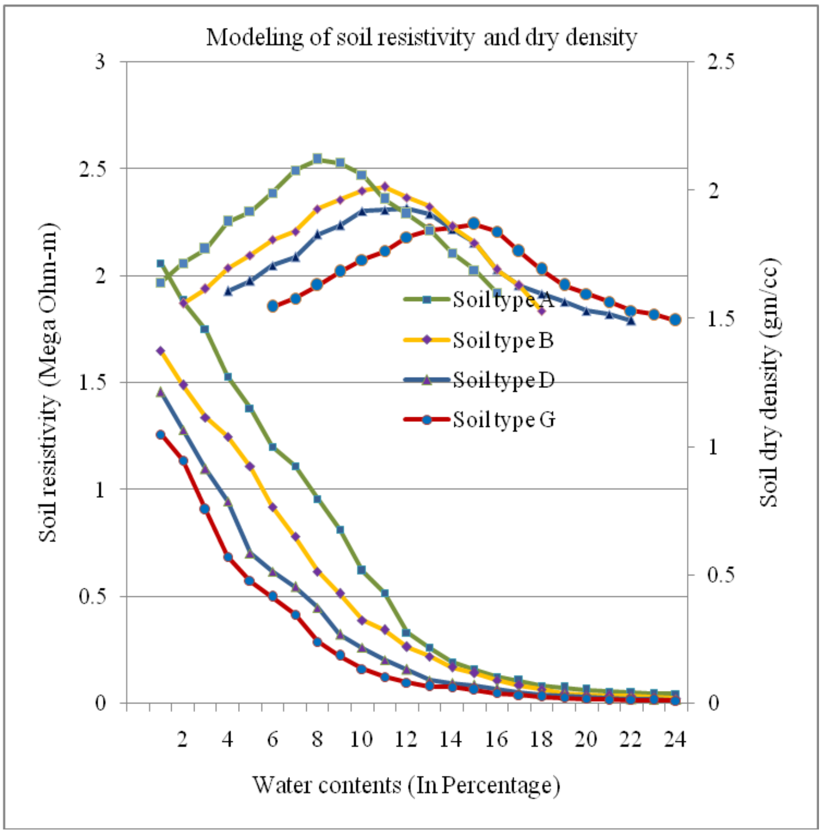

Figure 4. Maximum dry density and soil resistivity for changing of water contents in different soil

Moreover, percentage of soil particle sizes and type of soil is estimated according to sieve test, ASTM D-422. Sieve Aperture sizes used in the analysis ranges from 0.063 to 4.75 mm. The collected soil sample is categorized as soil type A, B, C, D, E, F and G for conducting our analysis in soil compaction measurements. Figure 4 shows the dry density and soil resistivity curves for soil type A, B, D and G with changing of water contents in soil. We have shown the dry density and soil resistivity curves for four types of soil rather than our tested seven samples in laboratory. Because, soil type B and soil type C is approximately same according to soil particle size distributions. In addition, soil type E, F and G reflect about same particle size distributions in laboratory observations.

Table 2 shows the percentage of soil particles, soil pH value, optimum moisture contents, maximum dry density of soil and soil electric resistivity for these seven types of soil. Results of table 2 are obtained through soil compaction testing, pH value testing and soil resistivity testing in laboratory. In soil type A, there are 25 percent of gravel, 60 percent of sand and 15 percent of clay as distribution of soil particles. The soil electric resistivity at optimum moisture contents for soil type A is seen as 0.956 Mega Ohm-m and pH value is as 4.10. For soil type C, the resistivity is taken as 0.56 Mega Ohm-m and pH value is taken as 4.74 in Table 2. Moreover, for soil type G, the resistivity is shown as 0.05 Mega Ohm-m where pH value is shown as 5.92.

Table 2. Data collecting in laboratory for the analysis on different soil

Soil Type	Percent of Gravel	Percent of Sand	Percent of Silt and Clay	Soil pH Value in laboratory	Optimum moisture contents (In Percentage)	Maximum dry density (gm/cc)	Resistivity at optimum moisture contents (Mega Ohm-m) in laboratory
A	25	60	15	4.05	10	2.12	0.95
B	12	70	18	3.44	12	2.01	0.51
C	18	72	10	4.74	12	2.06	0.56
D	8	56	36	5.12	14	1.93	0.15
E	6	40	54	4.32	17	1.86	0.07
F	10	44	46	6.10	16	1.88	0.1
G	5	31	64	5.92	18	1.81	0.05

The observations on soil electric resistivity of compacted soil in field are shown as Table 3. We have collected some soil sample as E, G from top soil to obtain presence of organic contents. Decaying of organic contents causes the increase of H^+ value of soil which is responsible to make the soil more acidic. According to research study of Ferreira et al. [4], increasing of acidity in soil makes it more corrosive.

In addition, less resistivity of soil shows the soil as more corrosive. More acidic soil shows high electric conductivity as reciprocal of less soil electric resistivity. In soil type A, the observation is as high resistivity, high acid pH and more sand in soil. But, high resistivity of soil would have less acid pH according to corrosive phenomenon. The result for soil type A is demonstrated as presence of more sand and 25 percent gravel shows more effects than pH reading of chemical characteristics on observations of soil resistivity. For soil type C, the resistivity at optimum moisture contents is revealed as 0.59 Mega Ohm-m for more sand and less clay in soil sample. There is medium acid pH seen in soil type C which is not more supportive to obtain the soil resistivity characteristics according to influences of pH value in soil. In addition, for soil type G, presence of more clay reveals more influence than less acidic pH value of soil on measurements of soil electric resistivity. According to the observations of table 3, effects of changes particle sizes have more effects than changes of pH value in acidic ranges on variation of soil electrical resistivity in soil.

Table 3. Observations of soil characteristics assessment parameters in field

Soil Type	Resistivity at optimum moisture contents (Mega Ohm-m) in field	Soil pH Value in laboratory	Observations
A	0.99	4.05	High resistivity, high acid pH and more sand in soil
B	0.52	3.44	Medium resistivity, high acid pH, more sand and less gravel in soil
C	0.59	4.74	High resistivity, moderately acid pH, more sand and less clay in soil
D	0.11	5.12	Less resistivity, moderately acid pH, more sand and medium clay in soil
E	0.08	4.32	Less resistivity, moderately acid pH, medium sand and more clay in soil
F	0.15	6.10	Less resistivity, low acid pH, medium sand and medium clay in soil
G	0.06	5.92	Less resistivity, low acid pH, medium sand and more clay in soil

Recently, researchers concentrate on soil resistivity measurements to estimate soil compaction characteristics [6-8]. Soil resistivity can be used to measure soil bulk density, dry density, optimum moisture contents, liquid limit, plastic limit and shear modulus of near surface soil. During soil resistivity measurements for soil properties investigations, there is one of the issues about chemical influences on soil electrical resistivity. Soil resistivity is seen within Mega Ohm-m ranges for compacted soil characterizations as seen in Figure 4. Changing of soil type shows more differences of soil resistivity for compacted soil. Alternatively, there are influences of soil chemical properties on soil resistivity measurements. But, the chemical property of soil does not show more influences in variation of soil resistivity of compacted soil. As an example, for more sand and less clay in soil shows resistivity as above of 0.5 Mega Ohm-m where less sand and more clay shows the resistivity as less of 0.1 Mega Ohm-m. There is large change in soil resistivity measurements due to soil particle size distributions. For chemical characteristics the resistivity can vary with Ohm range which is not more influential for soil chemical characterizations. It is concluded that changes of particle size have more effects than chemical characteristics in acidic range for soil characterization through electrical properties. This study is helpful to find the answer about soil chemical influences on soil resistivity measurements.

4. CONCLUSION

The laboratory testing program on soil characterizations is carried out to determine the effect of chemical characteristics for soil compaction measurements through electrical resistivity. Soil resistivity measurements with moisture contents and conventional laboratory test of determining bulk density and dry density are shown in the study. The pH value of different soil sample is obtained for the chemical characterizations of soil. The following conclusion is made based on test results on soil compaction including chemical characteristics.

1. The soil resistivity and compaction characteristics of soil are likely to be changed due to the chemical reactions of the acidic phenomenon.

2. Changes of particle sizes have more influences than changes of chemical characteristics in acidic range for soil compaction estimations with EC measurements.

This study would help to conduct further research of getting information of soil contaminations through EC in particular applications of geotechnical engineering.

ACKNOWLEDGEMENTS
This research is sponsored by Research Project of Science Fund No. 01-01-02-SF0681 from Ministry of Science, Technology and Innovation of Malaysia.

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