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Evalouation of Expansive Soil Properties by Electrical Resistivity

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Abstract: *Expansive soil creates problems for structures built on it due to its high swelling and shrinkage characteristics. Easy and quick methods instead of using traditional methods such as drilling and taking probes which are difficult to carry out, For long time, there is a great demand on using the geophysical methods and small, easy, and modern apparatus as to measure the soil characteristics in the field. The electrical resistivity method is considered one of these methods which measure directly soil properties from the ground surface level to any depth. In this investigation a resistivity field survey for a site using an electrical resistivity apparatus with eleven holes logs was performed. Research program has been conducted on specimens obtained by mixing commercial bentonite was added to clayey soil to produce sample with different swelling potential. Many correlations between electrical resistivity were determines with each of the following properties of soil: optimum moisture content, maximum dry density, Attreberge limits, swelling pressure, and swelling potential. Linear correlations between different bentonite ratios with electrical resistivity were made. Correlations between different bentonite ratios and the soil properties previously mentioned were conducted, finally, linear correlations between different soil properties at different bentonite ratios.*

Keywords: *Expansive soil, electrical resistivity, bentonite,* electrode.

I. INTRODUCTION

The problem of expansive soils is one of the most well known geotechnical problems that was studied and researched by a lot of geotechnical researchers. This problem was not recognized by soil engineers until 1930, the increasingly extensive use of concrete slab on ground construction after 1940, has further increased the damage to structures caused by expansive soils. Since the last six decades there was a world wide interest in expansive clay and shale's. The application of electrical measurements to evaluate engineering properties of soils has gained a wide, promising field of research in recent years. Conductivity of direct current was the first attempt used to characterize the pore structure of electrically non-conducting particles. In the last decades there is a great demand towards using special techniques and apparatuses for measuring the soil properties in situ. The electrical geophysical methods is one of these techniques which allow rapid measurement of soil electrical properties , such as resistivity , electrical conductivity and potential directly from soil surface to any depth without soil disturbance . Some in-situ electrical geophysical methods were used to evaluate temperature, water content and structure of soils. These methods are not commonly applied in soil studies mainly due to three reasons. Firstly, the equipment for geophysical methods of vertical four-electrode profiling, electrical sounding, ground-penetrating radar, etc. manufactured is suited only for exploration of deep geological profiles. Therefore, the distributions of electrical properties in shallow (0 – 5 m) soil profiles usually cannot be measured with such equipment. The methods need to be modified for soil investigations. Secondly, the theory about nature of development and distribution of soil electric field, which parameters is measured with the electrical geophysical methods, is still being developed. Finally, the in-situ measurements of electrical parameters need a specific calibration in every study to be reliable to evaluate different soil properties. Nowadays only the methodologies of four-electrode probe and electromagnetic induction method for application on saline soils are well developed. This dissertation includes broad material on applications of methodologies of four-electrode probe in soil studies.

II. EXPERIMENTAL WORK

2.1. Sample Preparation

Clay-bentonite mixture was prepared using clayey soil from a site, commercial bentonite (Betomid O C M a Brand D.F.C.P.4 produced by Egypt Mining & Drilling Chemical Company). Undisturbed sample from site were coated with wax and delivered directly to the laboratory. Natural soil was oven dried for 24 hours at 100 to 1050C. It was sieved on sieve No.4, then different bentonite ratios (10%-100%) were added and mixed in the dry condition using an electric mixer for at least 15 minutes to ensure that the soil mixture becomes homogeneous and of uniform in color. Different soil laboratory tests were then performed on that mixture. Prepared clay-bentonite mixture was then put into transparent plastic box as shown in Fig. (1). the transparent plastic was tested in the field, therefore was chosen to bear the sample and to keep its contents. In addition, it doesn't obstruct the sent wave from the apparatus or affect on the current.

2.2. Electrical Resistivity Apparatus

Eleven vertical electrical sounding were conducted in location by using wenner configuration techniques. Earth resistivity meter called TELLUROHM C. A2, Was used in this work. The TELLUROHM C. A2 is a work site instrument designed for earth resistance and soil resistivity measurements. Especially since it suited to measurements in difficult conditions such as when there are stray voltages present, high telluric currents and high value of auxiliary plate resistances.

Steel electrodes (40 cm long and 1.2 cm diameter each) were used for transmitting current and potential into the ground. To provide good electrical contact with the ground, it was necessary to use water around the electrodes. The electrodes were inserted into the ground to a depth which ensured a true contact between the electrode and the surface medium. Single conductor and low electrical resistance, 0.75mm2 wirers mounts on plastic reels were used. For the potential lines, two reels were used each of which has about 50 meters of wires. For the current lines, other two reels, each has 100 meters of wires been utilized. The field instruments and equipment are shown in Fig (2),

To enable these measurements, a wenner array of point electrodes was applied. The wenner array configuration applied to this survey is the most commonly used point – electrode surveying system. This method allows lateral and vertical sampling of apparent resistivity to be taken within the array. The lateral sampling collects measurements from a point mid array, which is at a depth of half that of the electrode spacing (a).
In this technique four electrodes are fixed in the earth, two for the potential and the others for the current. The distances between each one of them (a) are equal. The measurements at each station were carried in successive rate and increased continuously depends on the desired depth.

1.3 Procedure

At first, a hole was made in the ground by 1m width, 1.5m length and 90cm depth. The depth and the length were chosen according to the distance between the electrodes (a). This distance equals the required depth. To allow to the sent waves from the apparatus to the model, the model should be in the center of the hole. The model shouldn't be less than 80cm height, the length and the width of the model shouldn't be less than 20cm. the model with dimension 80 x 20 x 20 cm was chosen, the width of the hole shouldn't be less than the width of the model. Therefore, it was chose to be 1m in this research to facilitate the digging process. After that, the model with specimen was put inside in the center of the hole. To flatten the hole to the ground surface, the model axes was had by string to the hole to guarantee passing the sent waves from the apparatus to the specimen. After flatting the ground, the two electrodes (C and D) was put one on the left 25cm away from the center, the other on the right 25cm away from the center as shown in Fig (3). The sent wave from the electrode (C and D) passes 15cm below the top of the model because we had left 10cm between the ground surface and the top of the model. This distance (10 + 15) represents the whole depth of the wave between electrode (C and D).after that, the electrodes (A and B) was put, to get the required depth of the average wave (50cm), the electrode (C) was put at 50 cm away from electrode (A) and the same went the electrode (B) and (D).The sent wave from electrode (A) and (B) passes 15cm above the bottom of the model. As result, the distance between the two sent waves is 50cm which equals the required depth. However, the obtained reading (R) from the apparatus is the bisection wave to the two waves from electrodes (C to D and A to B). The bisection wave passes through the center of the model, 50cm away from the ground surface, and the sent wave is measured from the point of connection between the electrode and the ground surface and not from the end of the electrode underground. Next, the electrodes was connect to the apparatus by gave along press-on power button. Then the same method was applied on all the other specimens which were mentioned before. This formula was applied to get the electrical resistivity value:

$$\rho = 2\pi R\, a$$

Where:
ρ = electrical resistivity , R = reading from apparatus , a = required depth

Finally, correlations were mad between the electrical resistivity with some soil properties determined in the laboratory.

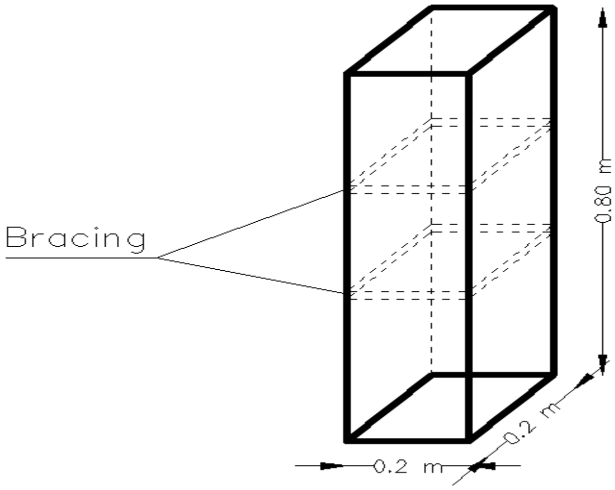

Fig (1): Transparent Plastic Box

Fig (2): Parts of Apparatus Used in Field Survey

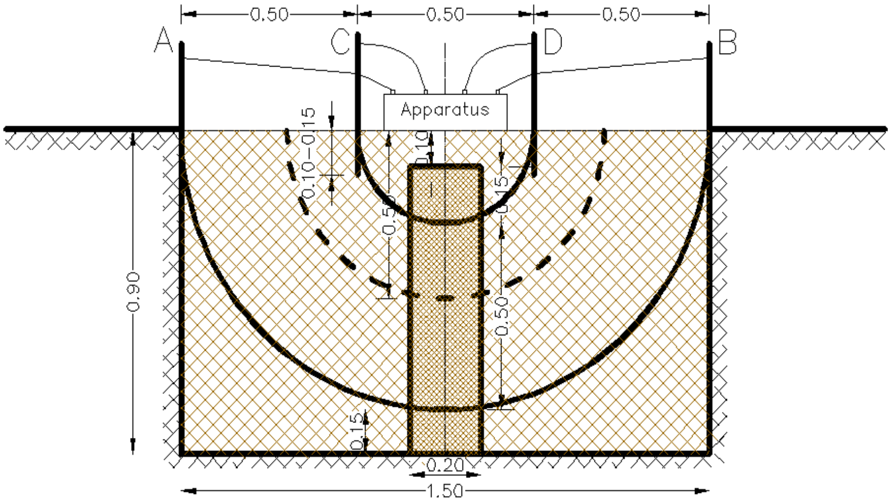

Fig (3): Configuration Array in the Field

III. Results And Analysis

In this section experimental results of to all testes carried out in this investigation are presented. Discussion and analysis of these results is also given. Correlation between the measured electrical resistivity value and its corresponding measured laboratory soil properties at different bentonite ratios are presented. This linear correlation may be used to determine different soil parameters on site as shown in the following.

3.1 Liquid Limit

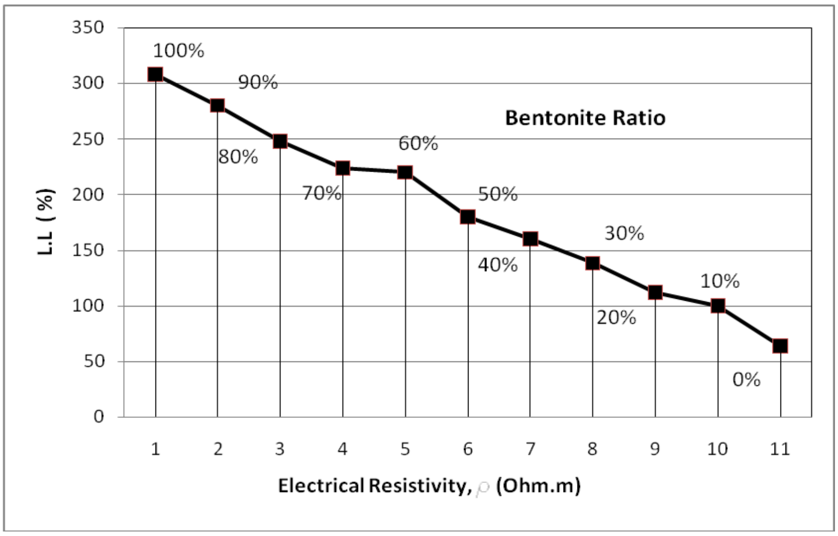

Fig (4): Correlation between Electrical Resistivity and Liquid Limit at Different Bentonite Ratios

Fig (4) shows the relationship between laboratory measured liquid limit, L.L and field measured electrical resistivity, ρ. Regression analysis of this relationship provided a linear correlation between electrical resistivity and liquid limit as follows:

$$\rho = -\ 0.0159\ L.L + 7.893 \qquad (2)$$

3.2 Plastic Limit

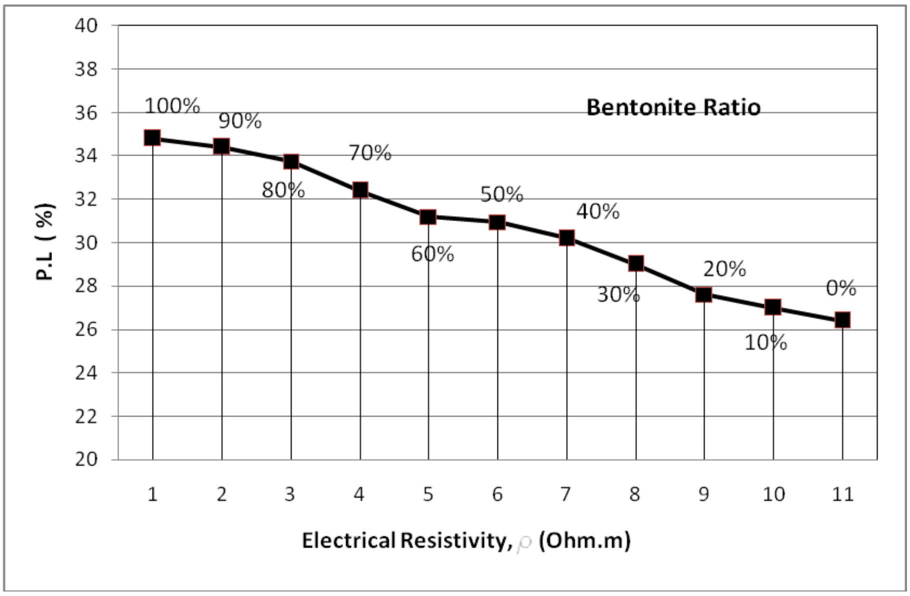

Fig (5): Correlation between Electrical Resistivity and Plastic Limit at Different Bentonite Ratios

Fig (5) shows the relationship between laboratory measured liquid limit, L.L and field measured electrical resistivity, ρ. Regression analysis of this relationship provided a linear correlation between electrical resistivity and Plastic limit as follows:

$$\rho = - 0.4117\ P.L + 17.629 \quad (3)$$

3.3. Shrinkage Limit

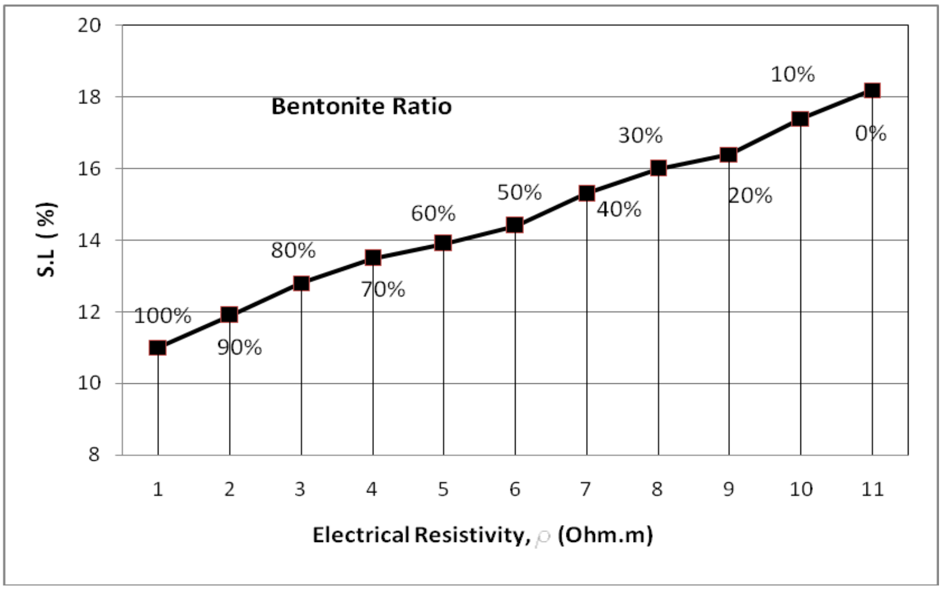

Fig (6): Correlation between Electrical Resistivity and Shrinkage Limit at Different Bentonite Ratios

Fig (6) Shows the relationship between laboratory measured shrinkage limit, S.L and field measured electrical resistivity, ρ. Regression analysis of this relationship provided a linear correlation between electrical resistivity and Shrinkage limit as follows:

$$\rho = 0.5499\ S.L - 3.076 \quad (4)$$

3.4. Swelling Pressure

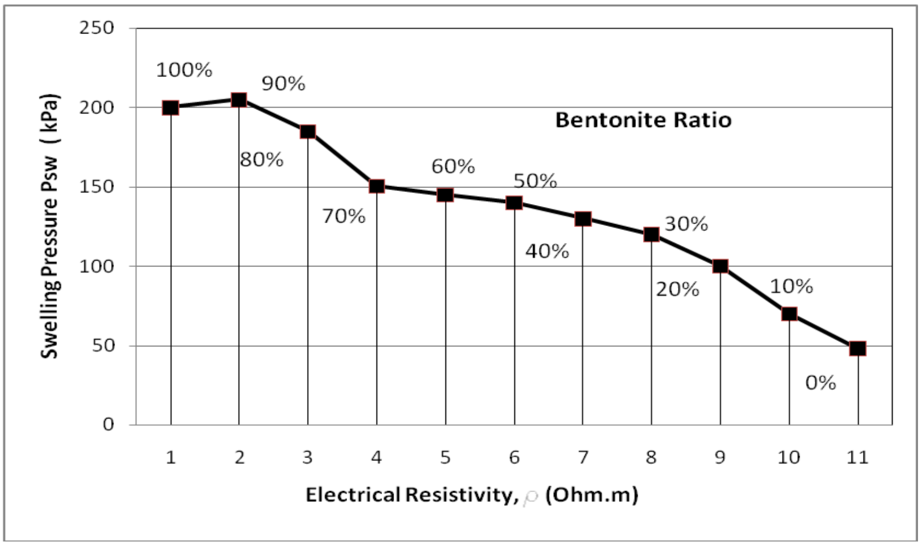

Fig (7): Correlation between Electrical Resistivity and Swelling Pressure at Different Bentonite Ratios.

Fig (7) shows the relationship between laboratory measured swelling pressure, (P_{sw}) and field measured electrical resistivity, ρ. Regression analysis of this relationship provided a linear correlation between electrical resistivity and liquid limit as follows:

$$P_{sw} = - 0.4258\rho + 3.4854 \qquad (5)$$

3.5. Maximum Dry Density

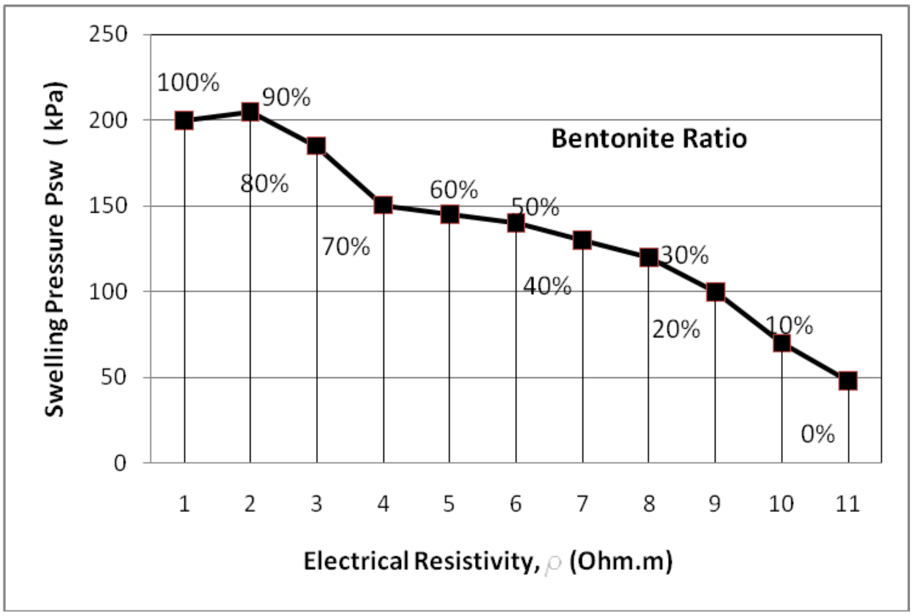

Fig (8): Correlation between Electrical Resistivity and Maximum Dry Density at Different Bentonite Ratios.

Fig (8) shows the relationship between laboratory measured maximum dry density and field measured electrical resistivity, ρ. Regression analysis of this relationship provided a linear correlation between electrical resistivity and maximum dry density as follows:

$$\rho = 13.85\ \gamma d_{max} - 15.579 \qquad (6)$$

IV. CONCLUSIONS

Different properties of clay-bentonite mixture were estimated using an electrical resistivity apparatus. With eleven holes logs were performed. Many correlations between electrical resistivity were determines with the results showed that for the soil used linear correlation between electrical resistivity and different soil properties. This may provide a direct method of estimating these properties on site. However further investigation on a wide variety of soil is needed to verify the included correlation.

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