GEOTECHNICAL AND ELECTRICAL RESISTIVITY STUDIES OF BASEMENT COMPLEX AREA OF ILOKO AREA, NIGERIA

ADIELA, U.P, [1]. AYODELE, MOSES OYEWOLE [2]
[1] Department of Petroleum Engineering, Nigerian Agip Oil Company, Port Harcourt
[2]Department of Geology, University of Port Harcourt, Port Harcourt, Nigeria
Email - omoboriowo.adedayo@fupre.edu.ng

Abstract: *Electrical resistivity survey involving both micro-resistivity and Vertical Electrical Sounding (VES) measurements was carried out at Iloko. This was to enable the generation of empirical equation relating the electrical resistivity with engineering parameters. The micro-resistivity measurements obtained down the hole and the VES interpretation results were plotted against each of the engineering parameters (Coefficient of Permeability, Consolidation and Compressibility, Liquid limit, Moisture content, Plasticity index, and Dry density).*
The results show that only few of the engineering parameters (Coefficient of Permeability and Consolidation) display non-linear relationship with (VES) electrical resistivity. Both the Coefficient of Permeability and Consolidation decreases with increase in electrical resistivity. The relevant empirical formulae were subsequently generated.

Key Words: *electrical resistivity, schiumberger array, geo-electrical, vertical electrical sounding (VES)*

1. INTRODUCTION

The engineering properties of soil and rock are useful in designing foundation under static loading. Hydraulic characteristic of subsurface aquifers are important properties for both groundwater and contaminated land assessments, and also for safe construction of civil engineering structures. Properties of particular interest to the foundation engineer include compaction, permeability, consolidation-swell, shear strength, stress-strain modulus and poison's ratio.

In addition, hydraulic conductivity/permeability (K), transmissivity (T), and storativity (S) are all commonly applied hydraulic parameters in flow modeling (Freeze and cherry, 1979; Fitts, 2002). Application of field hydrogeological methods of assessment is a standard technique for evaluating engineering parameter such as permeability (K), storativity (S), compressibility (My), transmissivity (T), consolidation(C) and shear stress (a).
Therefore, in this context, there is an attempt to generate empirical formulae that relate engineering parameters and electrical resistivity, which can provide rapid and effective technique for site foundation investigation and aquifer evaluation.

2. LOCATION AREA:

The survey area is located at lioko in Oriade Local government Area of Osun State.. The area lies between longitudes 7 038 50' and 7 038' 57" and latitudes 4 048'57"and 4. °49' 02".. The area is accessible through good roads and footpath networks to most of the area studied.

3. OBJECTIVES OF SURVEY:

The main objective of this study is to generate empirical formulae between electrical resistivity and engineering parameters. Others include.

- To delineate the subsurface layers and determine their resistivities and thicknesses
- To evaluate the competence of the near surface soil on which engineering foundation is expected to be founded.

4. METHODS OF STUDY:

The engineering parameters (coefficient of permeability, consolidation, and compressibility, liquid limit, moisture content, plasticity index, specific gravity) that were used in the survey area. Using Wenner and Schlumberger arrays, micro-resistivity measurements were obtained down the hole. Data were presented as profiles and different lithologic boundaries were identified.

For vertical electrical sounding, schlumberger array was adopted. Five VES points were occupied and quantitatively interpreted by a method involving partial curve matching.

The VES interpretation results were later plotted against engineering parameters at specific depth. These were used to generate the empirical formulae between electrical resistivity and engineering parameter.

5. BASIC PRINCIPLE:

The electrical resistivity method measures the bulk resistivity of the substance to determine geologic structure and physical properties of geological materials. An electrical current is introduced directly into the ground through current electrodes. The current and the potential electrodes are generally linearly.

The bulk resistivity of the soil is a function of both the resistivity of the pore fluid and the soil particles with their arrangements. Electrical measurements indicate not only the changes in the electrical properties of the soil and pore fluid due to the amount of total dissolved soils in the pore fluid, or the fluid conductance; but also due to the changes of soil type, or surface conductance (Weller *et al*. 1991).The two most important though related parameters in the electrical resistivity methods are the conductivity (a) and the resistivity (p).

$\sigma = 1/p$ (3)

Where a = conductivity which is siemens per meter (s/m).

ρ = Resistivity in ohm-meter (R-m)

The large contrast in resistivity between ore bodies and their host rock is exploited in electrical resistivity prospecting, especially for minerals that occur as good conductor. Approximate range of resistivity values of common rock types

6. DATA ACQUISITION AND PRESENTATION:

6.1 FIELD PROCEDURE

The electrical resistivity data ware acquired using ABEM SMS — 300 Terrameter and SAS —2000 Booster, 2 pairs of electrode (2- potential and 2 — electrical electrode), connecting cables and hammer.

6.2 SURVEY TECHNIQUES

Two survey techniques are used in the electrical resistivity method,. They are

(i) Horizontal profiling

(iii) Vertical electrical sounding (VES)

The horizontal profiling techniques measures lateral variations in ground resisitvity. This technique is very useful in rock boundary mapping, fracture, joints and fault detection.

In the vertical electrical sounding technique, vertical variations in ground resistivity are measured with respect to a fixed center of array. The technique is suitable for subsurface layer delineation and detection of structures and faults. Down the hole, micro resistivity measurements were obtained using Wenner and schlumberger configurations. These measurements were made at 10cm interval from top to bottom of the pit and trenches located in the survey area and data were presented as profiles. Micro resistivity values were plotted against engineering parameter in order to establish empirical formulae between electrical resistivity and engineering parameters.

For vertical electrical sounding, the schiumberger array was adopted and five VES points were occupied. The recorded data were plotted as depth sounding curve and these were qualitatively and quantitatively interpreted. The former involved visual inspection while the latter was effected by partial curve matching and computer iteration techniques.

6.3 DATA INTERPRETATION

The interpretation of the VES data was quantitative. The partial curve matching interpretation technique was employed in carrying out a quantitative interpretation of the sounding curves. The method involves a segment-by-segment matching of the field with a set of theoretically calculated two-layer curves and their corresponding auxiliary curves.

The field was superimposed on this set of two-layer master curves and moved around while keeping the respective axis parallel[, until a satisfactory match was obtained with one of the model curves and the origin (i) of the model curves was marked on the field curve. The resistivity ratio (ki) of the matched master curves was noted. Thereafter, the field curve was superimposed on the auxiliary curve with the cross-point (+,) and the appropriate auxiliary curve was traced out.

The vertical coordinates of the first cross point (+,) gave the thickness (m) of the first layer while the horizontal coordinates gave the resistivity (p) of the first layer:

The second layer resistivity (p) was calculated from equation:

$\rho_2 = \rho_1 \times K_1$——-——————----———— - (1)

Where ρ_2= resistivity of the second layer

ρ_1 resistivity of the first layer

K_1 = resistivity ratio of the master curve that matched the first segment of the field curve.

T he second segment of the curve was matched when the K1 auxiliary curve was kept at the origin of the two-layer model curves and the axes were kept parallel until a satisfactory match was obtained. The new origin was marked on the field curved and the reflection coefficient K2 gave the replacement resistivity (P2g.) and the replacement thickness (h2r) of the second layer. The third layer resistivity was obtained from the equation

P3 =P2XK2--------------------------------------(2)

Where
p3 resistivity of the third layer
P2 = resistivity of the second layer
K2 resistivity reflection coefficient of the master curve that matched the second segment of the field curve.

To obtain thickness (h2) of the second layers, the first cross point (i) was placed at the origin of the auxiliary curve while the axes curve kept parallel, the thickness ratio (Dn IDr)1 value was read of the location of the second crosspoint(+ 2). The second layer's thickness was obtained from the equation.

H2=(Dn)Xh1——- —–—-----—---—---- —-----(3)
Dr1

Where h1 thickness of the first layer
h2 thickness of the second layer
Dn /Dr1 is the value obtained at the location of the second cross-point.

For the quantitative interpretation of depth sounding curves with more than three layers, the procedures described above were repeated until the curves were completely matched.

Summation of successive thicknesses gave depths to resistivity interface. The layer resistivity values and thicknesses obtained from the vertical electrical soundings are presented in Table 1

TABLE 1: VERTICAL ELECTRICAL SOUNDING RESULTS

STATION POSITIONS	DEPTH(M) D1/D2/D3	LAYER Resistivity P1/ p2/ p3/ p4 (140hm)	GPS	curve
TRENCH 1 TRAVERSE 2 VES 1	1.9/6.0/30.3	437/666/65/277	N07^{0}38.855^1 E004^{0}47007^1	KH
PIT 1 TRAVERSE 2 VES 5	0.5/3.2/25.7	186/110/87/994	N07^{0}38.874^1 E004^{0}48.999^1	KH
PIT 2 TRAVERSE 2 VES 8	0.4/1.9/25.3	1123/186/69/1808	N07^{0}38.887^1 E004^{0}48.991^1	QH
TRENCH 2 TRAVERSE 2 VES 14	1.3/5.0/17.3	40/90/48/1131	N07^{0}38.855^1 E004^{0}48.978^1	KH
PIT 4 TRAVERSE 3 VES 4	0.2/5.7/21.8	578/2022/103/180	N07^{0}38.501^1 E4^{0}49.04.0^1	KH

7. RESULT AND DISCUSSION:

7.1 Geo-electric sections.

The geo-electrical section of the study area are displayed in Figures 1. Four geologic layers were delineated beneath the axis. The topsoil is composed of clay, sandy clay, clayey sand and laterite with layer resistivities of 40 — 1123 ohm-rn and thicknesses between 0.2 and 1 .9m. The second layer, which is lateritic clay, has resistivity values of 186 — 2021 ohm-rn with thicknesses between 1.0 and 6.Om

The clay, sandy clay weathered layer has resistivity values varying from 50 to 103 ohm-rn and thicknesses of between 16.1 — 28.5m. The fourth layer consists of the basement bedrock with resistivity values of 277 — 1808 ohm-rn.

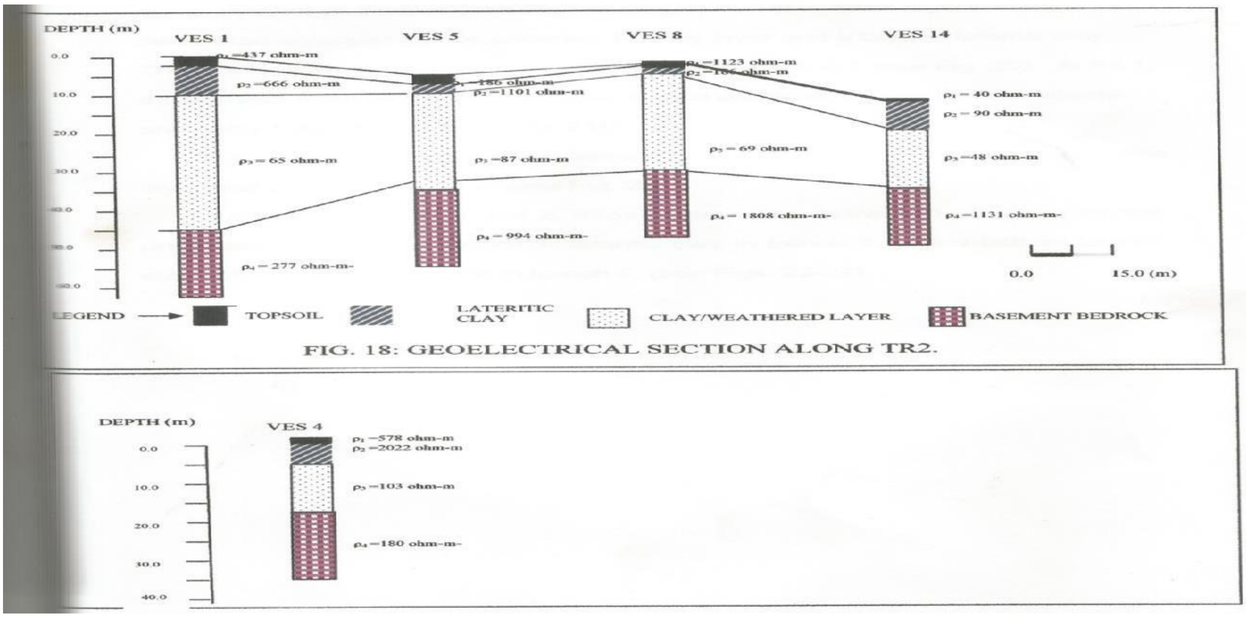

Figure . 1: GEOELECTRICAL SECTION ALONG TR3.

7.2 MICRO-RESISTIVITY MEASUREMENTS.

Micro-resistivity measurements that were made using Schiumberger array are presented as profiles (see Figure 2). At Pit 2, three layers were delineated-an upper topsoil underlain by clay layer and a bottom lateritic clay. The lithological interfaces occur between stations. At Pit 1, three layers were delineated-an upper topsoil underlain by thin layer of laterite and bottom lateritic clay (see Fig. 2).

At Pit 4, three layers were delineated-an upper topsoil underlain by lateritic layer and a bottom hard pan. At both trenches I and 2, three layers were delineated-an upper topsoil, underlain by laterite in trench I, lateritic clay in trench 2, and a bottom lateritic clay in trench 1, and laterite in trench 2.

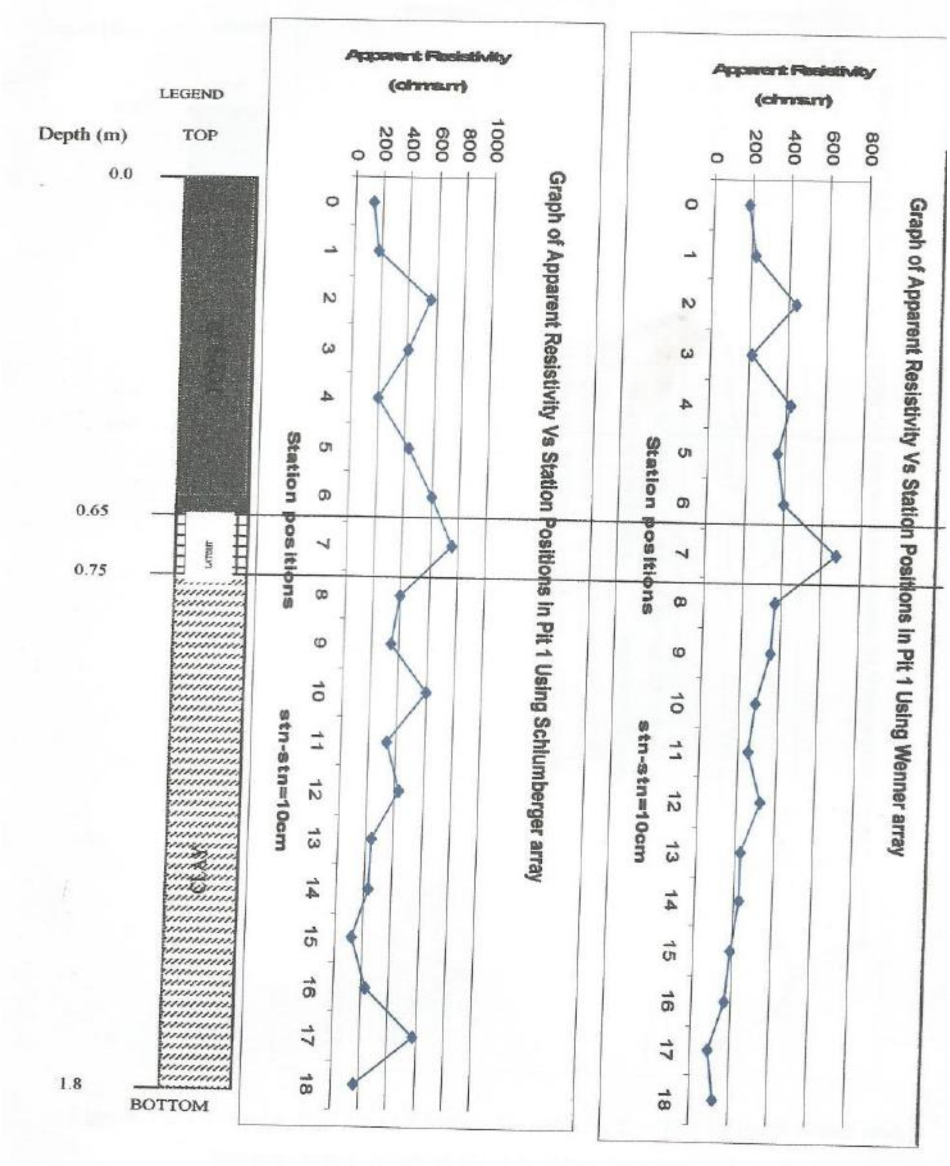

Figure 2: Lithological log of micro resistivity profiles using Wenner and Sclumberger array at pit 1 in investigated area

7.3 MICRO-RESISTIVITY AND GEOTECHNICAL PARAMETERS

The micro-resistivity measurements were related with geotechnical parameters at Pit 4, Trench 1 and Pit 2. The geotechnical parameters used are presented in the Tables 1

The plot of micro-electrical resistivity against Coefficient of Compressibility does not give any definite relationship (see Fig. 3). For Coefficient of Consolidation and Permeability, the micro-electrical resistivity value decreases with increase in both Coefficient of Consolidation and Permeability.

However the Liquid limit, Plasticity Index and Moisture content increases with increase in micro-electrical resistivity. .Meanwhile, the micro-electrical resistivity decreases with increase in Dry density.

7.4 GEOTECHNICAL PARAMETERS AND VES DATA

The vertical electrical sounding resistivity data were also related to engineering parameters such as Moisture content, Dry density, Plasticity index, Liquid limit, Coefficient of Consolidation, Permeability and Compressibility.

Some of the engineering parameters do not show appreciable relationship with (VES) electrical resistivity and these are Coefficient of Compressibility, Dry density, Plasticity Index, Moisture content and Liquid limit. Meanwhile, nonlinear relationship exists between Coefficient of Permeability and Consolidation with (VES) electrical resistivity.

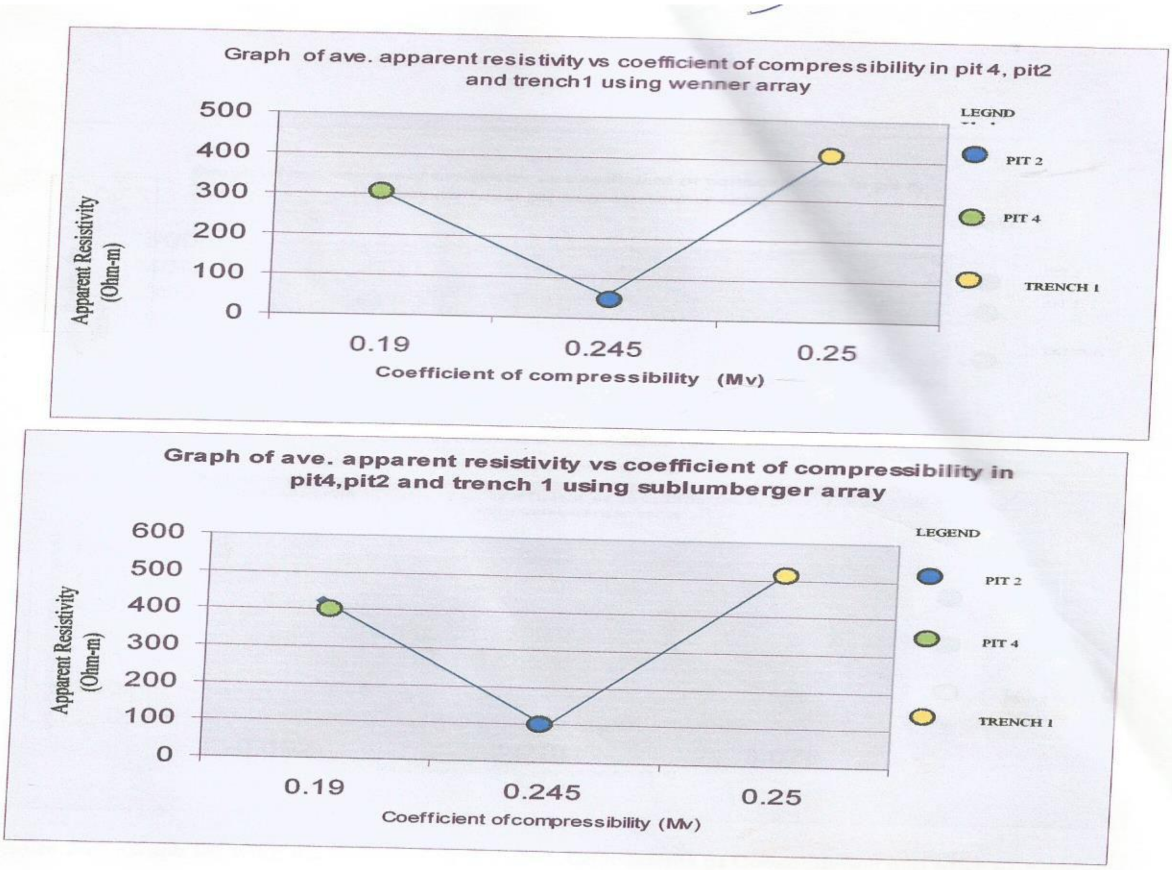

Figure 3: Graph showing the Relationship between Coefficients of Compressibility and Micro—Resistivity measurements using Wenner and Sublumberger Array in loko Investigated Area.

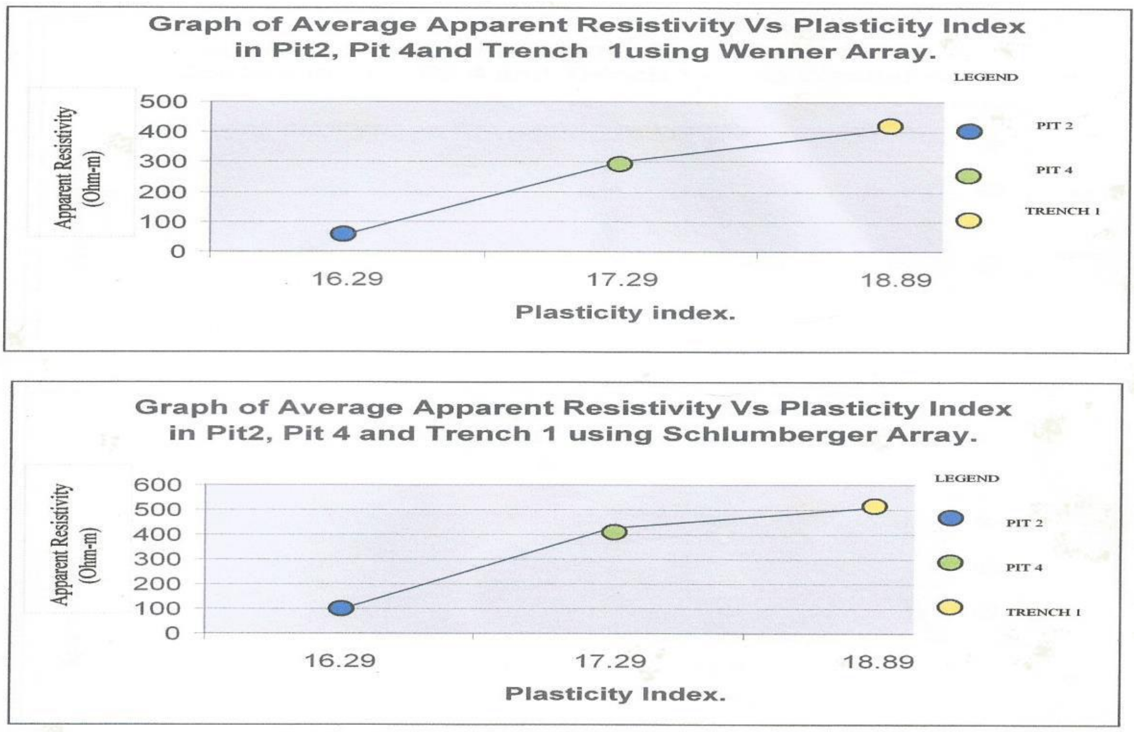

Figure 4: Graph showing the Relationship between Plasticity Index and Micro-Resistivity measurements using Wenner and Sublumberger Array in Iloko Investigated Area.

7.5 COEFFICIENT OF PERMEABILITY

The coefficient of permeability (K) exponentially decreases with increases in resistivity (see Fig. 4). The generalized equation between K and p is of the form.
p = Ae< (after Singh, 2005.)
Where p = resistivity of the soil
K = coefficient of permeability
A and B are constants.

These constants can be derived as follows;
From the graph,
2020 = AeB’:°0000047) (56)
666 = AeBOOOOl29) (57)
186 = Ae6°°oo°°255 (58)
From equation 56
A= 2020 = ………………….(4)
e°°°°°°478

recall equation 57
666 = Ae°°°°°°129

Substitute A as in equations 1 and 2
— 666 = 2020 x e°°°°°°1298
e°°°°°°47
666 OOOOO1298
2020 e°°°°°°478
0.329703 = e°°°°°°1298 +
0.329703 = e0000001298 - 0.00000478
0.329703 = e°°°°°°
Taking natural logarithms of both side
7/
Taking natural logarithms of both side
Ln (0. 329703) =
-1.10956303 = 0.0000082B
0.0000082B = -1.10956303
B = -1.10956303
0.0000082
B = -135,313
B = -1.35 x (60)
Recall equation 58
1 86 =
Substitute B as equation 3 in equation 4
186 = Ae°°°°°°255 X -135313
186 = Ae3°5
A = 186
e34505
A = 186 = 5861.96
0.03173
A = 5862
A = 5.862 x103 (61)

Therefore, the equation existing between electrical resistivity and coefficient of permeability is:
p = 5.862 x e135313k (62)

7.6 COEFFICIENT OF CONSOLIDATION

The coefficient of consolidation (Cv) decreases exponentially with increase in resistivity (p). The generalized equation that exists between p and C, is of the form:
$p = Ae^{BCV}$

Where p resistivity of the soil
Cv coefficient of consolidation
A and B are constants, they are derived in below:

From the graph, the following equation are derived.
2020 = Ae°692 (63)
666 = Ae916 (64)
186 = Ae3°788 (65)
Recall equation 63
2020 = AeO6O2B
A = 2020 (66)
e°692
Recall equation 64
666 = Ae1 91 6B
Substitute A as equation 66 in equation 64
666 = 2020 x e19
666 =
2020 e0692B
0.3297 = e19168 + eO.692B
0.3297 = e1916 0.6928
0.3297 = e148
Take the natural log of both side
In (0.3297) = logeet224B
-1.109572 = 1.224B B = -1.109572
1.224
B = -0.906513 (67)
Recall equation 65
1 86 = Ae3°78
Substitute B
186 = Ae3°78 X O9O65l 3 186 = Ae279025
A = 186
e29025
A= 186
0.061406043 A = 3029
Therefore, the equation that exist between resistivity and Coefficient of Consolidation (Cv) is:
p = 3029e°9065 Cv
p = 3.029 x I 03e°9065 CV

7.7 COEFFICIENT OF COMPRESSIBILITY

There is a non-linear relationship between both micro-electrical resistivity and VES data with coefficient of compressibility.

7.8 LIQUID LIMIT

This engineering parameter does not give any linear relationship with electrical resistivity(VES).

8. CONCLUSION:

The present study reveals that both micro-electrical and vertical electrical sounding (VES) resistivity values inversely vary with coefficient of consolidation and permeability.
The established empirical formulae between electrical resistivity and
coefficient of permeability (K) and consolidation (Cv) are;
p = 5.862 x 10 e3S3l3k
p = 3.029 x I 03e°9065 Cv
Where . p = resistivity of the soil
K = coefficient of permeability
Cv coefficient of consolidation
There are no well defined relationship between the other engineering parameters and electrical resistivity. Such engineering parameters are plasticity index, moisture content, dry density e.t.c.

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