Application of Schlumberger Method for Characterization of Soil

Bodh Ram Chaohan, Pooja Shrivastava, S.K. Shrivastava

***Abstract:** A nowadays, geo-environmental study such as soil contamination analysis, electrical properties of soil, and geo-technical centrifuge modeling needs a characterization of soil. This will help in estimation of soil properties, mathematical and physical modeling, field investigation and some other detailed phenomenon. In this study, we used a Schlumberger method for characterization of soil in the water conduit of village Visarpani, near Mainpat block of Surguja district of Chhattisgarh, India. In this conduit, water stream climbs itself towards uphill with the slope of 45^0 and travels distance about 150 meters in East to West direction and after turns towards downhill in North to South direction. Experimentally calculated Schlumberger resistance used in the theoretical calculations for finding resistivity and conductivity of soil and then predicted the soil characteristics at different intervals. This study showed that towards uphill resistivity is decreasing and conductivity is increasing regarding distance intervals.*

***Keywords:** Schlumberger Resistance, Resistivity, Density, Conductivity, Conduit.*

I. INTRODUCTION

In the field-based investigation, electrical resistivity and conductivity measurements are geo-physical approach that offers a destructive and easy means to collect constant data. Electrical resistivity and conductivity of soils are susceptible to the various factors such as ion concentration and mobility, a quantity of clay, temperature and water content. Electrical resistivity is an intrinsic property that computes the flow of electrical current in which material opposes the flow of it. The electrical resistivity method used in the geophysical testing and agriculture during last many years and the work famous by the efforts of Conrad Schlumberger in France in 1912.

Schlumberger method is becoming, increasing popular approach for geo-technical engineers: to derive geo-technical information of soil such as soil type, density, conductivity and texture from the data. Soils are one of the most essential natural resources, which produce basic needs of a human being such as food, fiber and fodder.

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With, the increasing of population food demand increasing day by day and it causes over-exploitation of natural resources. To overcome this, it is very important to use soils properly and efficiently by planning and management. Soils have become an inherent part of the land that forms different landscape by variation in their attributes and matrix. Therefore, the relationship between the electrical property and soil strength are important to assign the differences in runoff, deposition and erosion in landforms.

A field geo-environmental investigation was carried out to better understand the classification of soils at different distance intervals and develop a relationship between soil, resistivity, conductivity and density in Ultapani village, Mainpat block of Chhattisgarh. This may provide an economic, efficient and less time-consuming approach to geo-technical site investigations. Schlumberger resistivity method is most suitable for classification of soil in the site investigation as compared to other geo-technical methods. The study shows the comprehensive database about the characteristics and classification of soils at a different distance interval, which will help in developing proper soil and water relationship.

II. LITERATURE REVIEW

There is a possible relationship between strength of soil and electrical resistivity based on the different parameters which control the strength and electrical resistivity such water contents, particle size distribution, saturation degree and binding because of electrical flow in the soil subsurface. Resistivity also related to the salinity of fluid in saturation condition where soil strength is not considered (Sudha et al. 2009). In groundwater exploration geophysical characterization of the vertical fracture, zones are important because the main sources of water contaminated by these fractured aquifers. This subsidized the drilling of a well at the time of groundwater exploration (Posani et al. 2005). The geoelectrical method also used in the framework of risk assessment, develop a quantitative relationship between measured electrical resistivity and density due to compaction. This relationship is needed to calculate the amplitude of the signal of geophysical that increased the density. This helped in defining the parameters of the field such as sampling and survey length and interpret the posterior data. (Seladji et al. 2010) Along the positive relationship between electrical resistivity and geo-technical, parameters that are indirectly associated with the compressibility factors, which give an understanding of phenomenon relationship between soil settlement and electrical resistivity (Ghorbani et al. 2012).

Soil matrix and attribute governs the wide range of hydrological and ecological functions of soil, this need to be examining the geophysics in large-scale spatial and temporal domains, that can sight to have soil structure. There are different geophysical properties related to soil structure but there is a lack of pedophysical models, which defined soil attributes in terms of macroporsity and connectivity. This needed an image huge resolution by multiple geophysical data sets. So geophysical methodologies for soil structure should be characterized and test at sites (Romero et al. 2018)

Soil saturation degree depends on soil suction and resistivity; both are used for calculation of water contents variations. To obtained information about suction changes in large volume: it relates soil suction to the electrical conductivity not for only small areas. An analytical relationship between soil matrix and electrical resistivity by applying van Genuchten and Archie laws studied for Volcano ashy layer. The geophysical methods are more effective to monitoring the stress of soil specially in periodically events (Piegari et al. 2013). The air void ratio in soil will also have a definitely influence the electrical resistivity of soil and which need to take the moisture content and degree of saturation, and volume of the soil as the controlling factors in the soil sample (McCarter et al. 1984). Electricity flow in any material described by two mechanisms i.e. resistivity and conductivity. The primary cause of conduction in a material is due to movement of ions through the electrolyte in the void spaces. Geotechnical and geophysical applications are widely used to evaluate the electrical properties of soil. Resistivity is a measure as retards of electrical current and it does not depend on the material property and but depend on media geometry (L.Sebastian).

Application of geoelectrical method in organic soil by using electrical resistivity imaging (ERI) and resistivity cone penetration test (RCPT). ERI based on Schlumberger method and obtained a 2D images of resistivity in the medium of soil. RCPT also measured accurate electrical resistivity and conductivity in the medium of soil at selected points. Resistivity is a parameter that defined the variability in geological medium with respect to lithology in case of water conductivity is narrow.ERI also interpreted the boundaries between the soil layers (Kowalczyk et al.2017).

We also found resistivity values for different types of soil from the literature survey showing in Table I. According to Kaufman et al. (2001) there are overlapping between different types of soil and Palacky (1987) described a resistivity for similar types of soil. He calculated very low resistivity values for clays and for sand, its lower bound value surpassed with the upper bound value given by Kaufman.

Table I Classification of soil according to Kaufman (2001) and Palacky (1987)

Soil type	Soil classification	Resistivity (Ωm) (Kaufman and Hoekstra, 2001)	Resistivity (Ωm) (Palacky ,1987)
Clays	CH	1,000-5,000	300-10,000
	CL	2,400-6,000	-
	OL	2,650-7,500	-
Silts	ML	2,650-7,250	-
	SC	4,650-17,800	-
	MH	7,150-24,000	-
Sand	SM	9,600-45,250	47,500-1000,000
Gravel	GW	56,300-91,800	47,500-1000,000
	GC	12,900-40,500	-
	GP	91,500-233,250	-

From the literature, as various researchers work for this from last many decades but still it needs more research in this area. It is very challenging to understand the various effects of geotechnical parameters on electrical resistivity and conductivity in the field study where soils can extremely sensitive.

III. STUDY AREA AND LOCAL HYDROGEOLOGY

In Surguja district, Mainpat is a block in the northern region of Chhattisgarh state in India and is located about 55 kilometres from Ambikapur showing in Fig.1. The geographical distance of the Mainpat is 35 km from Darima airport and about 55 km from district headquarter Ambikapur in Surguja division. The height of the Mainpat hill is about 3560 feet from its base. In this block, there is a place called Ultapani in village Visarpani, which is situated 5 km before Mainpat Kamleshwarpur Chowk on the 3 km right side of the Ambikapur–Mainpat road. The altitude of the Ultapani village Visarpani Mainpat is 1085 m above sea level in the world map, latitude of the surface water source is located at 22^{0}52’52’’ N and longitude 83^{0}17’ 0’’ E. The water conduit starting from its source, called “Dhodhi” in local language, climbs itself to uphill of the slope of 45 ^{0} and travels a distance about 150 meters and after turns towards downhill. The people of this area called it a caricature of the nature. From the survey, we found that the groundwater level is very near to earth surface on the village Visarpani. In this area, there is a dense forest nearby, in some portion of the Mainpat large number of geographical changes are observed.

Fig.1 Location of Ultapani, Visarpani (Source: google map)

IV. MATERIAL AND METHODOLOGY

A. Materials

The Geo-physical investigation was carried out on **11/04/2019**. Using the following equipment acquired from department of physics, from Govt. SPM college Sitapur and Govt. R.G.P. G college Ambikapur, Surguja. In the research work, the Schlumberger method was adopted. The equipment used for the investigation are:

1. Voltmeter
2. Ammeter
3. Electrodes
4. Codes
5. Physical Balance

Fig.**2. At top of the hill - 06.01.2019**

Fig.3. Uphill conduit -11.04.2019

B. Methodology

In the Schlumberger method, the distance between the voltages probe is **a** and the distances from voltages probe and currents probe are **c**. Using the Schlumberger method, if **b** is small as compared to **a** and **c**, and **c**>**2a**, the apparent soil resistivity value is:

$$\rho_E = \pi \frac{c \cdot (c+a)}{a} R_S$$

where

ρ_E = measured apparent soil resistance (Ωm)

a = electrode spacing (m)

b = depth of the electrodes (m)

c = electrode spacing (m)

R_S = Schlumberger resistance measured as "V/I" in Figure (Ω)

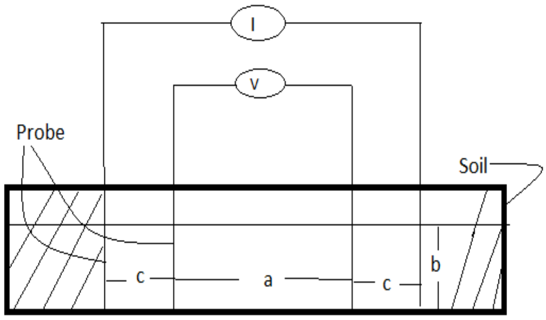

Fig.4. Measurement Technique

Six spot samples are marked on the Ultapani uphill water conduit surface in the interval of 30 m distance starting from its source “Dhodhi” to measure the resistivity, voltmeter probes and ammeter probes are kept as per schlumberger method.

C. Calculation

We used the schlumberger method to calculate the value of resistivity (ρ). In this method the distance between the voltmeter electrode is a, and the distance from voltmeter electrode and ammeter electrode are c

Resistivity of conduit surface soil (ρ) is –

$$\rho_E = \pi \frac{c \cdot (c+a)}{a} R_S$$

where,ρ - measured soil resistivity (Ωm)

a=0.15 m

b=0.10 m

c=0.35 m

The data obtained during the field study are below in Table II. We also calculated the density of soil in the field by taking the volume of soil.

Table II Calculated Resistance, Resistivity, Conductivity and Density at different intervals

S.No.	Spot Sample no.	Distance Interval	Schlumberger Resistance (R)	Resistivity (ρ)	Conductivity (σ)	Density (D)
1	1	0 (start point)	180	658.8	0.00151	1.024
2	2	30	165	608.9	0.00165	1.12
3	3	60	140	512.4	0.00195	1.32
4	4	90	125	457.5	0.00218	1.41
5	5	120	90	329.4	0.00303	1.52
6	6	150 (end point)	70	256.2	0.0039	1.65

V. RESULT AND INTERPRETATION

The results represent the classification of soil for different distance interval based on the calculated resistivity, conductivity and density in Table III, Table IV, and Table V. From the fig.5, it is also clear that soil is also affected by another parameter because a graph is not linear. The lowest resistivity **(ρ)** value find towards the uphill side of the conduit that represents soil belongs in the uphill side is the sandstone class and downhill side soil is the clayey sand.

From the electrical conductivity (σ) we also find out that soil is non saline because at every distance, conductivity value is less than one, and whenever a value is less than 1 soil is non saline. According to the British Standard BS-1377, a soil is slightly corrosive in this area because resistivity **(ρ)** value is greater than 100 Ωm. The density of the soil increases towards uphill which also described that soil is sandy at end of conduit. In this field study, we observed that at a distance of 150m, there is a noticeable variation in soil texture and matrix. This will give the chance of future study in the whole Mainpat area that has different hydro-geological conditions.

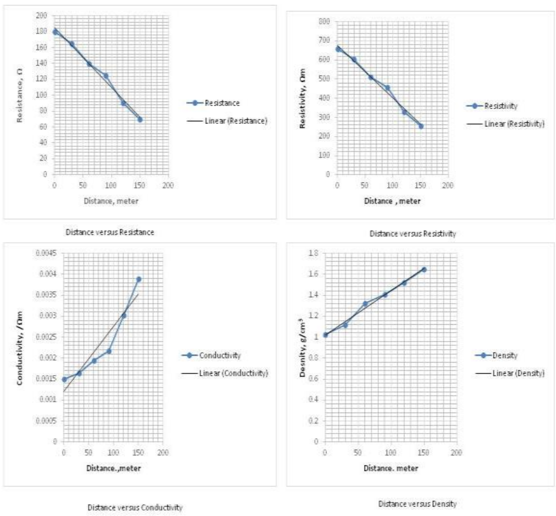

Fig.5.Resistance, Resistivity, Conductivity and Density

Table. III Soil classification according to Measured Resistivity

S.No.	Distance Interval	Resistivity (ρ)(Ωm)	Expected Formation
1	0 (start point)	658.80	Clayey sand
2	30	603.90	
3	60	512.4	Grass covered stony subsoil
4	90	457.5	
5	120	329.4	
6	150 (end point)	256.2	Sandstone

Table. IV Soil classification according to Measured Conductivity

S.No.	Distance Interval	Conductivity (σ(per Ωm)	Expected Formation
1	0 (start point)	0.00151	Non-saline Soil
2	30	0.00165	
3	60	0.00195	
4	90	0.00218	
5	120	0.00303	
6	150 (end point)	0.0039	

Table V Soil classification according to Measured Density

S.No.	Distance Interval	Density (D)(g/cm^3)	Expected Formation
1	0 (start point)	1.024	Colloidal clay
2	30	1.12	
3	60	1.32	Sand and silty clay
4	90	1.41	Silty clay with gravel
5	120	1.52	Well graded gravel/sand/silt/clay
6	150 (end point)	1.65	Loamy sand

VI. CONCLUSION

The method of investigation adopted in this study has helped in the classification of soil and has provided an understanding of characterization of soil according to their attribute and matrix. It correlates resistivity and conductivity with the soil matrix and along with the density that presents the classification and characterization of soil for the shorter interval of 30m. At this site, a different geological and hydro-geological environment requires an extensive research to understand the phenomenon of the water flow uphill side. Further study also needs an investigation for the different parameter of soil such as water content, saturation, bulk density, permeability and others soil classification parameter with laboratory measurements.

REFERENCES

1. Ghorbani, A., Cosenza, P., Badrzadeh, Y., & Ansari, A. (2012). Changes in the electrical resistivity of arid soils during oedometer testing. European Journal of Environmental and Civil Engineering, 17(2), 84–98. doi:10.1080/19648189.2012.747782.
2. K. F. E. (1979). L. A. Allaud & M. H. Martin 1977. Schlumberger. The History of a Technique. xxv 333 pp., 86 figs. New York, London: Wiley-Interscience. Price £16.00. ISBN 0 471 01667 5. Geological Magazine, 116(1), 73-73. doi:10.1017/S0016756800042102.
3. Kaufman, A. A., & Hoekstra, P. (2001). Electromagnetic soundings Elsevier Science B.V.
4. Kowalczyk S, Zawrzykraj P, Maślakowski M(2017): Application of the electrical resistivity method in assessing soil for the foundation of bridge structures: a case study from the Warsaw environs, Poland. Acta Geodyn. Geomater., 14, No. 2 (186), 221–234, 2017.DOI: 10.13168/AGG.2017.0005.
5. L. Sebastian Bryson , Evaluation of Geotechnical Parameters using Electrical Resistivity Measurements , Member, ASCE , Assistant Professor, Stocker Center 141, Department of Civil Engineering, Ohio University, Athens, OH 45701; PH (740) 593-1478; FAX (740) 593-0625; email: bryson@ohio.edu.
6. Palacky, G. (1988). 3. resistivity characteristics of geologic targets. Electromagnetic methods in applied geophysics (pp. 52-129) Society of Exploration Geophysicists.
7. Porsani, J. L., Elis, V. R., & Hiodo, F. Y. (2005). Geophysical investigations for the characterization of fractured rock aquifers in Itu, SE Brazil. Journal of Applied Geophysics, 57(2), 119–128. doi:10.1016/j.jappgeo.2004.10.005.
8. Piegari, E. and Di Maio, R.(2013) : Estimating soil suction from electrical resistivity, Nat. Hazards Earth Syst. Sci., 13, 2369-2379, https://doi.org/10.5194/nhess-13-2369-2013.
9. Romero-Ruiz, A., Linde, N., Keller, T., & Or, D. (2018). A review of geophysical methods for soil structure characterization. Reviews of Geophysics. doi:10.1029/2018rg00061.
10. McCarter, W. J. (1984). The electrical resistivity characteristics of compacted clays. Géotechnique, 34(2), 263–267. doi:10.1680/geot.1984.34.2.263.
11. Sudha, K., Israil, M., Mittal, S., & Rai, J. (2009). Soil characterization using electrical resistivity tomography and geotechnical investigations. Journal of Applied Geophysics, 67(1), 74–79. doi:10.1016/j.jappgeo.2008.09.012.
12. Seladji, S., Cosenza, P., Tabbagh, A., Ranger, J., & Richard, G. (2010). The effect of compaction on soil electrical resistivity: a laboratory investigation. European Journal of Soil Science, 61(6), 1043–1055. doi:10.1111/j.1365-2389.2010.01309.x.