Effect of Compaction on the Electrical Resistivity of Bentonite Clay Soil

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Abstract
In this study, the effect of compaction and moisture contents on the electrical resistivity of bentonite clay soil was investigated. From material characterization resistivity was identified as the critical parameter for soil. It was found that, with the increase of moisture and density (compaction), the resistivity of the soil decreased. The effect of compaction in soil resistivity is depends on the moisture of the soil. The resistivity of soil without moisture was in the range of 1000-111.1 Ωm and with 40% moisture, the resistivity of the soil was in the range of 43.5-2.7 Ωm.

1. Introduction

Electrical resistivity is used in many geological applications such as to estimate the quality of the soil/rock in construction, costal area saltwater-freshwater mapping, sand and gravel deposit exploration, detection of pipelines (Kowalczyk, et al., 2014). Electrical resistivity of soil is affected by porosity, electrical resistivity of pore fluid, degree of saturation, composition of soil, particle shape and orientation (Hassanein, et al., 1996).

According to ASTM G187-12a and ANSI/AWWA C105/A21.5-18 standards the soil resistivity has relationship with corrosive nature. As per ASTM G187-12a, soil resistivity of 0-500 Ohm-m has extreme corrosive nature and above 10,000 Ohm-m very mild corrosive nature.

In the study by Kowalczyk, et al., (2014) it was concluded that with compaction the electrical resistivity of the soil was changed significantly, and it could be used to estimate soil parameters. In the study by Azoor, et al., (2019) it was concluded the optimum moisture content of the soil (which has the maximum dry density) leads to maximum corrosion rate. Thus, the impact of compaction and moisture content in the soil resistivity and corrosion rate should be studied.

2. Objective

The objective is to study the impedance spectroscopy, horizontal and vertical resistivity, air porosity and density changes with different moisture and compaction conditions.

3. Methodology

In this study, dry soil and 40% moisture content bentonite soil was studied as shown in Figure 1. Two molds were prepared with wire and without wire configurations. To measure the horizontal resistivity, 4 holes were placed in the mold as in Figure 1(b) exactly same locations as Figure 1(a). Compaction was given to the sample by tamping the sample. Similar compaction was given to the wired and non-wired samples, and this was confirmed by measuring the density of the samples.

Conductivity probe was used to measure the conductivity of moisture soil. The resistivity was calculated as the reciprocal value of conductivity. Vernier caliper was used to measure the change in length of the soil sample height. The impedance spectroscopy was measured by two probe method, using LCR meter in 20Hz- 300kHz frequency range. Tap water was used in the study. The mass of the samples was measured using digital scale. For each moisture content different blows were given, and conductivity and impedance values were monitored. The wired and non-wired molds used for the study is shown in Figure 1.

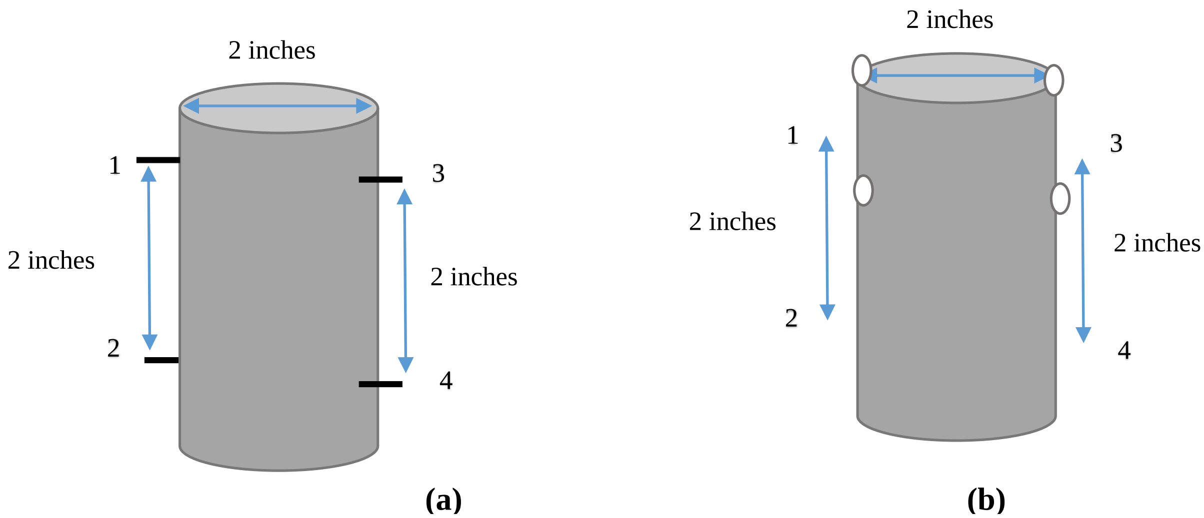

Figure 1 Test mold configuration (a) resistance measurements (b) resistivity measurements

In this study 6 difference combinations of impedance values, vertical resistivity and density changes were observed with changing moisture and compaction.

4. Results and Analysis

4.1 Material Characterization

The impedance models of bottom horizontal configuration of dry soil for density of 0.78g/cm^3 and 1.11g/cm^3 are given in Figure 2. Model parameters contact resistance, contact capacitance, Bulk resistance, R^2 and RMSE are given in Table 1. Bulk resistance and contact resistance were decreased with the increased soil density. Contact capacitance was increased with increased soil density.

In Figure 2, the impedance values are decreasing with increasing frequencies. But beyond 100 kHz, the impedance values are nearly constant. From Vipulanandan Impedance Model it follows case 2 and the bulk material is assumed as resistor only (Vipulanandan, 2021). With the increasing of the compaction the impedance spectroscopy is shifting down (decreasing).

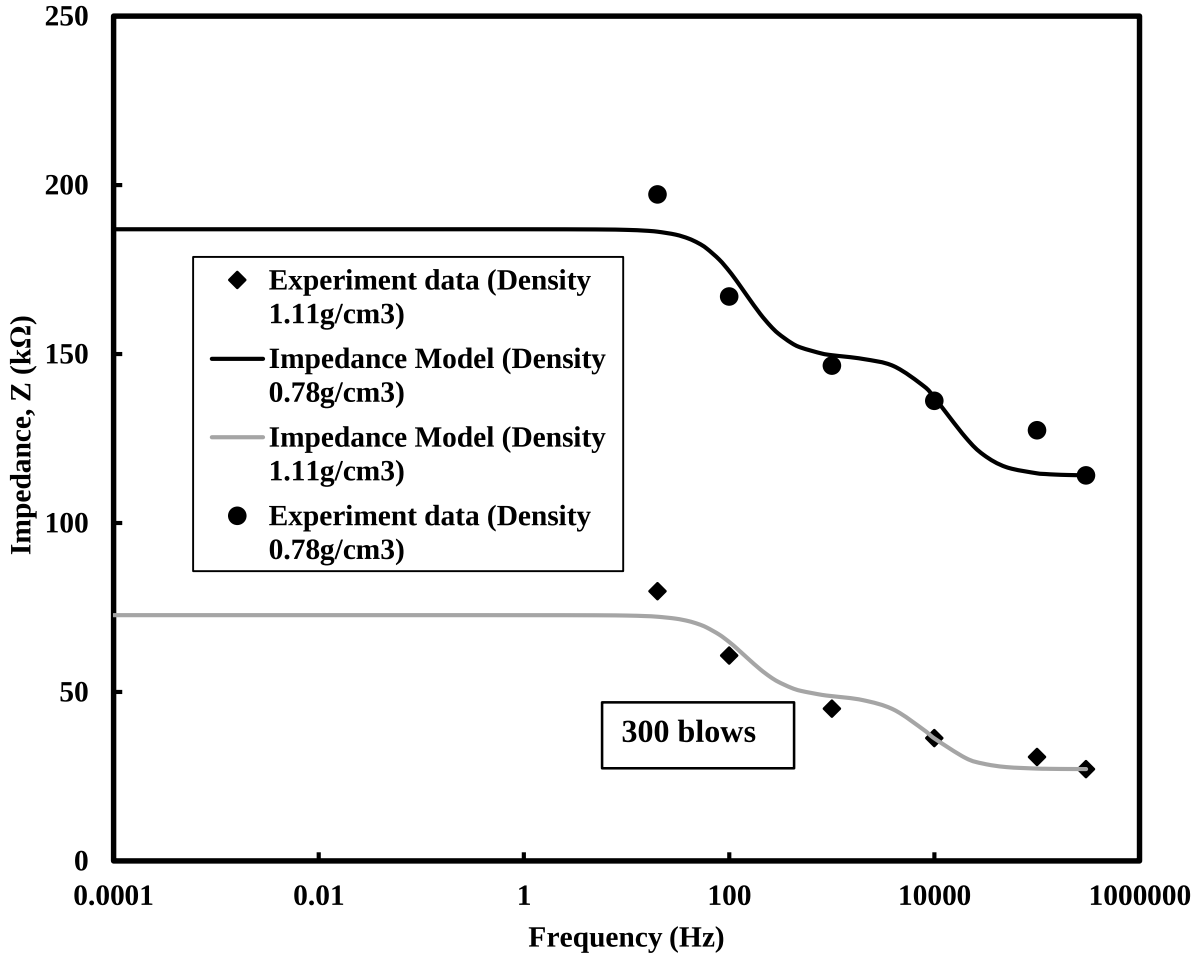

Figure 2 Impedance model for 0% moisture content with 0 Blow and 300 Blows

Table 1 Model parameters for 0% Moisture of 0 Blows and 300 Blows

Density (g/cm^3)	R^2	RMSE	Rc2	Cc2	Rc4	Cc4	Rb
0.78	0.9226	7.62 kΩ	37.8 kΩ	2.94E-8 F	35 kΩ	3.28E-10 F	114 kΩ
1.11	0.9514	3.07 kΩ	27 kΩ	4.61E-8 F	21.4 kΩ	8.67E-10 F	27 kΩ

4.2 Density change with compaction

For 0% and 40% moisture soil the density and void ratio values for different compaction are shown in Table 2. With the increasing of compaction effort, the density was increased, and void ratio was decreased.

Table 2 Density and Void Ratio for different blows

0% Moisture Content				
	Compaction			
	0 Blows	100 Blows	200 Blows	300 Blows
Density	0.78	1.07	1.08	1.11
Void ratio	1.83	1.05	1.03	0.98

40% Moisture Content				
	Compaction			
	0 Blows	100 Blows	200 Blows	300 Blows
Density	0.49	1.03	1.04	1.09
Void ratio	6.5	2.5	2.5	2.4

4.3 Resistivity change with compaction

The vertical resistivity values for different compaction effort and moisture content are shown in Table 3. With the increase of compaction effort, the resistivity was decreased.

Table 3 Resistivity change with different compaction for dry and 40% moisture soil

	Compaction			
	0 Blows	100 Blows	200 Blows	300 Blows
Resistivity Ωm (For 0% Moisture Soil)	100.0	166.7	125.0	111.1
Resistivity Ωm (For 40% Moisture Soil)	43.5	3.4	2.8	2.7

4.4 Resistivity and Density Relationship

The vertical resistivity change with density is shown in Figure 3. From Figure 3, the resistivity was decreased with increasing density and moisture content. For 0% moisture soil when the density was increased by 0.33g/cm^3, the resistivity was changed by 889 Ωm (1000 to 111.1 Ωm).

For 40% moisture content the density was changed by 0.6 g/cm^{3}and the resistivity was changed by 40.7 Ωm (43.5 to 2.7 Ωm). It implies that, the resistivity change with density is very high in low moisture soils. But for high moisture soil, the resistivity change with density is less. For high moisture soil, moisture has more influence than density.

5. Conclusion

1. For Bentonite clay soil, the impedance values are decreasing from 20 Hz to 100 kHz. Beyond this frequency, the impedance values become nearly constant. This implies that the impedance value is influenced by resistance of clay soil. This follows case 2.
2. With the increasing of the number of blows the impedance curve is shifting down.
3. The resistivity of the soil is decreasing with increasing density and moisture content.
4. With the increase of moisture content, density is decreasing
5. For low moisture soil the influence of density is high in reduction of density.

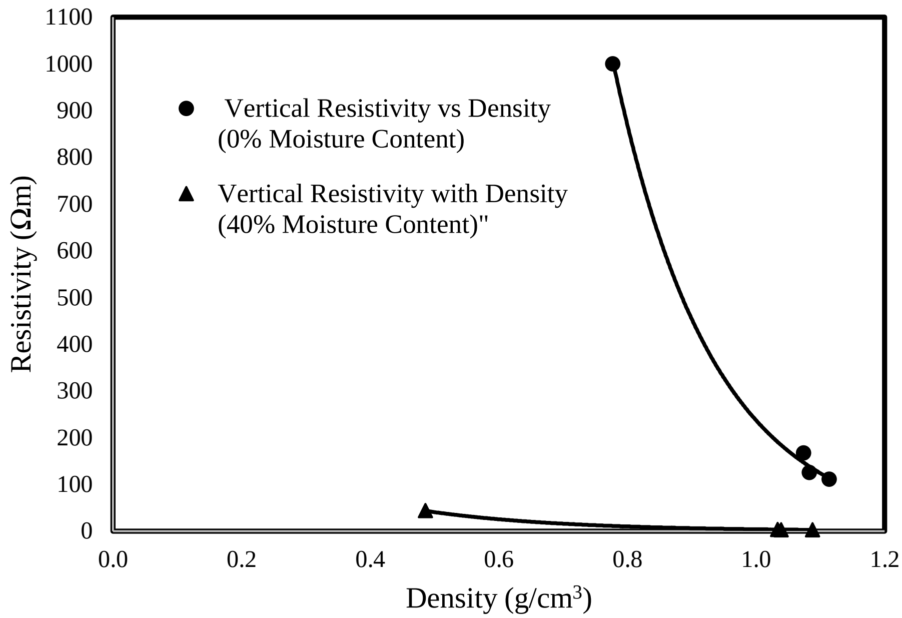

Figure 3 Resistivity change with density

6. Acknowledgement

This study was supported by the Center for Innovative Grouting Materials and Technology (CIGMAT), University of Houston, Houston, Texas.

7. References

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