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Low Frequency Dielectric Dispersion Characteristics of NaCl Contaminated Sandy Soil

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Abstract

Due to rapid industrialization and urbanization it is required to evaluate soil properties quickly and accurately without disturbing soil, removing soil samples and analyzing them in laboratory. There is also an increasing demand for utilization of sandy soils as a conducting and insulating material, which calls for extensive characterization of the sandy soil based on physical, chemical, mechanical and mineralogical investigations. This study is an attempt has been made to understand these mechanisms occurring in the sandy soil with the help of its electrical properties. This is being achieved, by conducting a series of laboratory tests on remolded samples by varying their clay content and water content in concentration of NaCl. In order to create conditions similar to field, samples were molded with different sand size particle.

Keywords- *Voronin's concept, Dielectric constant, NaCl concentration, Sand particle size, Clay content, Water content*

I. INTRODUCTION

The aim of the present investigation is to study the resistivity characteristics of sand with saline water and correlate it with various physical properties. Following measurements are taken to correlate resistivity values with different types of sand, at different clay contents, moisture contents and effect of particle size in pure and salted water. The purpose of the study is to understand the variation in soil electrical conductivity as measured in laboratory set-up, on the basis of physical properties of the sand.

II. OBJECTIVES

- The soil resistivity parameter was standardized for the measurement of the resistivity of sand during the experimentation.
- To examine resistivity characteristics of different types of sand and correlate it with physical properties.
- To examine resistivity characteristics of sand in pure water, 0.2 N NaCl and 1 N NaCl.
- To examine resistivity of sand in dry condition and saturated condition.

III. Methodology

3.1. Material Used

For the experimental study, sand was sieved to get graded sand. The one soil selected procured from Valiya-Netrang Road, near Bharuch (Gujarat) and the sand used in the present investigation is brought from Bahadarpur near Sankheda, situated in Gujarat (India). Three types of water selected as pure water, with 0.2 N NaCl and with 1 N NaCl. The samples were made prepared using constant volume mould.

The types of sand used in tests with clay as discuss below in table.

Normality	Clay content %	Water content %
Pure water, 0.2 N, 1 N	7.5 %, 10.0 %, 12.5 %, 15.0 %, 17.5 %, 20.0%	2.5%, 5.0%, 7.5%, 10.0 %, 12.5 %, 15.0 %.
Dry Sand		

Sand sizes considered for study

Sr. No.	Name	Sand size
1	A	4.75mm-2mm
2	B	2mm-1mm
3	C	1mm-600μ
4	D	600μ-425μ
5	E	425μ-300μ
6	F	300μ-212μ
7	G	212μ-150μ
8	H	150μ-75μ

3.2. Resistivity Mould

Resistivity mould of the dimension 50mm x 50mm x 30mm is prepared. The mould can be opened from the top and is made up of 8mm thick Perspex sheets, with 2mm thick stainless steel (SS) plates.

3.3. Resistivity Calculation

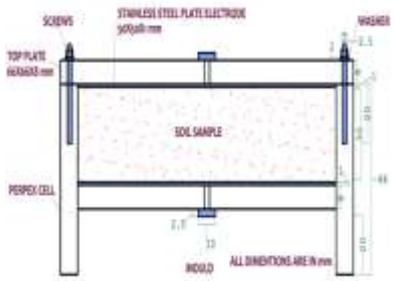
The specimen is put between two metal (copper) plates ensuing proper surface contact between the metal plates and specimen's surface to minimize the contact resistance. The resistance is then measured with the help of LCR-Q meter. Resistivity is calculated by given formula

$$\rho = \frac{RA}{d}$$

Where ρ= Resistivity in ohm-cm, R= measured resistance in ohm, A= Cross sectional area of sample in cm^2, d= Distance between electrodes in cm.

3.3.1 Dielectric Constant Determination

Dielectric constant is a measure of the energy stored due to polarization under the influence of an alternating electric field and is frequency dependent. The measurement of the dielectric constant of soil-fluid systems offers an opportunity to characterize the system. The dielectric constant and electrical conductivity measurements, together, have been useful in the analysis of some characteristics of adsorbed pore fluids on soil particles. To determine the dielectric constant of soil prepared from oven dried pulverized soil passing 425μ I.S. sieve. The density and moisture content of all contaminated as well as virgin pellets is kept according to MDD and OMC of virgin soil. Pellets were placed between two copper plates, connected with the probes of LCR-Q meter as shown in Fig.



Electrical resistivity mould of 50mm x 50mm x 30mm

The dielectric constant of the soil specimen was calculated by using following formula.

$$\text{Dielectric constant } k' = \frac{C_{Soil\,Specimen}}{C_{Air}} = \frac{C_s}{C_0} = \frac{c_s}{\varepsilon_0 \frac{A}{d}}$$

Where, $C_{Soil\ Specimen}$= Actual Capacitance of soil specimen, C_{Air}= Actual Capacitance of Air. A= area of electrode, d =distance between electrodes, ε_0 is the permittivity of the free space (= 8.85×10^{-12} F/m).

3.3.2 Dielectric Loss Determination

The Dielectric Loss represents the energy losses due to polarization and conduction. Dielectric losses due to polarization and conduction are measured together have been useful in the analysis of some characteristics of adsorbed pore fluids on soil particles. The dielectric constant of the soil specimen was calculated by using following formula.

$$k'' = \frac{1}{\omega \varepsilon_0 R \frac{A}{d}}$$

Where, ω= 2Πf, f in frequency, R is actual resistance, A= area of electrode, d distance between electrodes, ε_0 is the permittivity of the free space (= 8.85×10^{-12} F/m).

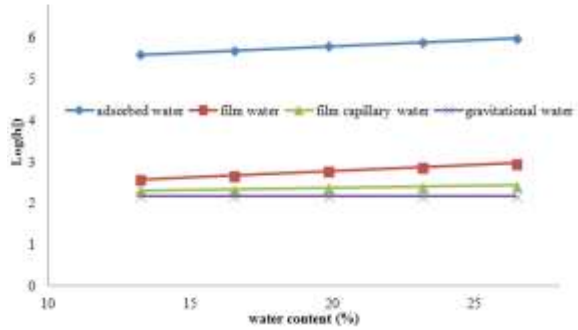
3.4. Test procedure

Mould filled with test sandy soil and compacted to achieve required density is connected to L.C.R meter to measure its resistivity or capacitance at a frequency of 100Hz and 1000Hz. Reading are noted after 2 min.

IV. RESULT ANALYSIS

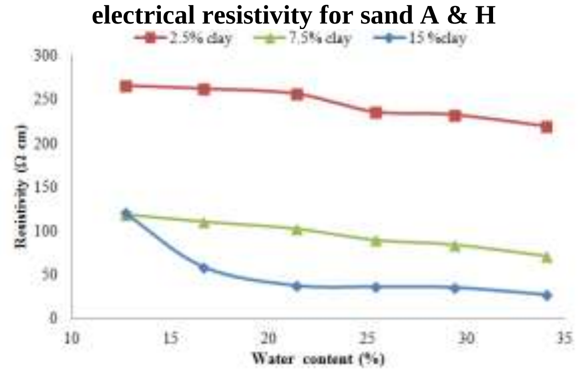
5.1. Water Retention Function based on Voronin's Concept

The relationship between electrical resistivity and water content were observed for sand and clay. Logarithm of experimental water content values was plotted that consists of four different segments. The linear segment represents the exponential relationships between water content and electrical resistivity in the characteristics ranges of water content.

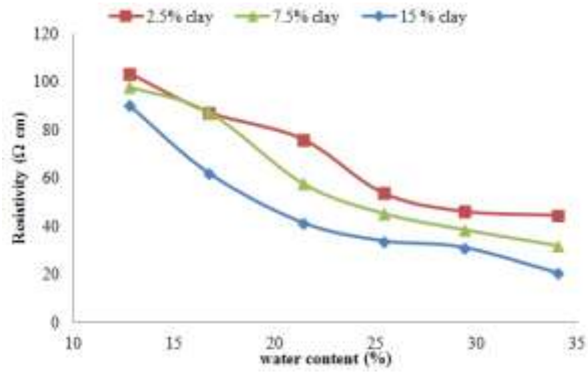


Voronin's concept

5.2 Exponential relationship between water content and electrical resistivity for sand A & H

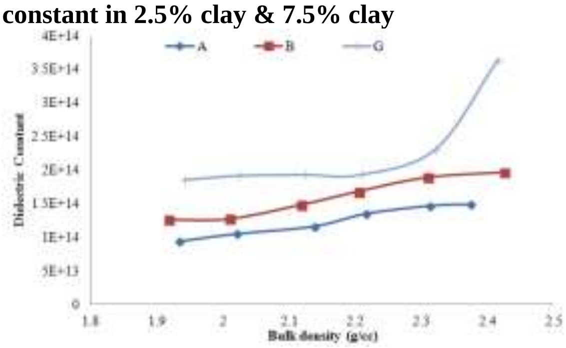


Exponential relationship between water content and electrical resistivity for sand A

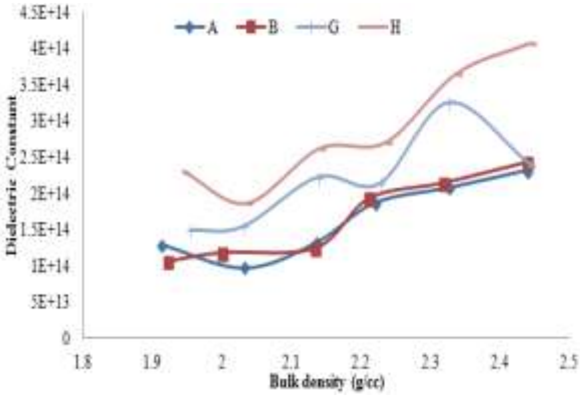


Exponential relationship between water content and electrical resistivity for sand H

5.3 Relationship between bulk density and dielectric constant in 2.5% clay & 7.5% clay

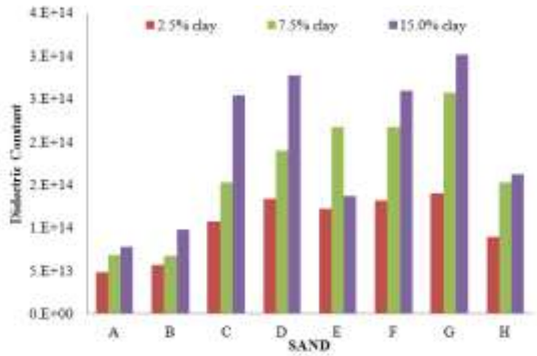


Relationship between bulk density and dielectric constant in 2.5% clay



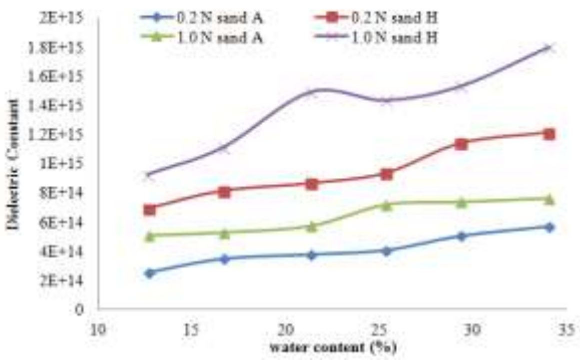
Relationship between bulk density and dielectric constant in 7.5% clay

5.4. Effect of sand size and clay content in pure water

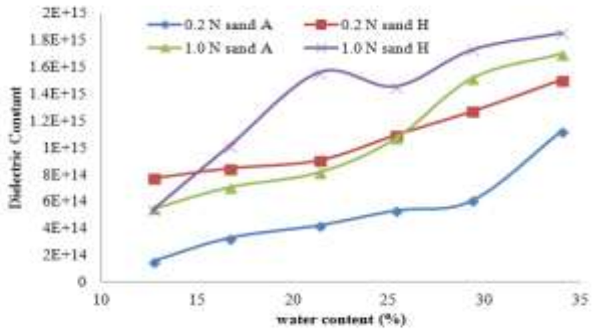


Comparison between sand size and dielectric constant with 2.5% clay, 7.5% clay and 15% clay at 34% water content

5.5. Relationship between water content and dielectric constant with salt contaminated sand in 7.5 % clay and 15% clay



Relationship between water content and dielectric constant with salt contaminated sand in 7.5% clay



Relationship between water content and dielectric constant with salt contaminated sand in 15% clay

IV. Conclusions

The conclusions based on the experimental study are summarised below.

- ✓ The real permittivity at lower frequencies tends to increase because of spatial polarization.
- ✓ The permittivity of soils with high specific area can be considered to be strongly affected by the electrical phenomena at the fluid soil interface.
- ✓ The influence of other polarization at high frequencies on the mechanism of the permittivity of the soil need to be thoroughly evaluated.
- ✓ Increased soil water interface area high clay content or high specific surface areas in the soil leads to increased amount of adsorbed water.
- ✓ Decreased amount of free water, molecules also affect the permittivity of the soil-water mixture.

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