ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com
International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 3, Special Issue 23, April 2016

# ELECTRICAL RESISTIVITY-A TOOL FOR MEASURE THE GEOTECHNICAL PROPERTIES OF SOIL SAMPLES

**E.M.Anju**, PG Scholar(Geotechnical Engineering), IES College of Engineering,Thrissur,hima.495@gmail.com

**M.N Sandeep**, Assistant Professor, IES College of Engineering, Thrissur, sandheepmn@gmail.com

**ABSTRACT:** Electrical resistivity measurement is time and cost effective and is a non-destructive method. By knowing the electrical resistivity we can predict the geotechnical properties without taking samples and without making bore holes. Preliminary objective of the study was to predict the geotechnical parameters in the field by using electrical resistivity of the soil. The electrical resistivity of soil can be correlated to the geotechnical properties of soil such as density, water content, unconfined compressive strength etc. Experiments were performed on clay collected from Coimbatore. A series of tests were conducted at different water contents and dry densities and electrical resistivity of soil samples were determined. Also tests were conducted to verify the measured electrical resistivity of soil samples with field condition. From the results it was found that the electrical resistivity value of soil is almost the same for both test conditions. Unconfined compressive strength tests were also conducted for the soil at different dry densities and water content. A programme was developed by using MATLAB to determine the density and water directly from the resistivity value. Knowing the value from MATLAB using the resistivity unconfined compressive strength curve can correlate the electrical resistivity with unconfined compression strength.

## INTRODUCTION (10 PT BOLD CAPS)

Geophysical soil investigations are indirect methods of soil exploration based on the variation of electrical, magnetic or seismic refraction properties of soil and rock which vary at different conditions. It can be effectively utilised to obtain information about subsurface conditions at preliminary stages of soil investigation which will be useful in the proper planning of a detailed soil investigation. Also geophysical methods are resorted in places where conventional soil investigation is difficult such as soil exploration below existing structures. In comparison to conventional methods, geophysical methods are cost effective and quick. Geophysical surveying techniques provide a toolbox of rapid, discrete and cost effective methods for the location and identification of subsurface features. Geophysical exploration has the advantage to locate boundaries between different elements of the subsoil as these procedures are based on the fact that the gravitational, magnetic, electrical, radioactive or elastic properties of the different elements of the subsoil may be different.

Electrical resistivity of the soil can be considered as an indirect method to study the spatial and temporal variability of soil physical properties. As the method is non-destructive and very sensitive, it offers a very attractive tool for describing the subsurface properties without digging. It has been already applied in various contexts like groundwater exploration, landfill and solute transfer delineation, agronomical management by identifying areas of excessive compaction or soil horizon thickness and bedrock depth, and at least assessing the soil hydrological properties. Electrical resistivity helps to give more idea about the soil properties. Electrical resistivity method is based on the difference in the electrical conductivity or the electrical resistivity of different soils. The electrical resistivity of soil can be correlated to the geotechnical properties of soil such as density, water content, unconfined compressive strength etc.

## MATERIALS USED

### Soil

Soil was collected from Coimbatore at an average depth of 2m from the surface. The soil collected was disturbed samples. The soil was initially air dried in open atmosphere prior to the testing.

### Experimental Setup

Figure 1 shows the test set up. An apparatus was constructed for measuring the electrical resistivity of the soil. A cylinder of length 10cm and diameter 5cm was used to prepare the mould.The cylinder was constructed using poly vinyl chloride (PVC), which is an electrical insulator (electrical resistivity $1\times10^{16}\Omega$-cm).The mould filled with soil at different dry density and water content was connected to the alternating current source (AC) of 230V, frequency 50 HZ. To regulate the voltage, the source is directly connected to a step down transformer with varying voltage between 0-200V. A voltmeter of accuracy 10V is connected in parallel to the cylindrical mould. An ammeter of accuracy 0.000001A is connected in series to the specimen. AC is used because application of direct current (DC) results in electro kinetic

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com
International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 3, Special Issue 23, April 2016

phenomena that can cause change in water content, soil structure and pore fluid chemistry (S.Zeyad et al.(1996).

A potential difference 10V was applied between the copper electrodes at both the ends of the cylindrical mould filled with soil. Copper electrodes of diameter 5 cm and thickness 2mm were used.

**Fig. 1 Test setup**

The mould was filled with soil at different condition depending on the density and water content using a tamper. The current flowing through the specimen for each voltage increment was measured from the ammeter. Electrical resistance R is then computed using ohm's law. And from the electrical resistance, electrical resistivity was calculated.

**Wenner Arrangement**

Wenner four electrodes array was used to measure the electrical resistivity from the field condition. Field condition was created in a test tank made up of glass (39cm x 39xm x 70cm). This was done to check the relation between the resistivity found by using the cylindrical mould and the resistivity in the field.

Soil was filled at a known depth, water content up to 8.5cm high and 4 electrodes of diameter 4mm and length 13 cm spaced at varying distance .The inner potential electrode was connected to the volt meter and outer current electrode was connected to the ammeter. An AC source of same accuracy is used to measure the resistivity of the sample in the mould as shown in figure 2.

**Fig. 2 Test setup –wenner array**

Soil resistivity measured in single layer of soil .

## RESULTS AND DISCUSSIONS

### Soil Properties

Properties of soil is given in table 1.

**Table 1** Properties of soil

| Properties | Values |
|---|---|
| Specific Gravity,G | 2.54 |
| Liguid Limit,WL(%) | 61.00 |
| Plastic Limit,WP(%) | 30.00 |
| Shrinkage Limit,WS | 15.00 |
| Plasticity Index,IP | 31.00 |
| Clay(%) | 11 |
| Silt(%) | 55 |
| Sand(%) | 34 |
| Soil Type | CH |
| Optimum Moisture Content (%) | 19.8 |
| Maximum Dry Density(kN/$m^3$) | 17.86 |
| Unconfined compressive strength (KN/$m^2$) | 58 |

## ELECTRICAL RESISTIVITY OF SOIL

### Variation of Electrical Resistivity with Density

Figure 3 shows the variation of electrical resistivity with density. Study was carried out under 1.3g/$cm^3$,1.4g/$cm^3$,1.5g/$cm^3$,1.6g/$cm^3$,1.7g/$cm^3$ and 1.78g/$cm^3$. Resistivity was measured for the water content 5%,10%,15%,20%,30%,40%, and 50% at different density.

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com
International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 3, Special Issue 23, April 2016

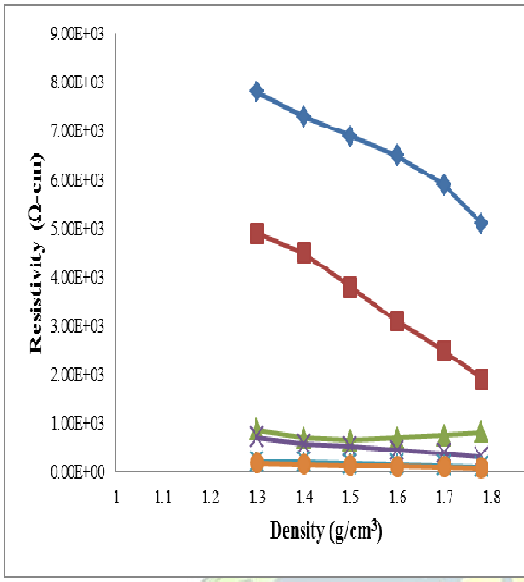


**Fig. 3 Variation of electrical resistivity with density at constant water content**

First line indicates the variation of electrical resistivity for 5% water content at density 1.3g/cm$^3$,1.4g/cm$^3$,1.5g/cm$^3$,1.6g/cm$^3$,1.7g/cm$^3$ and 1.78g/cm$^3$. Test was repeated for 5 different water contents. From the first line, for 5% water content resistivity various from 7.8 x $10^3$ Ω-cm to 5 × $10^3$ Ω-cm. The variation of electrical resistivity is less with the change in density. In all cases, increase in density leads to decrease in resistivity. But combining the 5% line and 10% line, the resistivity variation is very high and from that it is clear that water content has more influence on resistivity than density
.

**Variation of electrical resistivity with moisture content**

Figure 4 shows the variation of electrical resistivity with water content. Water content is varied for density 1.3g/cm$^3$ to 1.78 g/cm$^3$ and corresponding resistivity was noted down. Electrical resistivity decreases with increase in water content. Up to 20% water content the rate of decrease of electrical resistivity is high. After 20% water content, it is nearly equal to its shrinkage limit. Reaching shrinkage limit most of the voids are filled with water. After that the conduction remains almost in a uniform manner. In soil the electrical charge move through two paths. One is through the path of the water and other is through the surface of the clay. As a result increase in water content causes decrease the soil resistivity.

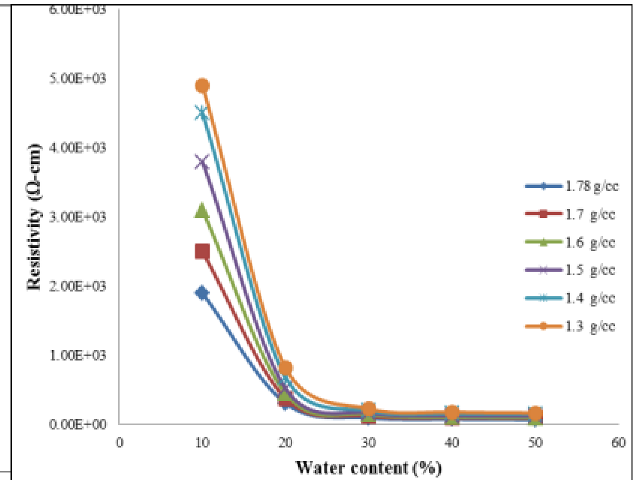


**Fig. 4 Variation of electrical resistivity with moisture content at constant density**

**ELECTRICAL RESISTIVITY AND UNCONFINED COMPRESSIVE STRENGTH**

Figure 5 show the variation of electrical resistivity and uniform compressive strength (UCC) for different density at different water content. Unconfined compressive strength and electrical resistivity of the same sample were measured. It is related using the graph. Figures show the relation of electrical resistivity and UCC for different densities.

Graph of electrical resistivity and UCC strength of different densities were drawn. If know the electrical resistivity from the previous graph we can calculate the water content density. If we know the density then using these graphs we can get the UCC strength.

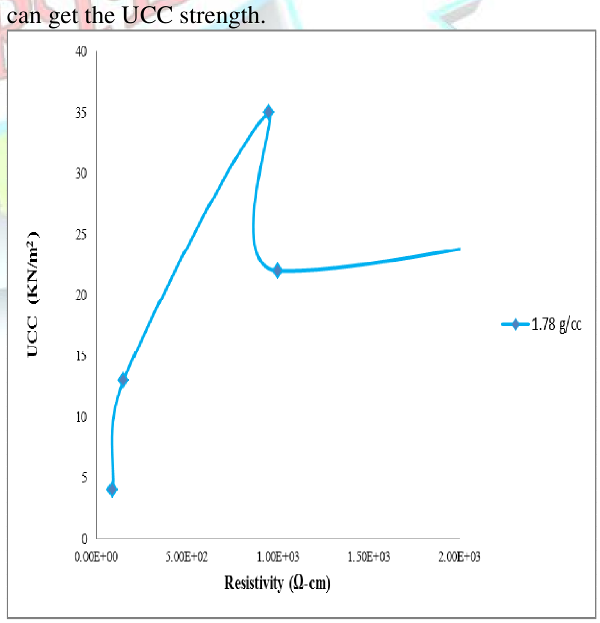


**Fig. 5 Variation of electrical resistivity with unconfined compressive strength**

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com
International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 3, Special Issue 23, April 2016

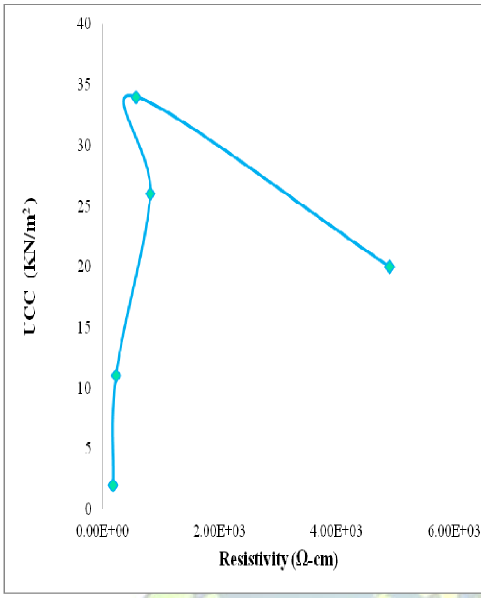


**Fig. 6 Variation of electrical resistivity with unconfined compressive strength**

## ELECTRICAL RESISTIVITY FROM THE FIELD SETUP

Wenner array was used to check the field condition. This was done to check whether the obtained value from the cylindrical sample is the same as the obtained value from the field set up. This was done in three stages. First experiment was done with single layer of soil by using soil 1 and soil 2. Then the same was done with double layer of soil.

In first case the tank was filled with 1.2g/cm$^3$ density and 20% water content up to 8.5 cm height. After leveling three electrodes were inserted with equal spacing. Spacing was varied and corresponding voltmeter and ammeter reading were noted and from that resistivity was calculated.

Figure 6 shows the resistivity obtained for 1.5cm, 3cm, 4.5 cm and 6cm spacing. Graph showing electrical resistivity obtained from field setup. Spacing difference does not affect the electrical resistivity. The spacing distance gives the depth of the layer for a particular resistivity.

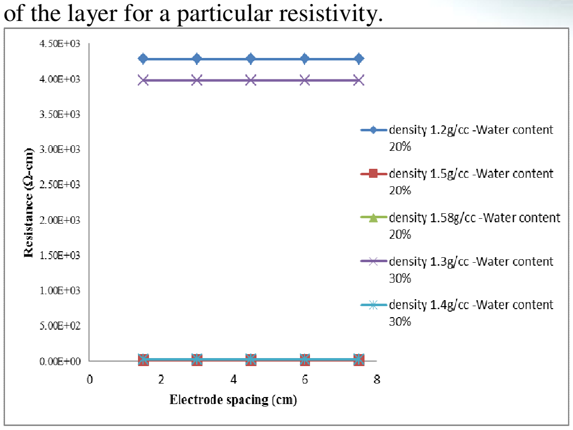


**Fig. 6 Variation of electrical resistivity with spacing of electrode**

Table 2 shows the electrical resistivity obtained from the test setup and field measurement of single layer of soil 1. Resistivity obtained from both the cases are almost the having same value. Resistivity value obtained from the cylindrical sample measurement is a good tool for correlating with the field electrical resistivity.

**Table 2** Comparison of the resistivity value –soil 2 –single layer

| Sl No | Density | Water content | Resistivity from measured sample | Resistivity From field setup |
|---|---|---|---|---|
| | g/cm$^3$ | % | Ω-cm | Ω-cm |
| 1 | 1.5 | 5 | 3.98E+03 | 3.80E+03 |
| 2 | 1.5 | 30 | 2.30E+01 | 2.20E+01 |
| 3 | 1.4 | 10 | 4.20E+03 | 4.30E+03 |

## PROGRAMME USING MATLAB FOR DIRECT MEASUREMENT OF DENSITY AND RESISTIVITY

From previous discussion it is clear that a unique relation exists between electrical resistivity, density and water content. Electrical resistivity of soils obtained from the laboratory measurement and the values obtained from the field setup almost have the equal value. So the electrical resistivity obtained from laboratory can be used as reference value. Graphs give a pattern of variation of electrical resistivity with different parameters. A programme was developed to find the value directly using the Matlab. In this programme if we are giving the resistivity value as input, then get water contentment and density get as output value.

In the programme resistivity of soil was defined by X while Y and Z defining the density and water content respectively. Looping was formed in between the X,Y and Z variables. From the preliminary studies of resistivity of soil at different conditions, a relation was formed between the variables. The same procedure was done in the case of both soils. Different steps are given below.

**Step 1**: Defined the function
**Step 2**: Defined (X,Y,Z) ;X is the resistance in Ω-m
Y is the density in g/cc
Z is the water content in %

**Step 3**: Defined the relation between X,Y

**Step 4**:After getting value of y ,relation defined between x ,y and z
**Step 5**: Run the programme

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com
International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 3, Special Issue 23, April 2016

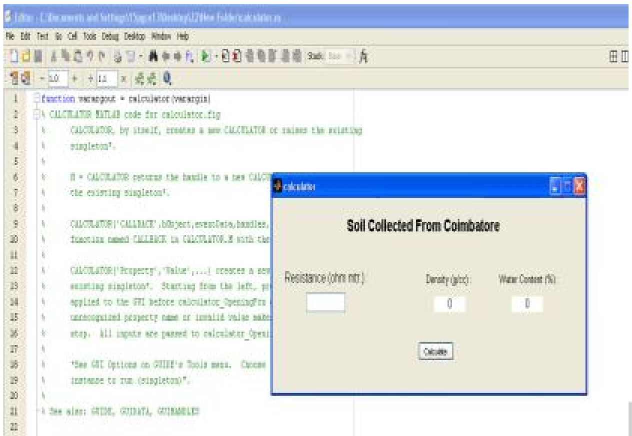


**Fig. 7 Opening window**

**Step 6**: Input the resistance value in Ω-m

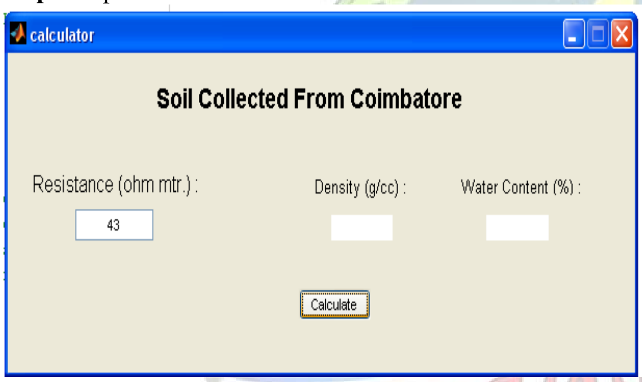


**Fig. 48 Input window**

**Step 6**:Get the out put value of density in g/cc and water content in %

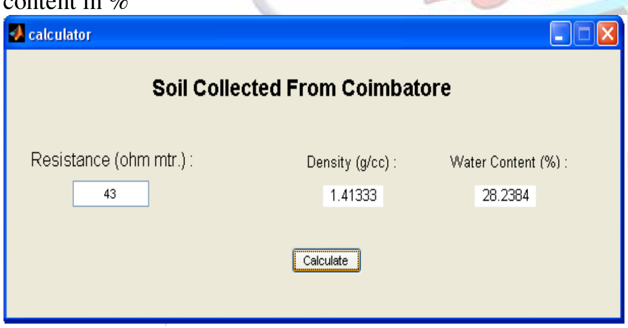


**Fig. 9 Out put window**

Electrical resistivity of soil and unconfined compressive strength gives a graphical relation. If we are getting the density value directly from the programme then with the help of graphical representation we can predict the range of unconfined compressive strength.

**UNCONFINED COMPRESSIVE STRENGTH CALCULATION FROM RESISTIVITY VALUE**

**Step 1:** Enter the value of resistivity in the input window The obtained resistivity of the soil is 58 Ω-m. Entered the value in the input window.

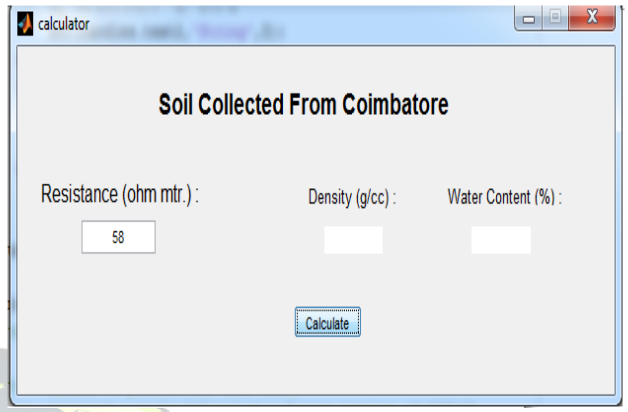


**Fig. 10 Out put window**

Obtained the density and water content corresponding to the given resistivity is nearly 1.7 g/cc and 21% respectively.

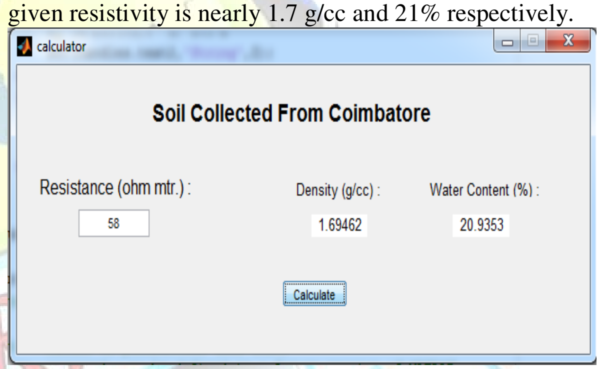


**Fig. 11 Output window**

**Step:2** Select the unconfined compressive strength corresponding to 1.7g/cc density.

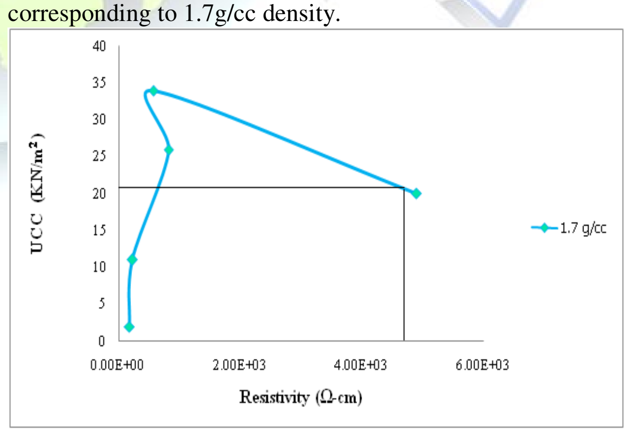


**Fig. 12 Variation of electrical resistivity with unconfined compressive strength**

For 58 Ω-m the unconfined compressive strength obtained for 1.7 g/cc density is 21KN/$m^2$. The value obtained from the experiment is 19.8KN/$m^2$. These two values are almost the same. So using this method, we can find the nearby unconfined value from the resistivity value.

**CONCLUSIONS**

The electrical resistivity of Coimbatore soil varied from 1.7E1Ω-cm to 2.48E3Ω-cm. At constant density the electrical resistivity of soils decreased with increase in water content .The rate of decrease in electrical resistivity is high till the shrinkage limit is reached and after that it almost remains the same. The decrease in electrical resistivity is due to the increase in electrolytic conduction at high water contents. The variation of electrical resistivity is less with the change in density of soil at constant water content. In all causes increasing density lead to decrease in resistivity.This is due to the better packing of soil particles and lower void ratio which results in better conducton.To validate and verify the electrical resistivity of soil found form cylindrical samples, tests were conducted in test tank to simulate field condition. For both the conditions the soil resistivity was found to be same for the two soils. This indicates the electrical resistivity obtained from the laboratory can be used as reference value to represent field condition. Programme developed using MATLAB is a good tool to predict the soil property.

**REFERENCES**

1. Abuzeid,M. M., Hassan,A.M., and Hassouna,A.F. (2014), Evalouation of expansive soil properties by electrical resistivity,*Journal of Engineering,IJMER* ,6(4), 2249–6645
2. M.H Ahmad,F., Bin Zainal Abidin, Saad ,R., and Wijeyesekera,D.C. (2014), The influence of soil moisture content and grain size characteristics on its field electrical resistivity, *EJGE,*Vol 18 ,Pg 699-705
3. Kalinski, R.J., and Kelly,W.K. (1994),Electrical-resistivity measurements fo evaluating compacted-soil Liners,*Journal of Geotechnical Engineering, ASCE*,120(2), 451-457
4. Shevnin, V., Mousatov,A., Ryjov,A., and Rodriquez,O.D. (2007), Estimation of clay content in soil based on resistivity modeling and laboratory measurements, *Geophysical Prospecting ,Vol* 55, 265–275
5. Skaggs, T.H. (2011), Assessment of Critical Path Analyses of the Relationship Betwee Permeability and Electrical Conductivity of Pore Networks.*Science Direct*,Vol 34,1335-13
6. M.H Ahmad,F., Bin Zainal Abidin, Saad ,R., and Wijeyesekera,D.C. (2014), the influence of soil moisture content and grain size characteristics on its field electrical resistivity, *EJGE,*Vol 18 ,Pg 699-705
7. Zamri, C., and Taohidul,S.M. (2012), Finding Soil Particle Size through Electrical Resistivity in Soil Site Investigations, *EJECE, Vol.* 17,1867-1876