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AN ASSESSMENT OF GEOTECHNICAL CHARACTERISTICS OF GHARRAF OIL FIELD AREA USING ELECTRICAL RESISTIVITY TEST

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Abstract

Geotechnical characteristics of soil are very important for civil applications and engineers because the structures almost construct and built on the ground such as high buildings, towers, bridges, tunnels and others on the soils. Electrical resistivity (ER) measurements are nowadays widely used to evaluate the geotechnical characterization of soil as they are fast, time-consuming and costly and non-destructive. This article provides the data of soil electrical resistivity measurements carried out on different zones and sites in Gharraf oil field area (north-western part of the Thi-Qar governorate in the south east of Iraq). In this study the analyses of the obtained data were carried out to propose a new empirical quantitative correlation between soil resistivity and geotechnical characteristics. The improved empirical relationships reflect a very good correlation and it were found that the electrical resistivity of soil has a significant assessment and good fitting with the some of important geotechnical parameters. It was also concluded that the electrical resistivity method which has an advantage over other soil investigation methods that saving and reduce cost. Finally, the new generated empirical equation can be used to evaluate the ultimate bearing capacity of the soil rather than using the traditional widely used equations which require several inputs coefficients calculated using the extensive laboratory and field works. However, the results showed a good and more reliable correlation between soil electrical resistivity and some geotechnical characteristics for the studied region soil.

Keywords:
Electrical resistivity;
Soil Investigation;
Bearing capacity;
Geotechnical Parameters;
Shear Strength.

1 Introduction

In geotechnical engineering applications, soils are defined as particulate material resulting from disintegration of rocks and decayed organic matter (solid particles) along with the air and/ or water that occupy the voids spaces between these particles. It used as a sub-surface material in several construction engineering projects and it foundations [1]. However, some of important ground physical properties should be evaluated in term of soil electrical resistivity, including its shear strength, SPT, degree of saturations, void ratio and porosity. To get an appropriate concept of understanding, it is essential to examine soil specimens not only based on classical investigation works skills but also through other associated disciplines like geological, geomorphological, and other field measurement such as soil electrical resistivity [2]. The geotechnical investigation site of any structure is considered one the most important and significant things before constructing infrastructure. It's conduct to give the background and information on the sub-surface for designing criterion and possible construction problems. There are various classical testing procedures for soil investigations tests [3]. For the civil engineering stable, roadways, overpass, and industrial projects, a soil investigation is needed to provide its main engineering properties such as soil type, consistency limits, index characteristics, density index, water table level, strength parameters of soil, (SPT) value and soil bearing pressure [4].

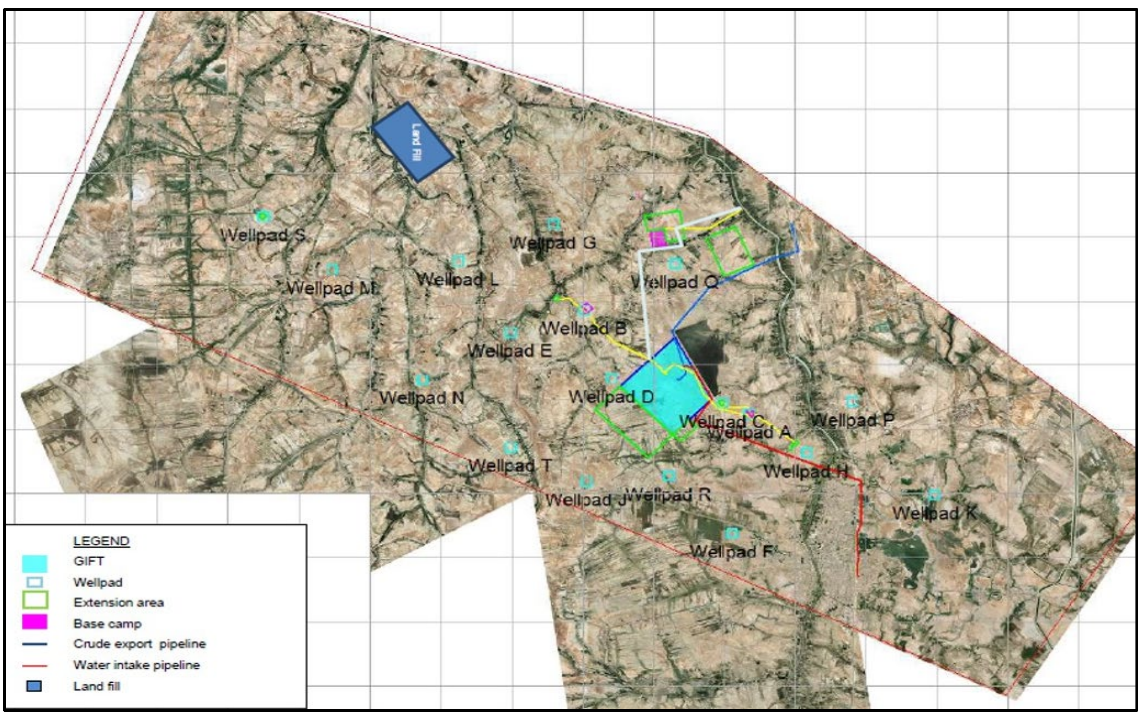
The in-situ and laboratory tests were conducted using undisturbed and disturbed samples which obtained from the exploratory number of boreholes. These methods are considered to be invasive technique, high cost and too time [5]. In order to reduce the cost and time during the geotechnical investigation, non-destructive methods are most compatible, easy, quick and economical to use their procedures and techniques to explain and determine different geotechnical physical engineering. They introduced high speed control the process of determining different subsurface exploration fundamental properties. These include number of techniques such as seismographs, the velocity of shear wave and soil electrical resistivity etc. Among these techniques, electrical resistivity test is recently a popular and widespread test to evaluate the sub-strata geological and ground engineering profile, as it has not be required an extensive effort and considered low cost [6]. Soil electrical resistivity has been utilized recently to evaluate the geotechnical information of substratum including the type of soil, particle distribution, shape and structure, the volume of soil moisture content, soil saturation degree, pore pressure, voids, and density (dry and saturation). It is also introducing an important relationships of various soil properties that built the gap bridge between the principal of geotechnical and geophysical and be able to investigate the important physical geotechnical properties [7]. The main objectives of this article are firstly, propose and generate a new empirical equations and correlations between resistivity and the soil characteristics in the context of electrical properties for Gharraf oil field soils in Southern Iraq. The soil investigation tests and laboratory works have been conducted at different location inside the field and then collected to evaluate the correlations between soil resistivity and those main and important geotechnical engineering parameters such as shear strength parameters (c, φ), standard penetration value (N-value), degree of saturation and void ratio. Moreover, the new generated empirical correlation obtained in this study can be used as suitable guideline to estimate these soil parameters and its bearing capacity. This study is organized in four sections, there are an introduction, methodology, discussion of results and conclusions.as described in the following sections.

2. Methedology

2.1 Site Investigation Description

Gharraf oil field region is situated in (southern part of Iraq) and located about 285 linear kilometers to the South-East of Baghdad City in Iraq. Gharraf is an anticlinal structure aligned northwest southeast and located about 30 km long and 10 km wide directions in the governate of Thi-Qar. The location and geological map of study areas is given in Figure 1. Generally, the sub-surface profiles of the tested boreholes are normally medium to consistency yellowish to brown clay to depth 12.0 m, then silty clay to the end of boring at a depth of (20.0) m.

a- Gharraf oil field location in the south east of Iraq



b- Map of the Gharraf oil field map

Fig. 1: Gharraf oil field location and site map

Several soil tests were performed inside this important area at different location. These tests required collections the soil samples to soil experimenter and this always required more time and very expensive. However, a time saving and low costly approach still need to reflects the principal characteristics of the soil. For this study, the electrical resistivity and laboratory tests have been carried out to describe the soil parameters for Gharraf oil field soil. The properties of soil in the laboratory and in-situ test consist of soil resistivity (ER) are used to develop the empirical correlations between them. The most typical geotechnical properties and soil electrical resistivity for selected borehole inside the area are plotted with the borehole depth as illustrated in Figure 2.

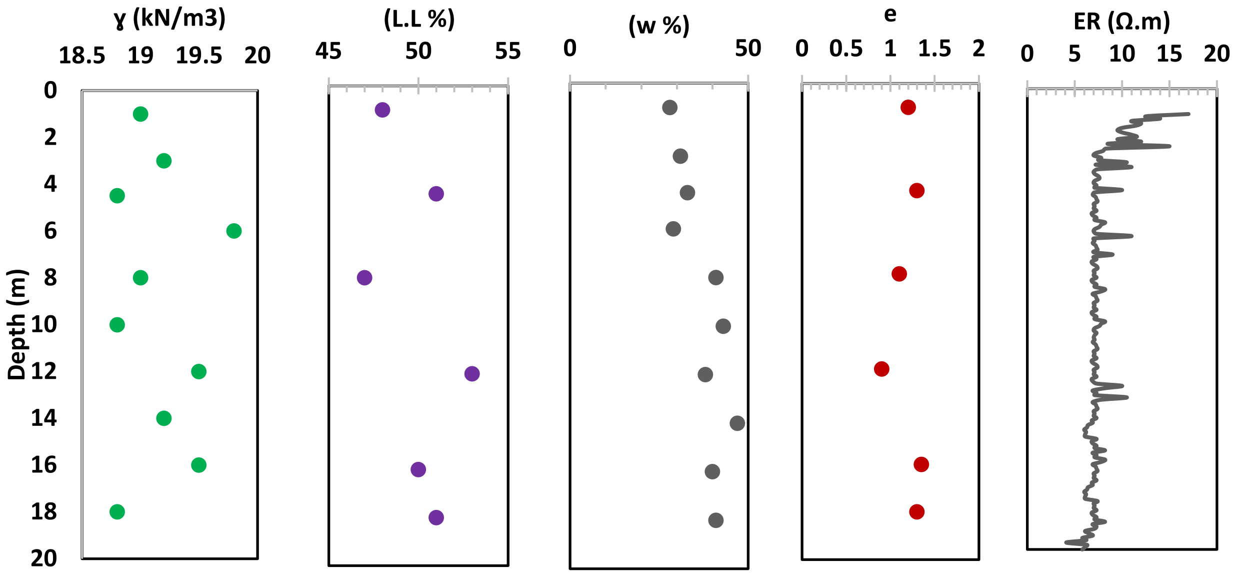


Fig. 2: Geotechnical properties of the borehole

2.2 Electrical Resistivity of Soil

Soil electrical resistivity has been considered one of the important properties of a geophysics tests. It is non-non-destructive method to investigate the soil characteristics in geotechnical applications [8]. It also reflects the main properties the sub-surface materials. It depends entirely on a set of effective effects related to the rocks and effects related to the interaction of mineral of particles with the pores water [9]. Soil electrical resistivity technique presents an electricity line into the earth surface at numbers of electrode poles fixed at equally distance and measures the amount of voltage electricity at different electrode poles spacings [10]. The geotechnical parameters of the soil layers related to the borehole depth were evaluated as a function of electricity resistivity. This procedure introduces the interpretation of the soil electrical resistivity data which reflect the resistivity/depth relationship of the soil beneath the soundings [11]. The Wenner electrode poles collection has been method used measurement principle with the ABEM SAS4000 software. Then, a computerize system is then connected with the electrode poles at each point on the earth and during the experimental investigation performed in the study area; [12]. The soil electrical resistivity four electrodes are set up in line in the ground equal spaced at distance (a) from one another (a) generated is used to measure the electrical current (I) between the two outer electrode poles (C1&C2) the potential ∆V is then measured with a voltmeter the two central electrodes (P1&P2) configuration was used in this survey see Figure 3. The resistivity test was done according to the BS-7430 the measurements were done at (50) points location. The soil resistivity values were calculated following Wenner equation [2]

$$\rho = 2\pi AR \tag{1}$$

where: ρ is the electrical resistivity value (Ω.m),

A - electrode spacing in [m],
R - the resistance value of the test in [ohm],

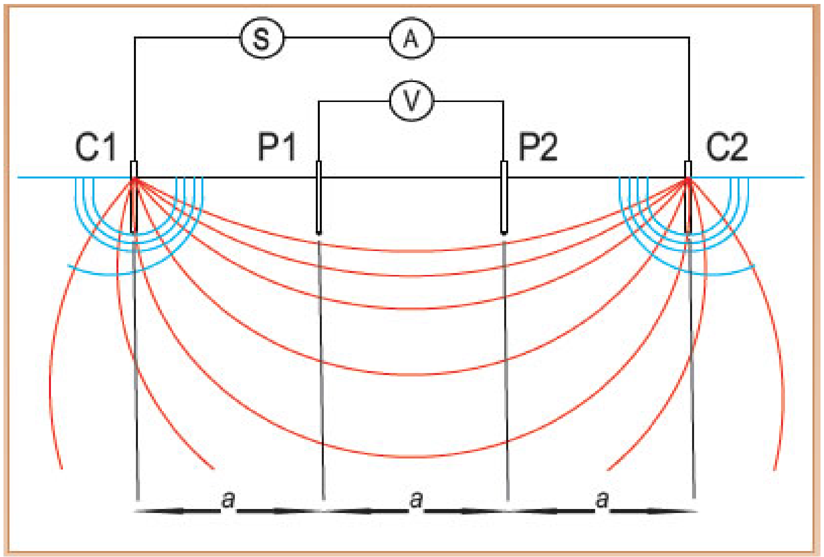
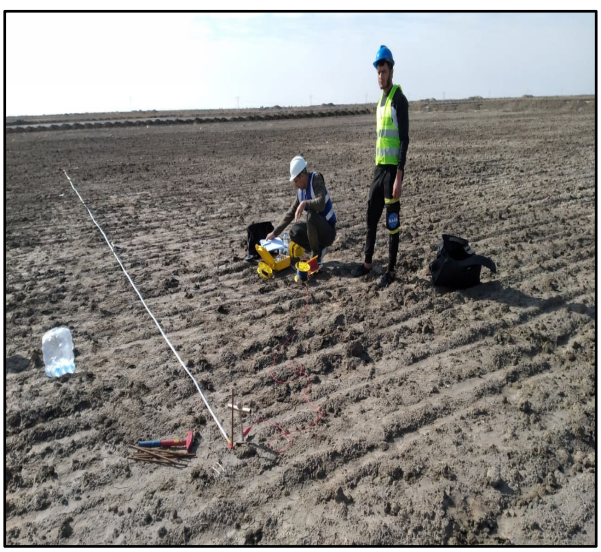


Fig. 3: Electrical Resistivity Field Measurements

The electrical resistivity sounding is used to make surveying along the soil profile depth in different zones inside the field area. In this procedure the configuration center is kept fixed to measure the electricity by successively increasing electrode spacing. The apparent electrical resistivity readings of electrode are used to estimate the thickness and resistivity of the subsurface formations. Then, the four electrodes in Wenner's configuration are settled in a line at equal distance 'a' between the sequential electrodes and depth [13]. The measurements were calculated at 1.0 m, 2.0 m, 3.0 m, 4.0 m, 5.0 m, 10 m, 15.0 m & 20.0 m inside the study area as shown in Figure 3 [14].



a- Setup for soil resistivity testing

b- Wenner Soil Resistivity

Fig. 4: Electrical Resistivity measurements at the selected area

3. Results and Discussion

3.1 Resistivity with Shear Strength Parameters

The correlation between electrical resistivity and the soil strength parameters are interpreted and developed in this study. The values of soil shear strength [undrained shear strength (c) and internal friction angle (φ)] were then plotted against the resistivity in Figure 5. It can be concluded that the value of resistivity increases, while soil cohesion increase. Then, the curve response to decrease with increasing of soil resistivity values. The reason of this increment is may could be due to the soil type becomes silty clay to sandy soil at this issue the soil cohesion parameter will be less 85 kPa. Hence, the possible reason that advantage to the high soil shearing angle of friction value is due to the high percentage of coarse particles especially at depth more than 15.0 m. Additionally reason for this increment in angle of friction value is also due to the range of moisture content values for the soil specimens were decrease dramatically from medium to low state.

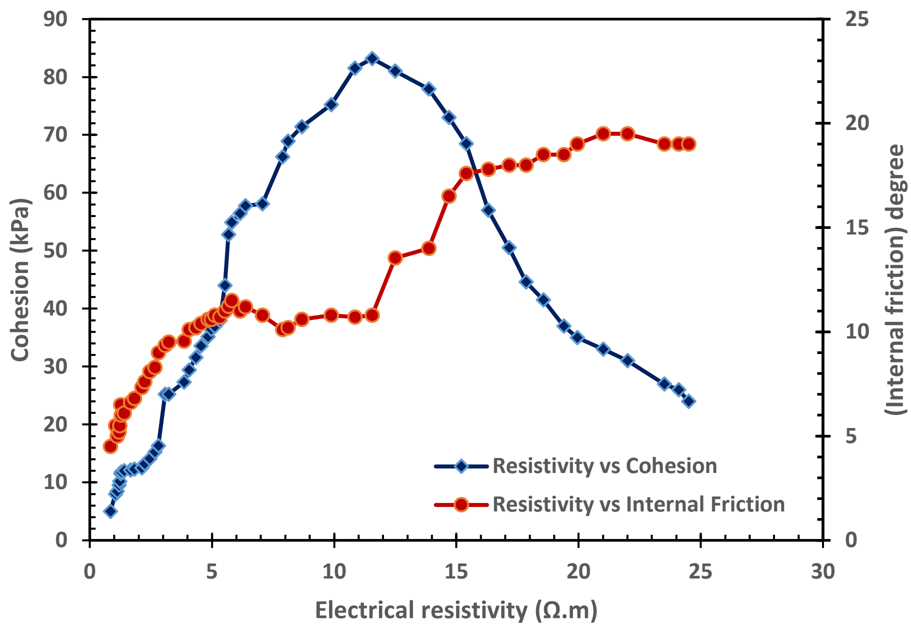


Fig. 5: Electrical resistivity and soil strength parameters responses

However, the soil shearing strength characteristics (cohesion and internal friction angle) at any depth were used to calculate the soil bearing capacity. So, one of the most development of this relationship that the soil ultimate bearing capacity (q_{ult}) was examined using three D/B ratios (0.5, 1.0 and 1.5) using the following conventional Terzaghi's equation.

$$q_{ult} = CN_c + \gamma D_f N_q + 0.5\gamma' B N_\gamma \quad (2)$$

Then. the obtained resistivity responses for each depth were plotted against the corresponding depth as illustrated in Figure 5. Based on these response, Eq. 3 was modified to evaluate the ultimate bearing capacity of the soil at (D/B=0.5) as illustrated in Figure 6. It can be found a new practical equation between the electrical resistivity (ER) and the soil ultimate bearing capacity as follows:

$$q_{ult} = -4.2\ ER^2 + 120\ ER - 92 \quad (3)$$

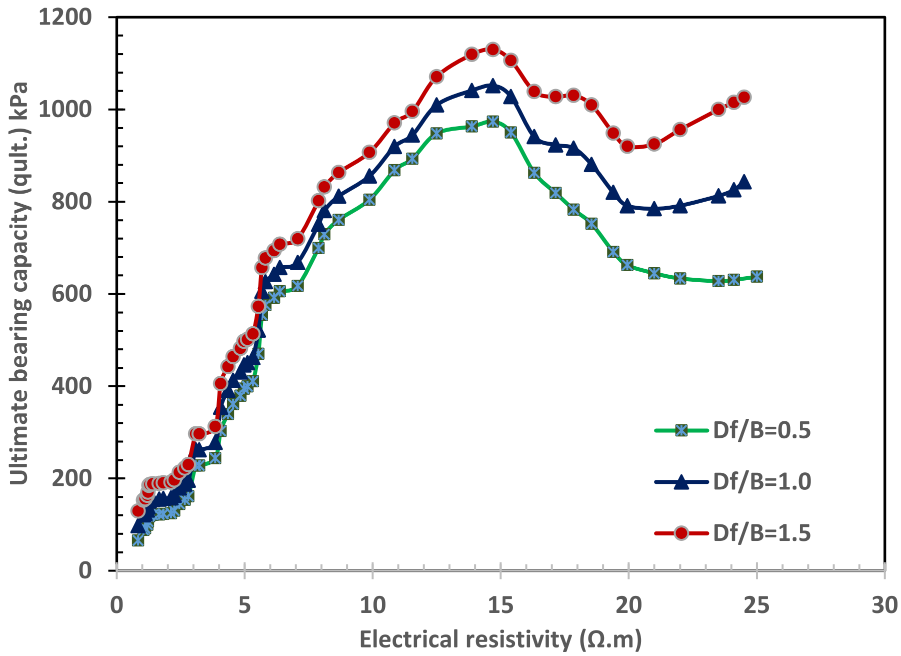


Fig. 5: Relationship between q_{ult} at different D/B ratios

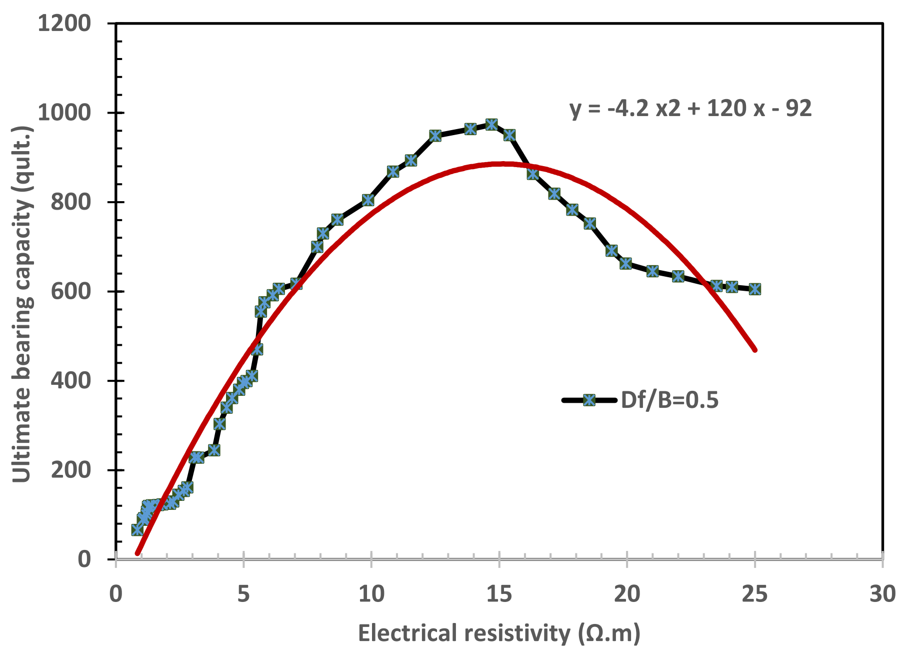


Fig. 6: Relationship between the ER and q_{ult} at D/B=0.5

3.2 Electrical Resistivity and SPT (N-value)

SPT test was carried out in accordance ASTM D 1586-11 at 1.5 m interval for each borehole. The machine divider spoon sampler fixing on the bottom of borehole and then permitted to plunge under its self-weight. Firstly, it has seated at the first 15 cm with the hammer falling blows at 750 mm. The raping assembly involves of a main driving head which have a 63.5 kg weight. It has a mechanical power and energy to fall weight through friction between the guides or between ropes the drive weight. The number of blows required to drive each 15-cm penetration is recorded. The soil report represents design SPT values considering the dilatancy correction, overburden pressure correction and energy [15]. The relationship between the electrical resistivity values (ER) and SPT is showed in Figure 7. The obvious regression trend shows a reasonable response with the coefficient of regression, R2 equal to 0.92. The reasonable response is may be due to to the high internal friction angle is due to the low value of water content.

$$\mathrm{SPT} = 10.8 \ln \mathrm{ER} + 6. \tag{4}$$

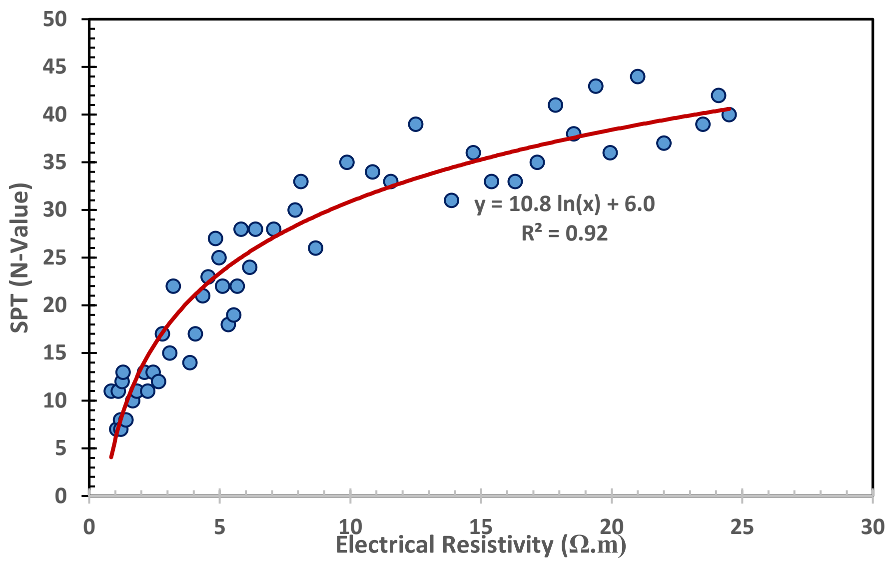


Fig.7: SPT as a function of Resistivity data

3.3 Electrical resistivity and Degree of Saturation (Sr)

Soil degree of saturation pointedly correlated with electrical resistivity for the number of 66 points in the form of linear relationship as shown in Figure 8. The degree of saturation is amount as the ratio of the water volumetric in the voids to the volume of voids of soil specimen. The correlation can be determined by a best-fit line using the collected data as a power function response. The degree of saturation for soil specimens decreased with an increase of Soil resistivity. The trend was also dependable on the soil clay mineralogy geochemistry and physical engineering properties of Gharraf region ground specimens which collected at different depths [9]. In general, these soils with abundant of grain minerals of the clay, pore size and their distribution. These layers are more active and, therefore, should display superior surface behavior [16]. The correlation between these factors is written by the following equation;

$$\mathrm{Sr} = 1.0\, e^{-0.017\mathrm{ER}} \tag{5}$$

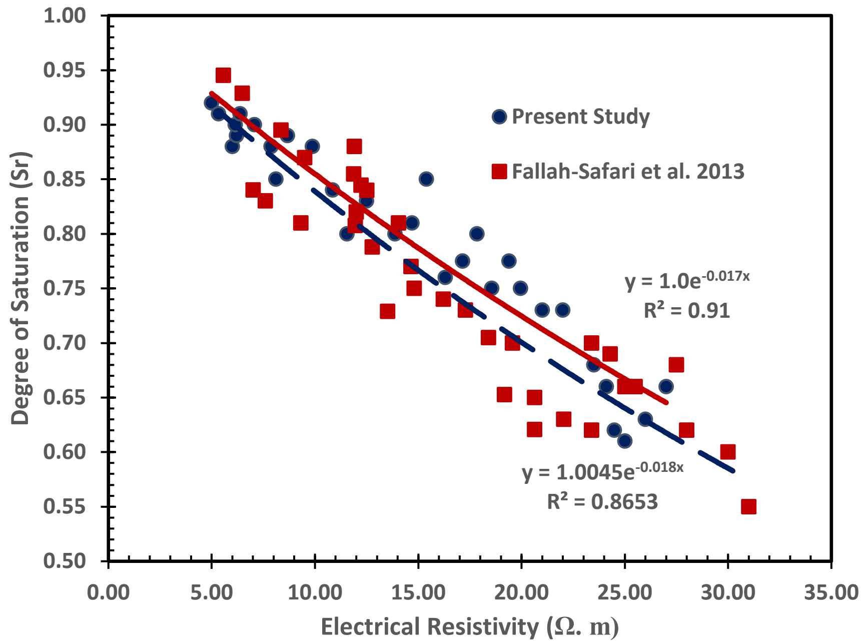


Fig.8: Correlation between ER and SPT values

3.4 Electrical Resistivity with Void Ratio(Vv) and Porosity (n)

In clays, void ratio and porosity are more important in governing electrical resistivity values. Figure 9 reflects the correlation between the electrical resistivity and void ratio. The void ratio (e) is evaluating as the void volume relative to soil grains volume in tested soil specimen. Whereas porosity (n) is defined as the number of pores, or open pores, between soil particles. Generally, the soil porosity explained as the first-order character that may be effects on the resistivity [17]. It found that the void ratio and porosity have a significant effect and explained highly correlated with the electrical resistivity. From the regression line of void ratio and porosity with electrical resistivity values, the empirical formulas are improved according to the collected data.

$$e = 2.12\ \mathrm{ER}^{-0.14} \tag{6}$$

$$n = 0.70\ \mathrm{ER}^{-0.057} \tag{7}$$

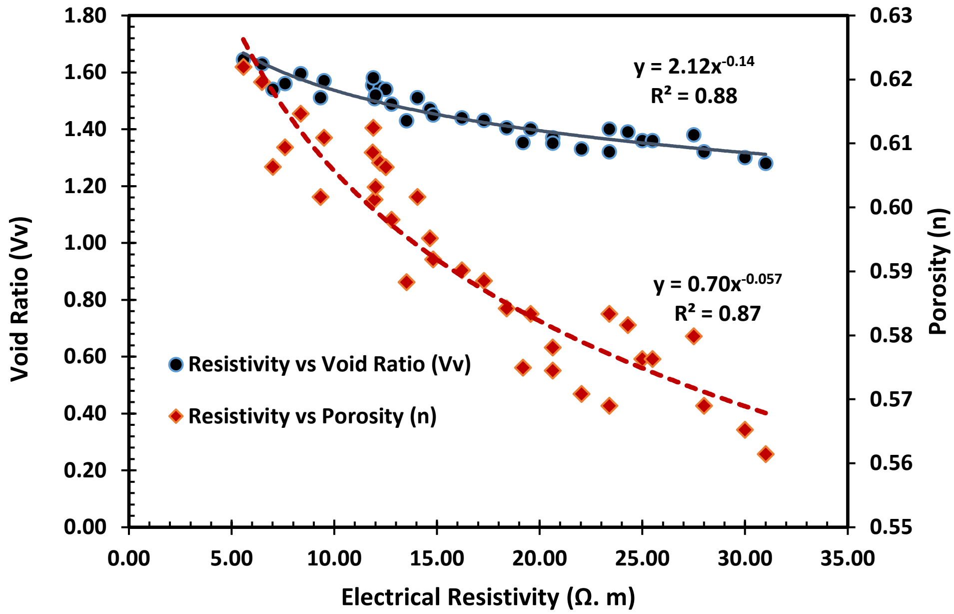


Fig.: Correlation between ER with V_v and n

4. Conclusions

The geotechnical investigation works at any project is considered hard works, time-consuming, destructive, and high cost. Other soil investigation procedure appears to be non- destructively, easily, quickly process and low costly than soil investigation tests and can offer a very attractively instrument for geotechnical engineering characteristics. The main purposes of this article are to find the relationship between soil resistivity data and some of important geotechnical parameters in Gharraf oil field region. The selected soil characteristics are soil shear parameters, standard penetration value saturation, air void ratio and porosity.

Findings in this research presents a very significant information and correlations between soil electrical resistivity (ER) and main various important soil parameters. The collected and obtained results were examined to provide the interrelationship among geotechnical properties and resistivity of soil. It also is concluded that electrical soil resistivity data alone can be used to evaluate the soil parameters for designer by using the suggested and proposed correlations, which previously known to be determined using an extensive field and laboratory testing. Moreover, a successfully improved empirical correlation models between electrical soil resistivity and soil parameters. Finaly, the ERT alone can be used to determine the soil ultimate bearing capacity rather than of using the conventional calculations that require many necessary inputs geotechnical parameters investigated using an extensive laboratory test.

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