Importance of Earth Resistivity Reading in Modern Geotechnical Engineering

Sreekumar N R [1], Basil Saman P M[2]

[1]*Assistant Professor, IES College of Engineering*
[2]*Postgraduate Student, IES College of Engineering*

Abstract— Ground resistance meters are a class of instruments designed to test the resistance of soil to the passage of electric current. Generally, ground resistance is tested to determine the adequacy of the grounding of an electrical system. Use of ground resistance tester in different areas of soil mechanics are studied in this study. When measuring earth resistance with an instrument, it is important to know the accuracy of the testing so validation of instrument is also carried out in this study by comparing the laboratory results with resistance data obtained. The resistivity method measures the apparent resistivity of the subsurface, including effects of any or all of the following: soil type, bedrock fractures, contaminants and ground water. Variations in electrical resistivity may indicate changes in composition, layer thickness or contaminant levels. Application of earth resistance readings in current situations are investigated thoroughly in this paper with help of various case studies conducted before. From this study it is identified as earth resistance tester has a wide applicability in geotechnical engineering

Keywords— Resistivity, Soil Type, Contaminants, Bedrock, Ground water

I. INTRODUCTION

An accurate understanding of soil type, bedrock fractures, contaminants, ground water and soil water changes in the unsaturated zone is crucial in understanding the geotechnical properties and behaviour of engineered earth structures. Water content changes cause cyclic processes of shrinkage, swelling, and cracking that adversely affects the engineering properties and behaviour of soils and is known to contribute to slope failures. Direct-current (DC) resistivity exploration is a traditional geophysical method. It employs two electrodes to inject electric current into the ground and other two electrodes to measure the electric potential difference. The measurements are often carried out along a line or in an area on the earth surface, and then the observed potential differences are converted into sounding curves or pseudo-sections of apparent resistivity's, which indicate the resistivity changes of subsurface rocks. Analyses of these data enable us to find the underground resistivity anomalies or outline the subsurface geological structure. The determination of soil profile is very critical in geotechnical investigation. To adequately design the geotechnical structure for any construction, it is necessary to accumulate sufficient data regarding the soil profile. Conventional method such as boring is proven to be efficient to provide sufficient data needed. However, the method is expensive, time consuming and intrusive. Large-scale project such as highway and railway usually required high number of boreholes to provide sufficient data for detail interpretation. Causing the construction time and cost to increase drastically. In recent years, geophysical methods have gained much attention as it is a non-intrusive investigation, and involves larger volume of investigation and rapid data interpretation. The advancement of the geophysical method such as Electrical Resistivity Tomography (ERT) allowed the mapping of the electrical resistivity distribution in the Earth, thus, allowing the estimation of the subsurface heterogeneity. The measurement of the ground surface (layers of materials with different individual resistivity) when current is injected into the ground through two current electrodes allows the determination of the subsurface resistivity distribution.

II. OBJECTIVE

The project aims at achieving the following objectives:

To study the current application of earth resistance readings

To compare the different types of application

To validate the efficiency of instrument used.

III. THEORETICAL BACKGROUND

Electrical resistivity of a material describes its ability to resist the flow of electricity. A DC or low frequency current is injected through a pair of electrodes and the resulting voltage difference is measured using another pair from which soil resistivity is calculated:

$$\rho = K\frac{\Delta V}{I}$$

Where, ρ is the resistivity (Ω.m), ΔV is the voltage difference (Volts), I is the current (Amps), and K, is a geometric factor (m). Resistivity, in turn, is related to different soil properties such as porosity, water content, and soil structure (Friedman2005).

Method of use

With development of computer technology and numerical computational techniques, accurate numerical simulations of subsurface electrical field and acquiring a large amount of data in fields become possible so that the traditional DC resistivity exploration was developed to a computerized geotomography technique, called electrical resistivity tomography (ERT), which employs a multielectrode equipment or system to automatically acquire a large number of data and applies a computer software to the reconstruction of subsurface resistivity structure with the observed data. Due to its conceptual simplicity, low equipment cost and ease of use, ERT is now widely applied in mineral exploration, civil engineering, hydrological prospecting and environmental investigations. Figure below shows how the resistance meter works.

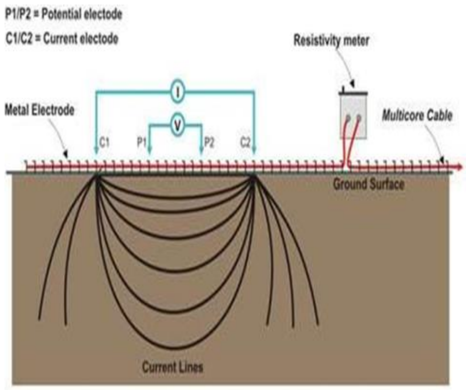


Fig. 1 General principle

Current flow in subsurface

Electrical current flow in the subsurface is primarily electrolytic. Electrolytic conduction involves passage of charged particles by means of groundwater. Charged particles move through liquids that infill the interconnected pores of permeable materials. So, resistivity value decreases as water content increases. Therefore, seepage through subsurface can be monitored by measuring the resistivity value. Current flow through the subsurface is shown in the figure below.

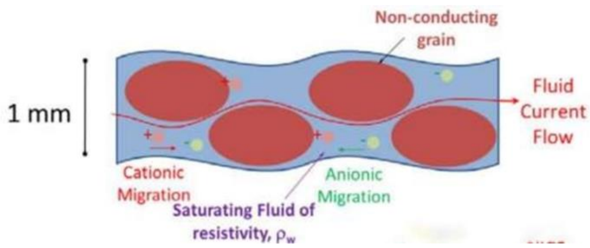


Fig. 2 Current flow in subsurface

IV. METHOD OF REPRESENTATION

Interpretation of the data, done either manually for simple/small scale systems or by the use of computer analysis, such as CDEGS. There are commercially available computer programs that take the multi-layer soil structure data and mathematically calculate the soil resistivity and provide a confidence level for the tests to evaluate the error. Typical RMS error should not exceed 10% for the model considered valid, but this in itself is not the final factor.

Testing Methods

The three main methods of electric resistivity surveys are vertical electric sounding (VES), electric profiling, and electric imaging. Setting Loading Measurement. VES is one of the more commonly used and cost-effective resistivity survey methods. Current is moved through the subsurface from one current electrode to the other and the potential as the current moves is recorded. From this information, resistivity values of various layers are acquired and layer thickness can be identified. Where VES focuses on determining resistivity variations on a vertical scale, electric profiling seeks to determine resistivity variations on a horizontal scale. Profiling can use the same electrode spacing configurations as VES. Since changing the spacing between electrodes only affects the depth at which the survey can reach, the profiling method does not involve manipulating electrode spacing. In many cases resistivity can change as both depth and horizontal distance increase. Both VES and electric profiling are limited to surveying in one direction. Electric imaging is able to survey both vertical and horizontal changes in resistivity. This method essentially combines the other two methods. Electrode spacing is increased and the survey is moved along a profile in order to measure both vertical and horizontal resistivity. These values are then used to create a pseudo section. ERT is the major component of Electrical imaging.

Electrode configuration

Factors such as maximum probe depths, lengths of cables required, efficiency of the measuring technique, cost (determined by the time and the size of the survey crew) and ease of interpretation of the data need to be considered, when selecting the test type. The Schlumberger array is considered more accurate and economic than the Wenner or Driven Rod methods, provided a current source of sufficient power is used. In the Wenner method, all four electrodes are moved for each test with the spacing between each adjacent pair remaining the same. With the Schlumberger array the potential electrodes remain stationary while the current electrodes are moved for a series of measurements. In each method the depth penetration of the electrodes is less than 5% of the separation to ensure that the approximation of point sources, required by the simplified formulae, remains valid. These are not the only array spacing's a resistivity survey can have. Others include the dipole-dipole array, the pole-dipole array, pole-pole array, the Lee-partition array, and the square array. Each of these various arrays differs in electrode spacing and the movement of either the current or potential electrodes.

V. VALIDATION OF INSTRUMENT

A. Materials used

The various materials used in the experimental program are laterite soil which collected from college campus. Bentonite clay and black cotton soil purchased from dealers through India mart. Earth resistance tester of having range 0-1000Ωm purchased from a seller at Thrissur district of Kerala.

For determining the type of soil and its properties these tests are conducted and results of the tests are tabulated. Table 1 shows the basic properties of soil.

Soil Properties	**Values**
Specific gravity, G	2.656
Liquid limit (%)	42%
Plastic limit (%)	25%
Shrinkage limit (%)	14.64%
Plasticity index (%)	17%
Soil Type	MI
Optimum moisture content (%)	14.13%
Maximum dry density (g/cc)	1.836
Unconfined compressive strength (kN/cm^2)	1.549
Coefficient of uniformity	15
Coefficient of curvature	1.251

TABLE 1

BASIC PROPERTIES OF SOIL

A glass was taken for validation the earth resistance tester. The glass is taken so that there is no chance of electric conductivity tends to zero loss in current passed to the soil. Also because of its transparency the layers of soils are visible and can be arranged in a good manner. The size of glass tank is taken as 400mmx400mmx200mm. Copper rod of length 150mm is taken as electrode. Figure below shows the earth resistance tester fixed in the glass tank

Soil layers are filled in the tank first. Three different types of soils are filled in tank layer by layer. Then testing was done with different spacing of electrode to get resistance values at different depth of investigation.

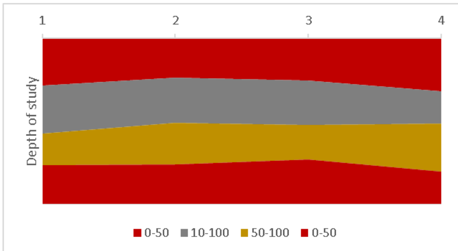
Soil Type	Obtained values	Standard values
Garden soil	4.33 Ωm	0-50 Ωm
Clay	31.66Ωm	10-100Ωm
Heavy clay	91.86Ωm	50-100Ωm
Garden soil	5.68 Ωm	0-50 Ωm

TABLE 2

TEST RESULTS FROM INSTRUMENT

So that the known resistance of soil can be compared with the obtained values of resistance for validation.

Test results shows that the validation is successful and the obtained value lies in between of standard values. So that now we can use this instrument in field study and also in laboratory testing process. And also, by drawing a graph with these resistivity values we can plot a soil profile easily. In field conditions soil profile will help to determine the positions of soil layer. Figure below shows graph drawn with using these resistivity values.



Soil profile obtained with instrumental results is compared with artificially made soil model in the laboratory and the result was successful. Here I adopted wenner array for study because in fields this type of array is most commonly adopted because potential electrode spacing increases as current electrode spacing increases. Less sensitive voltmeters are required. The wenner electrode array is used for profiling or mapping in soil testing because of an old standardized test, specified in ASTM G57, written for electrical soil testing. This standard specifies profiling and is performed with the wenner array. The wenner array is at a disadvantage when performing VES surveys. Since you will have to move all four electrodes for each new measurement, this means a lot of walking when the electrode spacing becomes large.

VI. CONCLUSIONS

Based on case studies and laboratory experiment we made these conclusions.

- This study investigated the effectiveness of ERT as a tool for identifying soil profile.
- Electrical resistivity is a nondestructive, rapid, and cost-effective methodology.
- Hence cost of instrument is low it can be adopted for preliminary surveys
- Earth resistance reading having a wide range of applications in geotechnical engineering.
- ASTM standards are available for checking adequacy of obtained resistivity values.
- Each of the NDT methods has benefits and limitations. Resistivity is particularly useful, when calibration data can be obtained in the lab before field work

REFERENCES

[1] Asem Hassan1 and David G. Toll, (2015), "Electrical Resistivity Tomography for Characterizing Cracking of Soils", ASCE.

[2] Md Zahidul Karim and Stacey E, (2018), "Predicting Soil Erodibility Using Electrical Resistivity Tomography", ASCE.

[3] Sabine Kruschwitz and Ernst Niederleithinger,(2015), "Use of Complex Resistivity Tomography for Moisture Monitoring in a Flooded Masonry Specimen", ASCE.

[4] Al-Fares W etal, (2014), "Application of electrical resistivity tomography in characterizing leakage problem in Abu Bara Earth Dam, Syria" International Journal of Geophysics, Article ID 368128.

[5] Arno Rein, Ruth Hoffmann and Peter Dietrich (2005), "Influence of natural time-dependent variations of electrical conductivity on DC resistivity measurements", ASCE.

[6] Christopher R. Clarke etal (2015), "Monitoring Long-Term Subgrade Moisture Changes with Electrical Resistivity Tomography", ASCE

[7] Michael Snapp, Stacey Tucker Kulesza, Weston Koehn (2015), "Electrical resistivity of mechanically stabilized earth wall backfill", Journal of Applied Geophysics

[8] Dahlin, T. (2001). "The development of DC resistivity imaging techniques."Comput. Geosci., 27(9), 1019–1029.

[9] Archie, G. (1942). "Electrical resistivity log as an aid in determining some reservoir characteristics" American Institute of Mining and Metallurgical Engineers, (146):55–62.

[10] Bai, W., Kong L-W, and Guo A-G. (2010). "Experimental investigation and sensitivity analysis for the effects of fracture parameters to the conductance properties of Laterite" World Academy of Science, Engineering and Technology,(71): 792-799.

[11] Kalinski, R.J. and Kelly, W.E. (1993). "Estimating Water Content of soils from electrical resistivity" Geotech. Test. J., (16): 323–329.

[12] Greve, A. K., Acworth, R.I., and Kelly, B.F.J. (2010). "Detection of subsurface soil cracks by vertical anisotropy profiles of apparent electrical resistivity "Geophysics, (75