Investigation of Geotechnical Factors Affecting Electrical Resistivity of Soil

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Abstract The use of electrical resistivity (ER) in subsurface investigation has increased in recent years. Resistivity imaging (RI) is a non-destructive method and provides a continuous image of the subsurface. However, only, qualitative evaluation of the subsurface can be obtained from RI. The correlations between ER results and geotechnical engineering properties of soils have become important for site investigation using this method. The primary objective of the current study was to determine the geotechnical parameters affecting electrical resistivity of compacted clays. Understanding the influential factors will be helpful in determining the correlations between RI results and geotechnical properties of soil. The geotechnical properties of soil obtained from laboratory tests such as oven dry test and standard proctor compaction test. The effects of moisture content, unit weight, and degree of saturation on soil resistivity were investigated. Resistivity tests were conducted on the actual field on composite soil at varying moisture contents, temperature, and unit weights. The field results reveal that a higher degree of saturation results in a lower electrical resistivity. The electrical resistivity increases gradually with increasing dry unit weight of soil.

Keywords Electrical resistivity · Water content · Degree of saturation · Dry unit weight

1 Introduction

For the accurate design and construction of civil engineering infrastructures, it is necessary to undertake Geotechnical investigation to find out the nature, types, and engineering properties of soils at that site. Such investigations are generally done by digging boreholes at different location at the site extending the same up to the desired depths for collection of soil sample from different depths [1].

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The different methods used for extending such boreholes are use or trial pits, shafts and headings, boring, augers, hand portable augers, wash borings, rotary drilling. Level and presence of the ground water table is also determined during the boring process.

Alternatively, in-situ tests for geotechnical investigation have also been devised.

Commonly used techniques are as follow:

- Plate load test
- Standard penetration test
- Cone penetration test
- Static cone penetration test.

Each of the above tests has their merits and demerits.

The use of electric resistivity(ER) in site investigation has been increasing all over the world. It is a convenient method for evaluating temporal variations of moisture and various geotechnical parameters of subsoil. Geotechnical engineers are able to investigate several parameters using conventional soil test boring methods; however, they can only obtain this information at certain locations and have to conduct interpolations to get area-wide information.

On other hand, ER is able to provide an image of the subsurface, as well as qualitative information of that particular sub soil [2]. Measuring of geotechnical properties has become an important thing for effective use of ER in engineering applications. The correlations of different geotechnical properties with ER will close the gap that currently exists between geophysical testing and geotechnical engineering, and therefore, geotechnical engineers will be able to interpret the geophysical data and utilize the information for their design, therefore making this method more effective for subsurface investigation.

In this study, the different sites are selected at Pune district in Maharashtra. The soil samples are collected from those sites to conduct the test in laboratory and get various geotechnical properties such as moisture content, dry unit weight, and degree of saturation and so on. The geotechnical properties of soil obtained from laboratory tests such as oven dry test and standard Proctor compaction test. The effects of moisture content, unit weight, and degree of saturation on soil resistivity were investigated. Resistivity tests were conducted on the actual field on composite soil at varying moisture contents, temperature, and unit weights [3].

2 Procedure (in Laboratory)

There are different field sites are selected at nearby Pune. From this sites, the soil samples are selected where the electric resistivity test are performed. Sample collected is brought to the laboratory for measuring properties of soil such as different values of water content and dry unit weight of that different soil at different sites.

Table 1 Soil with moisture content

Soil sample	Moisture content (%)
1	48.00
2	10.00

Table 2 Soil with dry unit weight

Soil sample	Dry unit weight (kn/m^3)	Optimum moisture content (percentage)
1	12.00	24.5
2	16.00	23.0

Oven dry test is done to determine the water content in soil by oven drying method as per IS: 2720, Part 2 (1973). Soil sample from site 1 shows the moisture content of 48% and from site 2 shows an moisture content of 10% (Table 1).

The standard Proctor compaction tests were carried out according to the Indian standard method (IS: 2720 Part 7, 1997). Two soil samples are taken from site 1 and site 2 for conducting standard Proctor test, to measure dry unit weight (kn/m^3) (Table 2).

3 Procedure (on Field)

For lateral and vertical profiling of soil using resistivity technique, resistance (Ω) is calculated in the field using the Wenner method and Schlumberger method, using instrument electric resistivity imaging (ERI) [4]. In these methods, four electrodes are used in which inner electrodes are potential electrodes and outer electrodes are current electrode. DC (direct current) is applied at the current electrodes, and potential difference is measured at potential electrodes.

Difference between Wenner and Schlumberger method is only about spacing between the electrodes. In Wenner method, the electrodes are equally spaced, but in Schlumberger method, spacing between the current electrodes is three times the spacing between the potential electrodes.

A site selection is also important criteria before conducting the ER test. For taking readings and well set up of ERI instrument, the plain terrain should be there. Such sites are helpful for placing the electrodes with suitable span.

A site at Pune district, Maharashtra is selected for field experimentation. The electrodes are arranged with suitable and constant span and arrangement of acceptor, and electrodes are done carefully. After proper inspection of the setup, the readings are start to collected. Prior of that inputs are set on that ER machine.

Inputs consist following data-

(a) Name of location
(b) Latitude and longitude of site

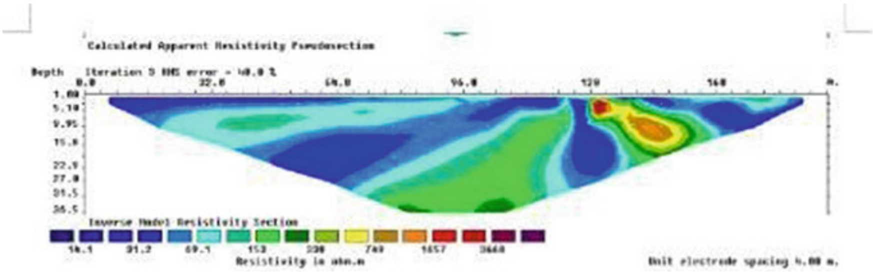
(c) Nearby locations
(d) Span between electrodes
(e) Number of electrodes
(f) Technique used on site.

The input data are useful for future working of electrical resistivity of same site and store the record of the electrical resistivity values which we get as output.

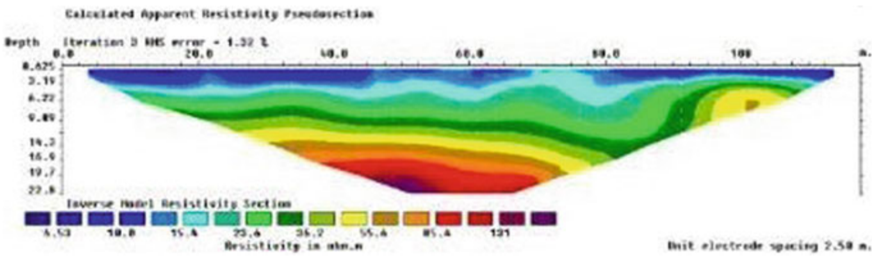
4 Observations and Results

4.1 Soil Profile (Resistivity Pseudo-section)

SITE-1: Calculated apparent resistivity pseudo-section at site 1, Pune district, Maharashtra. The laboratory results obtained from soil sample selected from this site give the moisture content of 48% and dry unit weight of 12.00 kn/m^3.



SITE-2: Calculated apparent resistivity pseudo-section at Pune district, Maharashtra. The laboratory results obtained from soil sample selected from this site give the moisture content of 10% and dry unit weight of 16.00 kn/m^3.



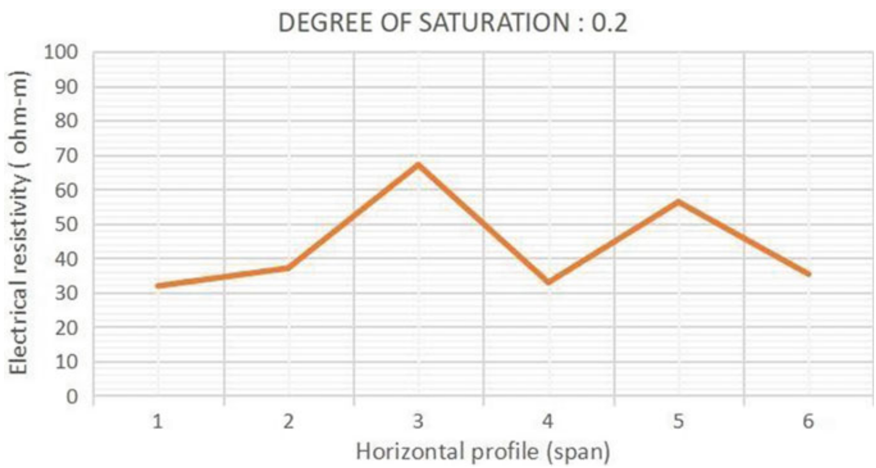
4.2 Relation of Degree of Saturation with ER of Soil

The water content and dry unit weight can be combined to a single geotechnical parameter called degree of saturation. The degree of saturation increases with the increase of water content or dry unit weight. The variations of soil resistivity with the degree of saturation are presented in above figure for the soil Samples 1 and 2. To obtain the degree of saturation, a specific gravity of 2.6 was considered to be constant. Soil resistivity decreased with an increase of degree of saturation. An increase in degree of saturation yields changes in orientation of clay particles. Therefore, soil resistivity decreased with the increase in degree of saturation, as presented in graphical representation of 2 different sites.

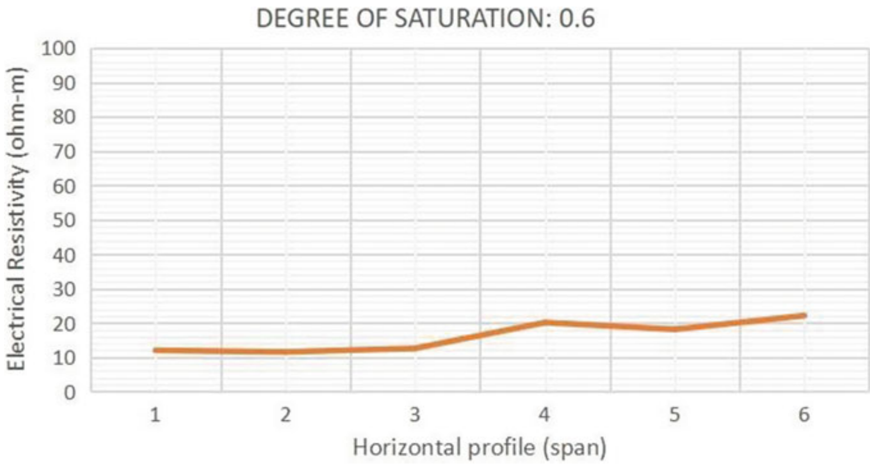
At site 1, the soil sample is taken which gives the value of degree of saturation of 0.2. The graphical representation is showing the relationship of degree of saturation with electric resistivity as *x*-axis representing electrodes span in meter and *y*-axis representing electric resistivity in Ω-m (Graph 1).

At site 2, the soil sample is taken which gives the value of degree of saturation of 0.6. The graphical representation is showing the relationship of degree of saturation with electric resistivity as *x*-axis representing electrodes span in meter and *y*-axis representing electric resistivity in Ω-m (Graph 2).

After the comparing all the graphs of degree of saturation with electrical resistivity, we get that the electric resistivity of soil decreases with increase in degree of saturation of soil, as shown in below figure. With the increase in degree of saturation of soil as 20 and 60%, the soil shows the variation in electrical resistivity as decreasing the values as 42.28 and 12.22 Ω-m. This study shows the inversely proportional relation of degree of saturation and electric resistivity [1].



Graph 1 Relation of degree of saturation with electric resistivity



Graph 2 Relation of degree of saturation with electric resistivity

4.3 Relation of Dry Unit Weight with ER of Soil

To determine the correlation of soil resistivity with dry unit weight, resistivity tests were conducted at different sites having various values of dry unit weights while considering the moisture content constant [1]. Tests were conducted on three sites at Narayan Gaon, Pune. The soil samples are collected from that respective sites and laboratory testing are done as mentioned above to find the properties of soil that are Samples A, Sample B, and Sample C at optimum moisture contents of 24.5, 23.0, and 21.5%, respectively.

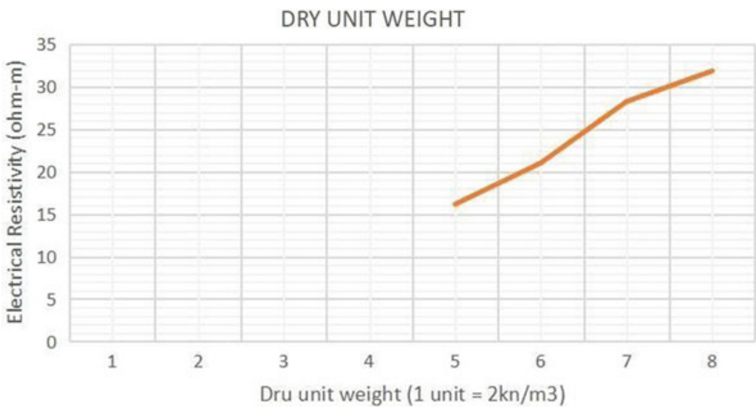
Dry unit weights were varied from site to site, as site 1 and site 2 having the value of dry unit weight of 12.00 and 16.00 kn/m^3, respectively. Soil resistivity decreased with the increase of unit weight in each condition (Graph 3).

Table 3 shows the soil with dry unit weight and their respective average ER value:

As dry unit weight of soil increases as 12.00 and 16.00 kn/m^3, the respective electric resistivity values also get increased as 19.18 and 32.32 Ω-m. This shows that the relation between ER and dry unit weight is directly proportional.

5 Conclusion

- After the complete study of electrical resistivity of soil with different geotechnical parameters such as degree of saturation and dry unit weight of soil, results show the some relation exist between them.
- This relations can useful for further study of the electrical resistivity of soil at different sites.



Graph 3 Relation of dry unit weight with electric resistivity. Graphical representation having dry unit weight (kn/m^3) as *x*-axis and electrical resistivity (Ω-m) as *y*-axis

Table 3 Soil with various properties

Soil	Dry unit weight (kn/m^3)	Electric resistivity (Ω-m)
Site 1	12.00	20.12
Site 2	16.00	32.32

- Understanding the effects of geotechnical parameters on soil resistivity will help to develop the correlations between ERI results and geotechnical properties.
- With the increase in degree of saturation of soil as 20 and 60%, the soil shows the variation in electrical resistivity as decreasing the values as 42.28 and 12.22 Ω-m. Inversely proportional relation is existing between the degree of saturation and electric resistivity of soil.
- As dry unit weight of soil increases as 12.00–16.00 kn/m^3, the respective electric resistivity values also get increased as 20.12–32.32 Ω-m. This shows that the directly proportional relation exists between dry unit weight and electrical resistivity of soil.
- However, the current study presents the effects of different soil parameters on resistivity. Similar trends are expected to be observed for other sites with different composition of soils.

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