Correlation of Electrical Resistivity Test with the Geotechnical Parameters of Sandy Soil

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Abstract

Non-destructive tests (NDTs) are the most economical and easy to use techniques to determine different soil properties. They expedite the process of determining sub-surface characteristics. These include Ground Penetrating Radars (GPRs), Seismographs, Shear Wave Velocity (SWV) and Electrical Resistivity Test (ERT) etc. ERT is nowadays getting worldwide popularity for determining the sub-surface geology in geotechnical engineering, as it does not require extensive testing. This research aimed at developing empirical correlations of ERT with different soil parameters by performing extensive conventional laboratory tests in order to get all the required soil parameters by just performing ERT in the future, which otherwise require great time and effort to be determined by the conventional laboratory tests. The developed correlations include relationship of resistivity value obtained in the field with the internal friction angle ($r^2 = 0.964$), cohesion ($r^2 = 0.946$) and the bearing capacity of shallow foundation ($r^2 = 0.90$) for depth to width ratios of 0.5 and 1.0 respectively. The regression coefficients obtained ensured the development of quite good correlation for the sandy-clayey soil.

Keywords

Non destructive tests • Electrical resistivity test • Soil parameters

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1 Introduction

ERT is an in situ NDT which can be used to have a good knowledge about sub-surface profile. The major benefit of this test is that it does not require extensive testing and material transportation to the laboratory thus not only does it save a lot of money but it can enable us to get rid of the extensive laboratory testing too. The other benefits include less expertise, less operational costs, faster operation and less personnel required [1, 2]. These benefits make ERT very popular among the investigators to use for reconnaissance survey of any site, to determine different sinkholes, study crack propagation in soils [3], problematic soil seams, settlement issues in an already constructed building, factor of safety (F.S) of any landslide etc. [4, 5]. But, as it is still a new technique in the geotechnical engineering, it lacks reliable and sufficient amount of research which can be readily used. Despite being an expedite and easy to use technique, one has to conduct extensive laboratory tests after performing ERT in order to determine different geotechnical properties of the soil for different design procedures. The currently existing correlations include a relationship of resistivity with cone penetration and moisture content [2], resistivity with SPT blows [1], hydraulic conductivity of compacted clays [4, 6], Atterberg's limits and dry density etc. [7]. But no research has been able to develop comprehensive relationship with a high confidence value between ERT and geotechnical soil parameters in such a way that performing ERT alone would be enough to use the developed correlations to determine almost each soil parameter, which otherwise would require a lot of testing, time and money to be determined.

The correlations which were developed based upon this research included the relationship of resistivity with shear strength parameters (internal friction angle (ø) and cohesion (c)) and allowable bearing capacity for shallow foundations with depth to width ratio (D/B) of 0.5 and 1.0.

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2 Methodology

The research included performing the ERT using Wenner-Schlumberger array at 7 different locations on the site, each of 1 km long and then the bore holes were drilled at the test location to recover the soil samples. A total of 7 boreholes were drilled using motorized auger. 28 probes were erected at 1 m c/c spacing and contours were generated. The soil samples were recovered using shelby tubes from each 1.5 m depth up to a maximum depth of 7.5 m. These soil samples were then waxed and transported to the laboratory, where the conventional laboratory tests including soil gradation, direct shear tests and triaxial tests were performed in accordance with the ASTM (2014) standard procedures.

Finally, the resistivity values obtained at each depth were plotted against the obtained laboratory soil parameters of the same depth and the empirical correlations were developed using the regression analysis.

3 Results

3.1 Correlation with Shear Strength Parameters

In order to develop the correlations of resistivity with the strength parameters, direct shear tests were performed on the soil samples recovered from different depths. The values of internal friction angle (ø) and cohesion (c) were then plotted against the resistivity (R) obtained at the same depth as shown in Fig. 1. The developed equations are given by Eqs. 1 and 2.

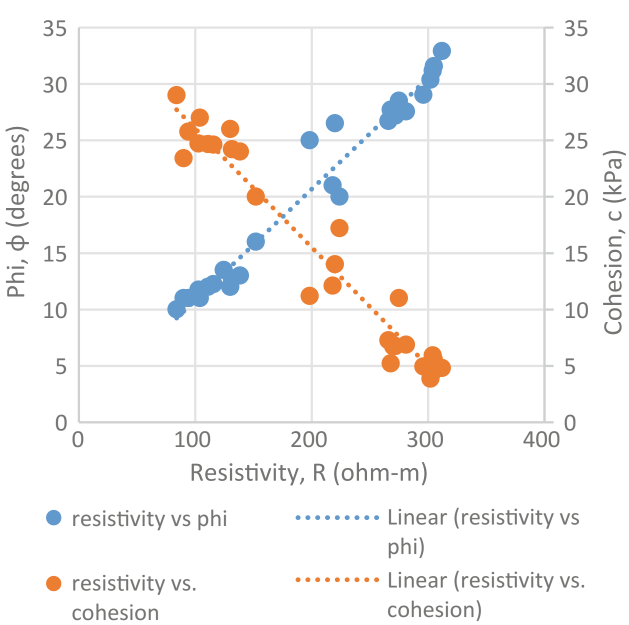

Fig. 1 Correlation of resistivity with the shear strength parameters

$$\phi(^\circ) = 0.0985R + 0.973 \quad (r^2 = 0.964) \qquad (1)$$

$$c(kPa) = 36.569 - 0.1052R \quad (r^2 = 0.964) \qquad (2)$$

3.2 Correlation with Bearing Capacity

Bearing Capacity analysis at any depth requires detailed calculations of overburden stresses, cohesion, friction angle, bearing capacity factors, relative density etc., if conventional equations are to be used. So, in the development of this correlation, the allowable bearing capacity (q_a) of soil was calculated with D/B ratios of 0.5 and 1.0 using conventional Terzaghi's bearing capacity equation by keeping F. S = 4.0 and then plotting these values for each depth against the obtained resistivity at that corresponding depth as shown in Fig. 2. Based on the developed plot, Eq. 3 was suggested for the calculation of allowable bearing capacity. From Fig. 2, it is also evident that D/B ratio has no major influence on the empirical correlations developed.

$$q_a(kPa) = 48.446e^{0.0083R} \quad (r^2 = 0.903) \qquad (3)$$

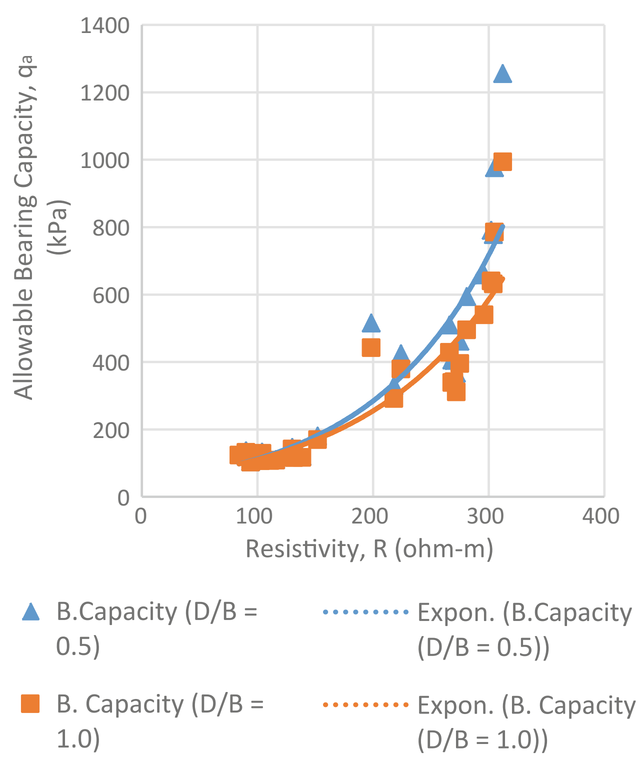

Fig. 2 Correlation of resistivity with allowable bearing capacity (D/B = 0.5, 1.0)

4 Discussion

Figure 1 shows that the trend lines developed have high regression values of $r^2 = 0.964$ and $r^2 = 0.946$ for friction angle and cohesion, respectively. It is also evident from the plot that the greater the density and internal friction angle, the greater the resistivity would be, while the greater the cohesion, the smaller the resistivity value would be. It means that as the particle size increases, its resistivity value also increases and vice versa.

Figure 2 shows that the trend lines developed from the plots yielded high regression values of about $r^2 = 0.912$ and $r^2 = 0.903$, respectively. The benefit of this correlation is, that just using the resistivity value now, one can obtain the allowable bearing capacity value instead of using the existing cumbersome conventional equations which require many inputs calculated using laborious tests to yield this value.

5 Conclusion

From this research, it is concluded that: firstly, ERT can be well correlated with the different geotechnical soil parameters. Secondly now ERT alone can be used to determine the soil parameters for the design procedures by using the developed correlations, which previously had to be determined using extensive laboratory testing.

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