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Effect of Electrical Conductivity on Geotechnical Parameters of Clays

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Abstrat. The use of electrical methods has known in recent year's significant development in several fields such as geophysics, agriculture, geology, geotechnics ... etc. The main interests of the electrical methods are multiple: possibilities of spatialization of the measurements, the possibility also to acquire data's in a continuous way in the time; the speed and low cost of the measures. In view of these attractive features, a large number of applications have been developed for electrical measurements in a wide variety of scientific and engineering fields.
The mean aim of this work is to establish relationships between electrical conductivity and soil geotechnical parameters such as water content, degree of saturation, porosity and ion concentration. The soil selected for this study is a clay from the region of Ain-Nouissy (Mostaganem).

Keywords. Electrical conductivity, Water content, Degree of saturation, Clay; Porosity.

INTRODUCTION

Electrical resistivity is a parameter well known in the geophysical field. It represents the capacity of the soil to oppose the passage of an injected current. In Soil Science, the main advantages of electrical resistivity are based on its high sensitivity to the small electrical variations of subsurface, its speed of acquisition of measurements and its non-destructive character.
The resistivity or its inverse, the electrical conductivity, has been used as a "measure" or as an indicator of the influence of different parameters. Many studies have shown the strong dependence between resistivity measurements and various intrinsic soil variables, both physical and chemical (Wei et al., 2013; El Oumri and Vieillefon, 1983 ; Keller and Frischknecht, 1966). If moisture, salinity and saturation are considered as the main sources of influence for some authors (Rhoades et al., 1976), others show strong relationships with dry density, water content,

temperature, mineral composition and structure of the soil (Archie, 1942; Abu-Hassanein et al., 1996 ; McCarter and Desmazes, 1997).
Conducted a study of the relationship between the electrical resistivity of a saline soil and the water content, salt content, porosity and degree of saturation (Li, 2012). They observed that the electrical resistivity of the saline soil decreased with the increasing water content, salt content and degree of saturation, and it increased with the increasing porosity.
For a given material, the propagation of the electric current depends on the chemical nature of the solid and liquid phases as well as their respective content (Gupta and Hanks, 1972; Nadler, 1982; Rhoades and Ingvalson, 1971). The interpretation of the electrical signal received after injection of the current will be all the easier since some of these parameters will be considered as invariant.
Due to the importance of electrical resistivity, our research team conducted a laboratory study to determine the influence of electrical resistivity on fine soil geotechnical parameters. The test is based on the deriving of the electrical resistivity by injecting an electric current of 15, 30 and 45 volts into the soil samples. The injection of the electric current ensures the unsaturation of the soil at the end of the test.

MATERIAL AND METHODS

The soil studied in the LCTPE laboratory of the University of Mostaganem is a clay from Ain-Nuissy region (Mostaganem). The properties of this soil are listed in Table 1.

Table 1. Geotechnical properties of the studied soil.

Geotechnical properties	Standards	Values
Wet Density $\mathbf{G_h}$	NF P 94-050	1.74
Density of solid $\mathbf{G_s}$	NF P 94-054	2.7
Dry density $\mathbf{G_d}$	NF P 94-050	1.5
Liquidity limit **WL (%)**	NF P 94-051	42.8
Plasticity Limit **Wp (%)**	NF P 94-051	22.1
Plasticity index $\mathbf{I_p}$ **(%)**	NF P 94-051	20.7
Optimum water content $\boldsymbol{\omega_{opt}}$ **(%)**	NF P 94-093	17.50

Figure 1 shows the installation of the experimental glass cell and its peripheral circuit.

Fig. 1. Experimental cell.

In both ends of the sample area, two copper plates were used as electrodes to pass electrical current.
The two electrodes were subjected to an electrical current with voltages of 15 - 25 - 35 and 45 Volts in order to determine the variation of the electrical resistivity as a function of the water content, the degree of saturation and the porosity. Measurements of the electrical resistivity are obtained using an "ARDUINO" data acquisition card (Figure 2).

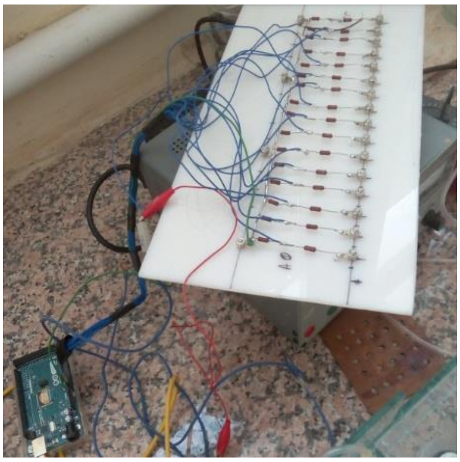

Fig.2. Arduino mega acquisition card.

The second part of the test consists of salinizing the soil sample with 0.5 mole of the NaCl following the same procedures as the first tests.

RESULTS AND DISCUSSION

Figure 3 shows the variation of the water content as a function of the electrical resistivity at 15 ; 30 and 45 volts. The increase in the applied current causes a decrease in the water content, (for an electric current of 15 volts we have a water content varied of 30.72% and 53.78% and for 45 volts we have a variation of 12.2% to 39.87%).
According to this figure, the electrical resistivity are significantly influenced by water content.

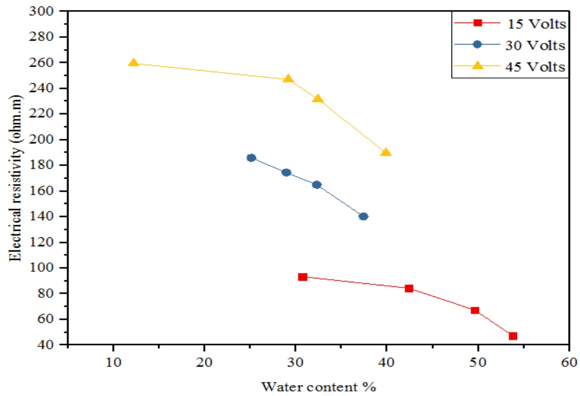

Fig.3. Effect of water content on electrical resistivity at 15, 30 and 45 volts.

The degree of saturation is calculated by the relation 1.

$$S_r = \frac{\omega . G_s . \rho_d}{(G_s . \rho_w) - \rho_d} \qquad (1)$$

With:
ω Water content.
G_s Density of the solid grains.

ρ_d Dry density.

Figure 4, shows the decrease in electrical resistivity as a function of the increase in the degree of saturation with a DC variation of 15, 30 and 45 volts. The application of the electric current varies the degree of initial saturation along the sample from the anode to the cathode.

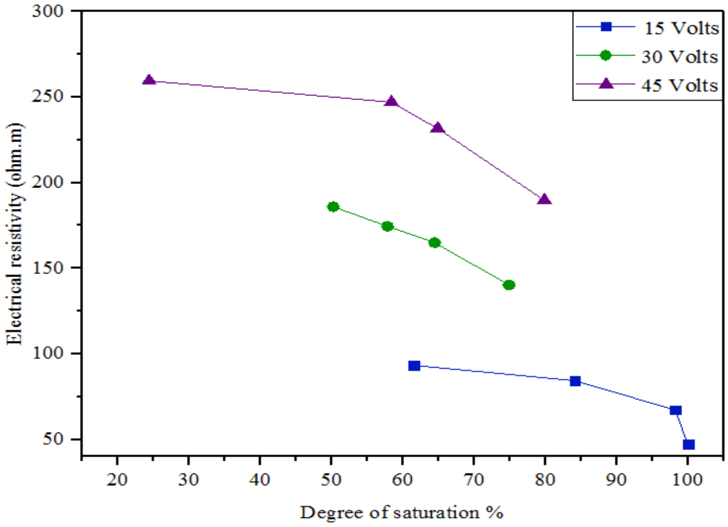

Fig.4. Effect of degree of saturation on electrical resistivity at 15, 30 and 45 volts.

The third factor that affects the electrical resistivity is the porosity. It is calculated with the following formula:

$n = 1 - \frac{\gamma}{(1+\omega).\gamma_s}$ (2)

Where :

γ is the total weight of the sample.

γ_s is the weight of the solid grains.

The influence of this parameter on the electrical resistivity is shown in figure 4. It is noted that there is a decrease of the porosity with the increase of the electrical resistivity for the sample. From the figures below the variation of the porosity and the degree of saturation is practically semilary.

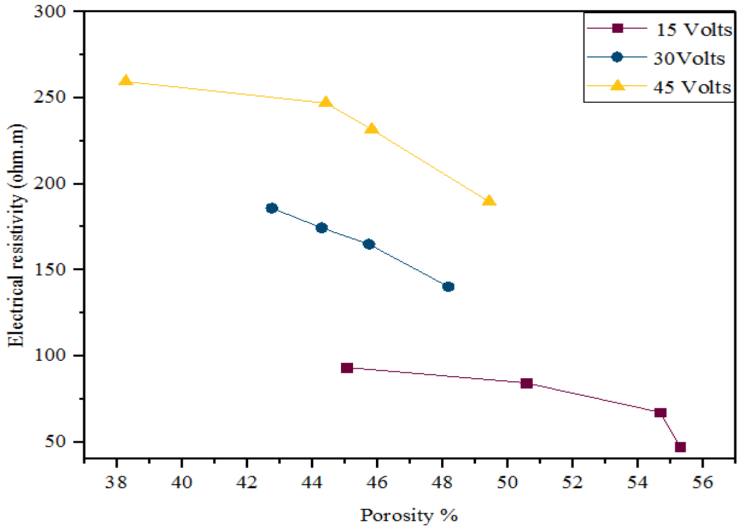

Fig.5. Effect of porosity on electrical resistivity at 15, 30 and 45 volts.

For the second stage of the test, an attempt was made to add a solution of 0.5 mole of NaCl to the soil sample to see the effect of the ion concentration on the electrical resistivity. The following figure shows the variation of the electrical resistivity over time without and with NaCl by injecting an electrical current of 15 and 25 volts.

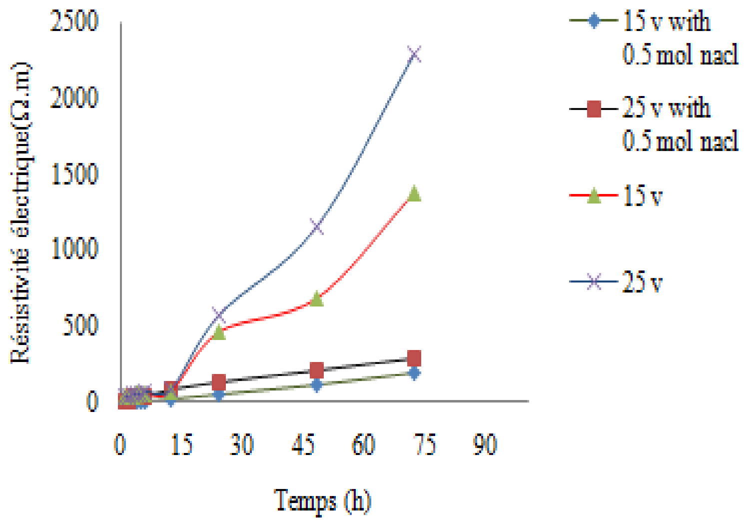

Fig.6. Variation of the electrical resistivity as a function of time for 15 and 25 volts.

The decrease of the electric current over time causes a decrease in the electrical resistivity. At the end of the test, for a value of 2293 Ω.m to 72h for the test of 25 volts there is a value of 287 Ω.m for the same time and the same voltage with 0.5 mole of NaCl. It means that the concentration of salt in the soil sample decreases significantly the electrical resistivity.

CONCLUSION

Electric current was used as an indicator to characterize the different parameters of a soil study. The main purpose of this study is to determine the influence of electrical conductivity on geotechnical factors such as water content, degree of saturation, porosity and concentration of ions.

This paper presents some results of the experimental work on the variation of the electrical resistivity as a function of the water content, the degree of saturation and the porosity at 15, 25, 35 and 45Volts test. These parameters cause a decrease in the electrical resistivity.

Experience shows that the addition of a saline solution of 0.5 mole NaCl reduce significantly the value of the electrical resistivity during the same duration of the test and for the same voltage. In the next step test, we have to deduce the influence of the geotechnical parameters on the electrical resistivity using different salts with several concentrations.

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