Soil Profiling by using Electrical Resistivity Method

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Abstract - *Conventional identification of soil involves the collection of soil samples and conduction of various tests. Collection of soil sample may be disturbed soil sample or undisturbed soil sample. The identification of soil includes various tests. Conventional soil sampling process may be difficult during the difficult construction areas like steep and hilly terrain, coastal regions etc. Problems in the conventional method of soil identification and sampling can be overcome by using geophysical methods. Geophysical method includes seismic refraction method, electrical resistivity method, ground-penetrating radar, magnetic, etc. Electrical resistivity method works on the principal of Ohms law. It measures the resistivity of soil. Geophysical method of soil exploration is a faster method. Requires less cost and cover larger areas. The study area was JNNCE Campus, Savalanga Road, Navule, Shivamogga, Karnataka. Electrical Resistivity of a soil depends on the soil type, water content, density of soil and the composition of the soil. Schlumberger Array arrangement is symmetric, collinear and uses four electrodes. Results indicates that Soil resistivity values increases with depth. At deeper depth higher resistivity value obtained indicates that the presence of parental soil deposit. Higher resistivity values at deeper depth also indicates decreasing moisture content and increasing density of soil. The results indicates that Electrical resistivity method is also one of the powerful tool for identification of soil.*

Key Words: Electrical Resistivity1, Soil Resistivity2, Soil Classification3, Soil Profiling4, Subsurface5 etc

1.INTRODUCTION

Conventional identification of soil involves the collection of soil samples and conduction of various tests. Collection of soil sample may be disturbed soil sample or undisturbed soil sample. The identification of soil includes various tests like Sieve analysis, Atterberg Limits, etc. Conventional methods give very accurate results, but these are time consuming. Conventional soil sampling process may be difficult during the difficult construction areas like steep and hilly terrain, coastal regions etc. Difficult construction areas require a greater number of samples and high accuracy of sampling. In these cases, soil identification processes were costly and time consuming. These problems in the conventional method of soil identification and sampling can be overcome by using geophysical methods. Geophysical method includes seismic refraction method, electrical resistivity method, ground-penetrating radar, magnetic, etc. Now a days geophysical method of soil exploration increases because it gives the results of subsurface investigation over large areas. Electrical resistivity method works on the principal of Ohms law. It measures the resistivity of soil. Geophysical method of soil exploration is a faster method. Requires less cost and cover larger areas.

2. Literature Review

1. Mohd Hazreek Bin Zainal Abidin et. al., (2013) as conducted test on The Influence of Soil Moisture Content and Grain Size Characteristics on its field Electrical Resistivity. The study presents a demonstration of the influence of soil moisture content and grain size characteristics to field resistivity data as much desired for ERM verification. 2D ERM was performed using a set of ABEM (SAS) 4000 based on pole-dipole array. Three soil samples from locations lying along a survey line were collected immediately for moisture content and particle size distribution test according to BS 1377 (1990) Laboratory geotechnical tests strongly indicated that the electrical resistivity data can varied with the moisture content and grain size character. Soil electrical resistivity values decreased with increasing moisture content and fines content. The correlations established between the above parameters in this study, help to strongly ratify the field ERM data and thus contribute to a meaningful ERM interpretation. (Mohd Hazreek Bin Zainal Abidin, 2013)

2. Z A M Hazreek et. al., (2015) as conducted test on soil identification using Field Electrical Resistivity Method. The study performed a field electrical resistivity method (ERM) using ABEM SAS (4000) at two different types of soils (Gravelly SAND and Silty SAND) to discover the behavior of electrical resistivity values (ERV) with type of soils studied. Soil basic physical properties were determined through density (ρ), moisture content (w) and particle size distribution (d) to verify the ERV obtained from each type of soil investigated. It was found that the ERV of Gravelly SAND (278 Ωm & 285 Ωm) was slightly higher than Silty SAND (223 Ωm & 199 Ωm) due to the uncertainty nature of soils. This finding has shown that the results obtained from ERM need to be interpreted based on strong supported findings such as using direct test from soil laboratory data. Furthermore, this study was able to prove that the ERM can be established as an alternative tool in soil identification provided it was being verified through other relevance information such as using geotechnical properties. (Z. A. M. Hazreek, 2015)

3. Ibrahim Adewuyi and Falae Philips (2018) as conducted test on Integrated geophysical and Geotechnical Methods for Pre-Foundation Investigations. An integrated geophysical and geotechnical investigation for a proposed building foundation

of an industrial plant layout was carried out to determine the competency of the subsoil as foundation materials. Electrical Resistivity Imaging (ERI) and soil analyses techniques were adopted. Two traverses of four Vertical Electrical Sounding (VES) points were carried out and 8 Boreholes for Standard Penetration Test (SPT) were drilled. In addition, soil samples were taken at 1.5 m and 10 m depths and subjected to various laboratory analyses. Three geoelectric layers were delineated from VES including topsoil, saturated sandy clay soil and limestone. The SPT N value indicates that the relative density of the soils is medium dense to very dense while the result of the geotechnical analyses shows that maximum dry density of the soils range from 1680-1900 kg/m3 and 1600-1850 kg/m3 respectively at 1.5 m and 10 m while the optimum moisture content range from 14-19% and 13-19% respectively at1.5 m and 10 m. The soils are silty sand with low plasticity deputing low to medium swelling potential. Conclusively, the subsurface on which the foundation of the industrial structures will be located within the study area is safe and fairly competent for any engineering work. Owning to the water lodge nature of the area it is advice that the building should rest on pill between 5 m and 10 m depth. (Falae, 2018)

3. METHODOLOGY

3.1 Study Area

The study area was JNNCE Campus, Savalanga Road, Navule, Shivamogga, Karnataka. The study area is covered under longitude: E 75°34'42" -E 75°34'38", latitude: N 13°58'6" - N 13°58'9" and elevation 610m from Mean Sea Level.

3.2 Electrical Resistivity Method

Electrical Resistivity of a soil depends on the soil type, water content, density of soil and the composition of the soil. Electrical resitivity method requires four electrodes. These electrodes are driven in the ground in a straight line. The spacing between the electrodes depends on the depth of investigation. Generally the four electrodes are placed at a equal distance apart. A current is passed between the two outer electrodes and the potential drop between the inner electrodes is measured by the use of a potentiometer. The test is done by driving four electrodes into the ground along a straight line at equal distances. This is shown in the figure 1.

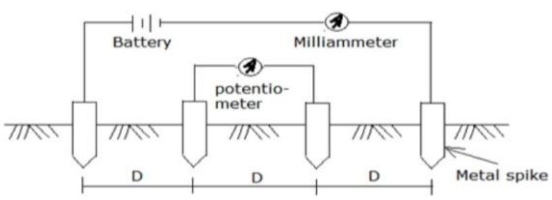

Fig.1: Electrical Resistivity Method

$$\rho = \frac{2\pi DE}{I}$$

$$\rho = 2\pi DR$$

Where ρ = Mean Resistivity (ohm-cm)
D = distance between the electrodes (cm)
E= potential drop between outer electrodes (volts)
I= current flowing between outer electrodes (amperes)
R= resistance (ohms)

3.3 Schlumberger Array:

Schlumberger Array arrangement is symmetric, collinear arrangement. Four electrodes are used in this arrangement. Current electrodes are denoted as A and B and potential electrodes are denoted by M and N. Distance between M and N is denoted by 'a' and the distance between A and B is denoted by '2S'. The Schlemberger Array arrangement is shown in figure 2. The distance between current electrodes should be greater than five times distance between potential electrodes (AB>5MN). The apparent resistivity is given by

$$\rho_a = \frac{\pi\left(\frac{S^2 - a^2}{4}\right)}{a}\frac{\Delta V}{I}$$

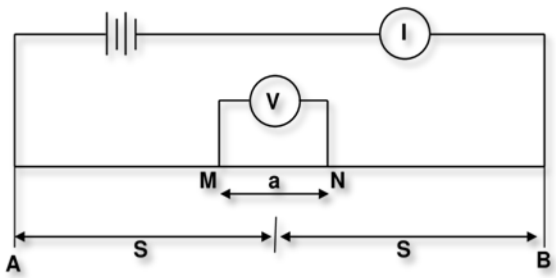

Fig.2: Schlumberger Array

where, ΔV is the potential drop and

I is the applied current.

4. Result & Discussion

The soil resistivity data were interpreted by using quantitative method based on curve matching method and computerized interpretation methods. The soil resistivity of all the four lines is summarized in table 1.

From the table 1 , it can be interpreted that the soil layers are made up of different types of soil represented in the form of resistivity values. It can be observed that the resistivity in the topsoil layer ranges between 45.913 Ωm to 428.387 Ωm between 0.75m to 1.5m. This indicates that up to 1.5m may be filled up soil.

Table -1: Soil Resistivity of I, II, III and IV Line

MN/2	AB/2	I Line	II Line	III Line	IV Line
		ρa=K*R (Ohm-m)	ρa=K*R (Ohm-m)	ρa=K*R (Ohm-m)	ρa=K*R (Ohm-m)
0.5	1.5	280.35	372.623	523.796	77.671
0.5	2	113.91	251.219	342.476	46.688
0.5	3	278.788	97.206	100.174	36.762
0.5	4	150.738	54.895	44.806	37.339
1	4	186.28	62.813	108.283	37.799
1	6	119.351	56.378	154.519	51.433
1	8	111.669	69.929	90.799	61.027
1	10	182.008	81.911	287.856	68.389
2	10	143.41	81.313	78.676	66.241
2	15	217.723	126.817	136.88	103.224
2	20	284.126	177.501	155.43	148.28
5	20	240.681	169.677	220.193	140.24
5	25	257.354	239.833	231.544	137.344
5	30	374.209	297.829	242.055	401.685
5	35	304.454	289.382	431.813	427.668
5	40	416.905	321.952	306.621	348.658
5	45	424.5	410.084	445.88	472.884
5	50	428.387	409.558	482.61	338.837

Table -2: Soil Resistivity values of different soils with different colours (Hoekstra, 2001)

Soil Type	Soil classification	Resistivity (Ohm-m)	Color Notations
CLAY	CH	10-50	
	CL	24-60	
	OL	26.5-75	
SILT	ML	26.5-72.5	
	SC	46.5-178	
	MH	71.5-240	
SAND	SM	96-452.5	
GRAVEL	GW	563-918	
	GC	129-405	
	GP	915-2332.5	

The table 2 represents the color code given for the different types of soil.

Table 3 indicates the Resistivity of soil and soil classification of I Line. Table 3 indicates soil resistivity ranges from 113.91 Ωm to 428.387 Ωm. Up to 3m depth resistivity values are changing in a very irregular pattern indicates the filled-up soil. Then from 4m depth resistivity values increasing linearly indicates natural soil deposit. Intermediate layer moderate resistivity of 120 Ωm to 240 Ωm indicates the mixer of sandy soil. For deeper depth resistivity values are increasing up to a 428.38 Ωm at a depth of 50m. Deeper depth of soil profiling indicates the Sandy soil with a mixer of silt.

Table -3: Resistivity of soil and soil classification of I Line

MN/2 (m)	AB/2 (m)	I Line ρa=K*R (Ohm-m)	Soil Classification			
0.5	1.5	280.35				GC
0.5	2	113.91	SC	MH		
0.5	3	278.788				
0.5	4	150.738	SC			GC
1	4	186.28				
1	6	119.351	SC			
1	8	111.669		MH		
1	10	182.008				
2	10	143.41	SC		SM	
2	15	217.723				
2	20	284.126				GC
5	20	240.681				
5	25	257.354				
5	30	374.209				
5	35	304.454				
5	40	416.905				
5	45	424.5				
5	50	428.387				

Table -4: Resistivity of soil and soil classification of II Line

MN/2	AB/2	II Line ρa=K*R (Ohm-m)	Soil Classification			
0.5	1.5	372.623	GC			
0.5	2	251.219				SM
0.5	3	97.206		MH		
0.5	4	54.895				
1	4	62.813				
1	6	56.378	OL	ML		
1	8	69.929				
1	10	81.911			SC	
2	10	81.313				
2	15	126.817				
2	20	177.501		MH		
5	20	169.677	GC			SM

5	25	239.833				
5	30	297.829				
5	35	289.382				
5	40	321.952				
5	45	410.084				
5	50	409.558				

Table 4 indicates the Resistivity of soil and soil classification of II Line. Table 4 indicates soil resistivity ranges from 54.895Ωm and 410.084 Ωm. soil resistivity of line II also shows up to 3m depth resistivity values are changing in a very irregular pattern indicates the filled-up soil. Then from 4m depth resistivity values increasing linearly indicates natural soil deposit. From 4m t 25m indicates a resistivity value of 54.895Ωm to 239.833Ωm indicates silt or sandy soil. From 25m depth resistivity value increases from 239.833Ωm to 409.558Ωm indicates sandy soil with a mixer of clay or silt.

Table -5: Resistivity of soil and soil classification of III Line

MN/2	AB/2	III Line				
		ρ_a=K*R (Ohm-m)	Soil Classification			
0.5	1.5	523.796				
0.5	2	342.476	GC			SM
0.5	3	100.174			SC	
0.5	4	44.806	OL	ML		
1	4	108.283				SM
1	6	154.519		MH	SC	
1	8	90.799				
1	10	287.856	GC			SM
2	10	78.676				
2	15	136.88			SC	
2	20	155.43		MH		
5	20	220.193	GC			
5	25	231.544				
5	30	242.055				SM
5	35	431.813				
5	40	306.621	GC			
5	45	445.88				
5	50	482.61				

Table 5 indicates the Resistivity of soil and soil classification of III Line. Table 5 indicates soil resistivity ranges 44.806 Ωm to 523.796 Ωm. soil resistivity of line III shows higher resistivity values in the top layer. Indicates the filled-up soil with mixer of fine and coarse soil. From deeper depth resistivity values increase in a linear pattern. Resistivity values of deeper depth indicate sandy soil with a mixer of silt.

Table 6 indicates the Resistivity of soil and soil classification of IV Line. Table 6 indicates soil resistivity ranges 36.762 Ωm to 472.884 Ωm. Soil resistivity of line IV shows higher resistivity values in the top layer up to 2m. Indicates filled-up up soil with mixer of silt and sandy soil. From 3m depth resistivity value increases with the depth. This indicates the deposition of natural soil from 3m depth. Up to 10m depth resistivity value indicates the silty sand or sandy clay. From 10m depth resistivity values increased and it indicates sandy clay or sandy silt.

Table -6: Resistivity of soil and soil classification of IV Line

MN/2	AB/2	IV Line				
		ρ_a=K*R (Ohm-m)	Soil Classification			
0.5	1.5	77.671	MH			SC
0.5	2	46.688				
0.5	3	36.762	CH			
0.5	4	37.339				
1	4	37.799		OL	ML	
1	6	51.433	CL			
1	8	61.027				
1	10	68.389				
2	10	66.241				SC
2	15	103.224				
2	20	148.28	MH			
5	20	140.24			GC	
5	25	137.344		SM		
5	30	401.685				
5	35	427.668				
5	40	348.658			GC	
5	45	472.884				
5	50	338.837		SM	GC	

Table 7 indicates generalized soil profiling for all the 4 lines.

Table -7: Sub soil Stratification and Zone of soil

Depth (m)	Resistivity (Ωm)	Probable Soil classification	Remarks
0 - 1.5	45 - 428	Sand / Gravel	Filled up soil
2 - 10	50 - 180	Silty Sand / Clayey Silt	Natural Weathered soil
10 - 20	150 - 240	Silty Sand	
20 - 50	240 - 472	Gravelly Sand	Natural Soil

3. CONCLUSIONS

The following are the conclusions drawn from the electrical resistivity test

• The top layers approximately up to 2m depth indicate resistivity values are changing very abruptly indicates the filled up soil.

- The middle layer approximately 2 to 10m depth indicates resistivity values increases with depth indicates the natural soil deposit. Based on obtained resistivity values it may be concluded that silty or clay soil with a mixer of sandy soil.
- For deeper depth resistivity value increases with the depth indicates sandy soil or gravelly soil. This indicates the natural parental soil deposit with higher resistivity values.
- Higher resistivity values at deeper depth also indicate decreasing moisture content and increasing density of soil.

The results indicate that Electrical resistivity method is also one of the powerful tool for identification of soil.

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