Electrical characterization of Sand and Clay material with different Loading

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Abstract

In this study, electrical properties of sand and kaolinite clay soil with loadings were investigated. From the study, for both sand and clay soil, with the increase of loading the vertical resistance is decreasing. But with more loadings, the density and resistance of the sand soil is not changing much. For clay soil with a small increment in density the resistance continues to reduce. Compared to sand the density increment in clay is less in each loading. But for clay with a small increment in density the resistance changes significantly.

1.Introduction

Soil resistivity property is used to relate with degree of compaction, soil moisture, contamination of soil, soil strength and particle size distribution. The change of resistivity of soil with stresses can be utilized to predict the changes of stress using real time monitoring of soil structures. This study will be useful in subgrade construction, foundation construction and landslide monitoring.

In a study by Owusu-Nimo, et al., with 2%,5% and 10% bentonite clay, it was concluded that, with the increase of effective stress the soil resistivity increases. In a study by Zhou, et al., in losses soil, with the load increase of 0-1600 k Pa, the electrical resistivity change of from 295-200 Ωm was observed. It was stated that, up to peak stress the resistivity of the soil decreased with increasing load and with further load increase resulted crack formation, the resistivity was increased.

This study was conducted to identify the electrical behavior of densified clay and sand soil with loadings. So, for the study, densified soil was taken. It was studied, for sand and clay material, soil change of resistivity was same as change of resistance. Thus, resistance changes were measured in the study.

2. Objective

The objective is to study the resistance change of Kaolinite clay and sand soil with loadings.

3. Methodology

In this study, 0%, 1% 5%, 10% sand, and 0%, 1%, 2%, 10%, 20% Kaolinite clay were used. Impedance spectroscopy, mass, volume, resistivity of the initial soil was measured. The resistivity of the soil was measured using a soil resistivity probe. The impedance spectroscopy was measured by two probe method, using LCR meter in 20Hz- 300kHz frequency range. The compacted soil resistance change was studied with change of stress. Resistance values were measured in selected frequency within 10-300 k Hz frequency, where the imaginary part of the impedance is minimal.

In this study, confined soil samples were prepared, so that higher loadings can be given to the sample without failure. In this study, vertical resistance changes with stresses in densified soil were studied. Sample was isolated from the machine using rubber stopper in the top and geotextile was used in the bottom. Vertical deflections were calculated from machine readings and horizontal deflections were measured using vernier caliper. The configuration of the soil mold is given in Figure 1.

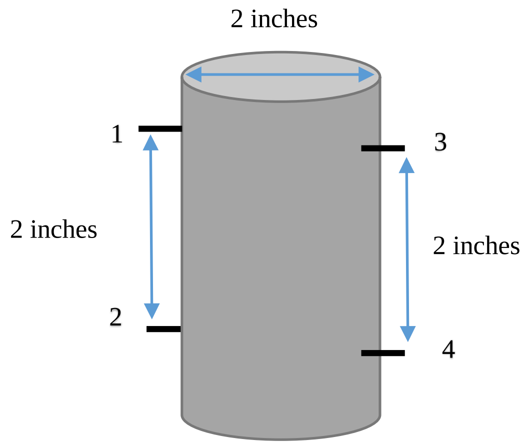

Figure 1 Test mold configuration of resistance measurements

4. Results and Analysis

4.1 Material Characterization

The impedance models of vertical configuration of 5% moisture sand with density of 1.79g/cm^3 and 20% moisture Kaolinite clay with density of 1.47g/cm^3 are given in Figure 2 and 3. Model parameters contact resistance, contact capacitance, Bulk resistance, R^2 and RMSE are given in the Figures.

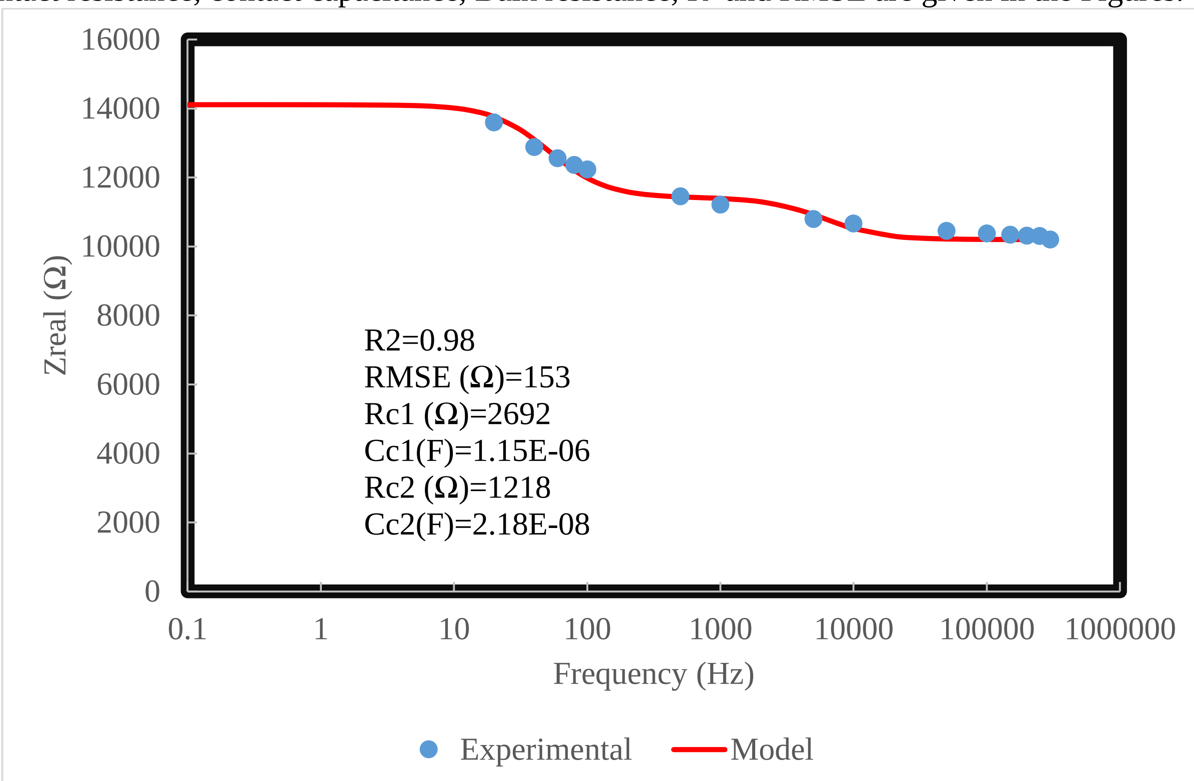

Figure 2 Impedance model for 5% moisture Sand

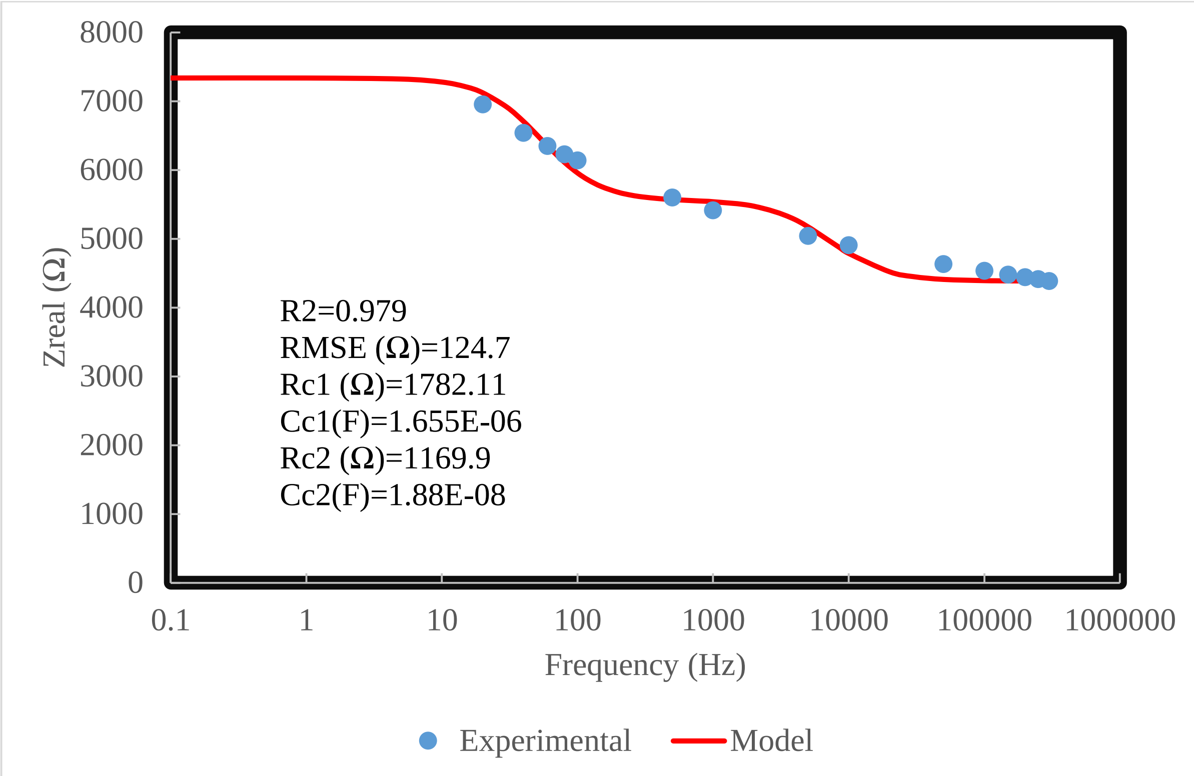

Figure 3 Impedance model for 20% moisture Clay

In Figure 2 and 3, the impedance values are decreasing with increasing frequencies. But beyond 10 kHz, the impedance values are nearly constant. From Vipulanandhan Impedance Model it follows case 2 and the bulk material is assumed as resistor only (Vipulanandan, 2021).
Impedance measurements of dry sand and dry clay were not stable. Thus, resistance change with loading study was not conducted on dry condition.

4.2 Resistance change with loading

From the literature, the following viable reasons are identified to change the resistivity of the soil with stress.

1. With applied stress, resistivity increases due to the deviatoric stress resulting in shape changes in the micro structural configuration.
2. With stress, solid particles become more compact and conductive path shortening will cause resistivity reduction.
3. With the load compaction, porewater connection will improve and this will cause resistivity reduction.
4. In a failed sample, fine cracks can be developed, and resistivity will increase.

<u>4.2.1 Resistance change of Sand.</u>

Vertical resistance change was studied for 0% to 10% moisture densified sand soil, for 5% moisture density vs vertical resistance change is given in Figure 4. From first loading to fourth loading the resistance of the sample reduced by 50% and density of the sample increased by 12.3%.
In the first loading the resistance reduced by 35% and the density of the sample increased by 7%. Resistance change was not significant in unloading. With second and third loadings resistance decreased by 8 and 5.5%. In fourth loading both resistance and density of the sample has not

significantly changed. This implies, in sand sample the resistance reduction with load is associated with density change. With densification the particle and porewater connection is improving and the resistance is reducing.

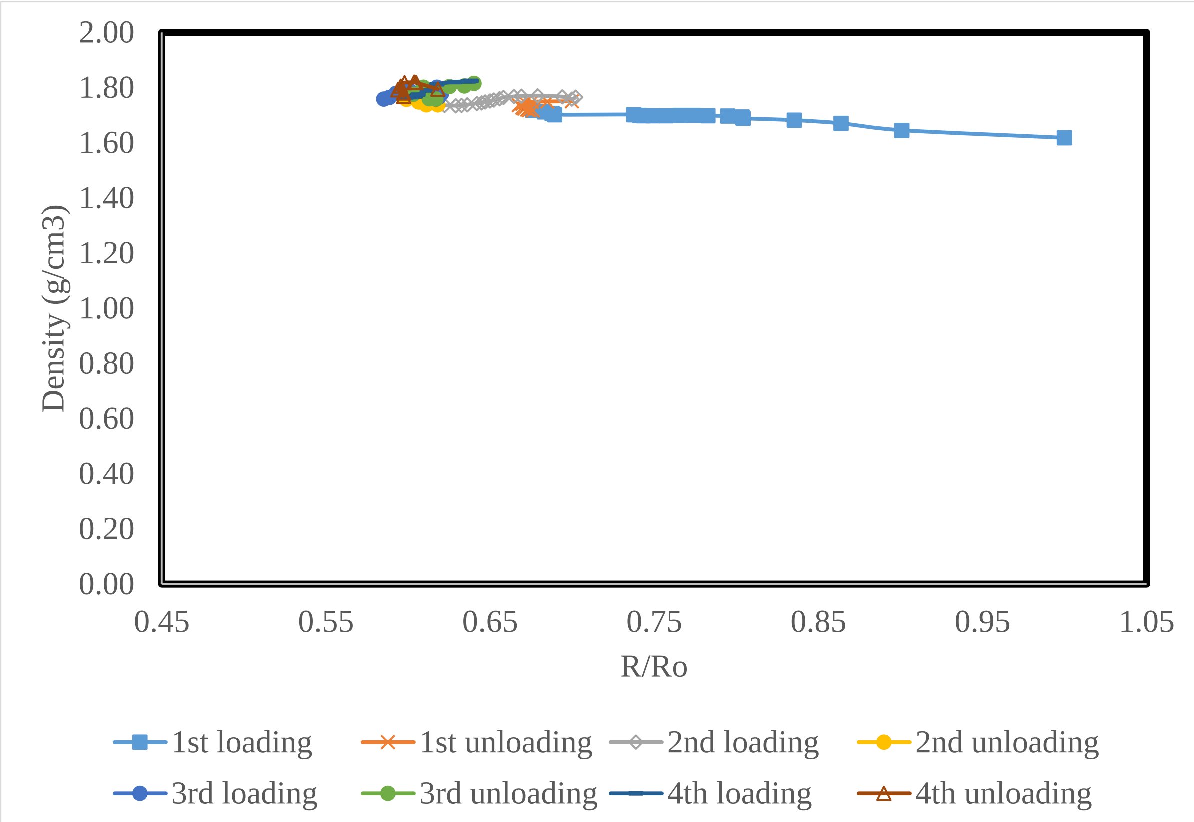

Figure 4 Density vs Resistance change for 5% moisture sand.

4.2.2 Resistance change of Kaolinite Clay

Vertical resistance change was studied for 0% to 20% moisture densified Kaolinite clay soil. For 20% moisture clay density vs vertical resistance change is given in Figure 5. From first loading to third loading the resistance of the sample reduced by 32% and density of the sample increased by 2.1%.

In the first loading the resistance reduced by 9.5% and the density of the sample increased by 1%. Similar to sand, for clay sample resistance change was not significant in unloading. With second and third loadings resistance decreased by 7.5% and 6.4%. In clay sample the vertical resistance reduction is associated densification resulted conduction path improvement.

For clay with each loading the density increase is less compared to sand. For clay with a small increment in density the resistance of the clay reduces significantly.

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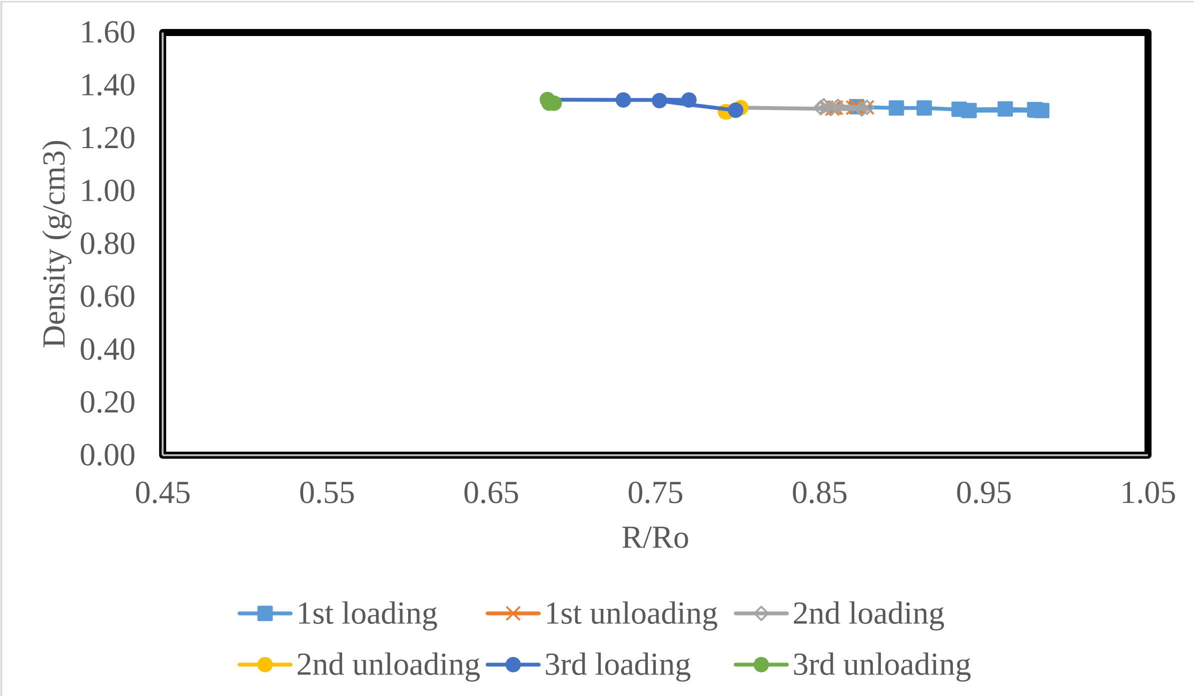

Figure 5 Density vs Resistance change for 20% moisture clay.

5. Conclusions

From the study the following conclusions are made.

1. For both Sand and Kaolinite clay, beyond 10k Hz frequency, the impedance values become nearly constant. This implies that the impedance value is influenced by resistance of soil. This follows case 2.
2. For sand soil the vertical stress shows only resistance reduction of soil due to small increase in density.
3. For sand with more loadings, the density and resistance of the sand soil is not changing much.
4. For clay soil the vertical stress shows only resistance reduction of soil due to small increase in density.
5. For clay soil with a small increment in density the resistance continues to reduce.
6. Compared to sand the density increment in clay is less in each loading. But for clay with a small increment in density the resistance changes significantly.

6. Acknowledgement

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7. References

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