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Assessment of Foundation of Power Plant At Ihie In Ukwa West Local Governmentarea, Abia State Southeastern Nigeria, Using An Integrated Approach

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Abstract: ***The rate at which structure (buildings), collapse in Nigeria with its attendant loss of lives and properties has assumed an alarming proportion in recent times. Efforts to mitigate such incidence has necessitated an integrated geophysical and geotechnical investigation of a proposed power plant building sites with a view to determine the suitability of the site for the proposed project. Vertical electrical sounding using schlumberger configuration with electrode spacing of 200m. Ten (10) numbers of holes were bored through clay, silts, sand and similar soft materials to depth not exceeding 10m vertically. Soil sampling at 1.5m depth interval were carried out on each borehole to a depth of 10m, samples were later taken to the laboratory for analysis to determine their Engineering properties. The results revealed clay and sand materials characterized by bearing pressure of 189KN/m^2.The Liquid Limit ranged between 25% and 40% with an average of 32.5% while the Plastic Limit ranged between 10% and 24% averaging 17% and a degree compaction of 90-95%be recommended for the foundation of the power plant.***

Keywords: Geophysical survey, Geotechnical analysis, Foundation Suitability, Cone Penetrometer Test and Power Plant**.**

1. Introduction

When The rate of failed structures in Nigeria has increased in recent times (Oyedele, et al., 2011). This has necessitated a detail investigation of sub-soil which plays a major role in solving foundation problems. These investigations basically yield information on the nature and engineering properties of a proposed site so that proper foundation design and recommendations can be made for a proposed construction of power plant building in Ihie, Ukwu west local government area of Abia state. Because significant attention is not attached to foundation of buildings, building foundation have always been treated lightly, and the resulting problems are always embarrassing (Robert, 1996). This assertion can be attributed to the minimal attention towards the use of geophysics in foundation studies. In Engineering Geophysics and site investigation, structural information and physical properties of a site are sought (Sharma, 1997). This is so because the durability and safety of the engineering structural setting depend on the competence of the material, nature of the sub-surface lithology and the mechanical properties of the overburden materials. Foundations are affected not only by design errors but also by foundation inadequacies such as sitting them on incompetent earth layers. When the foundation of a building is erected on less competent layers, it poses serious threat to the building which can also lead to its collapse. Therefore, there is need to evaluate the foundation integrity of the buildings of power plant in Ukwu-west in terms of the subsurface structures and nature of the soil. The ultimate aim of subsurface investigation is to assess enough information to select the most appropriate foundation solution, to outline problems that could arise during construction and on a more general scale to highlight potential geological hazards in the examined area (Tomlinson, 1980). Most builders fail to recognize that the soil surrounding a foundation is responsible for the majority of foundation failures. Even foundations built with good materials and first rate workmanship will fail if poor soil conditions are not considered (Robert, 1996). As a result of failure of buildings the geoelectrical method as an effective tool for gaining knowledge into the subsurface structure, in particular, for identifying anomalies and defining the complexity of the subsurface geology is fast gaining grounds (Soupois et al., 2007; Colangelo et al., 2008; Lapenna et al., 2005). In recent times, much attention is being paid to the electrical resistivity imaging (ERI) method (Loke et al, 1996; Giano et al., 2000), which provides a high spatial resolution with a relatively fast field data acquisition time and is low in cost (Lapenna et al., 2005).

2. Geology of the Study Area.

The area lies within the Sedimentary Terrain. It is within the transition zone between the Coastal Plain Sands also called the Benin Formation and the Ogwashi-Asaba Formation of the Bende-Ameki Group. The Coastal Plain Sand Conformably overlies the Ogwashi-Asaba Formation.

2.1 Coastal Plain Sands (Pleistocene -Oligocene)

The Coastal Plain Sands was deposited during the Pleistocene-Oligocene period of the Tertiary Era. These groups of sediments which are widespread only in the southern part of Nigeria are overlain by recent alluvium sediments. They spread from Umuahia and Aba in the east of Nigeria to the coast, where the sediments overlies the oil bearing Akata Formation as shown in Fig.1. The deposit consists of sand and clays but predominantly sands of whitish to light grey colour below the zone of aeration. It is however reddish to brownish when exposed to the atmosphere.

Ogwashi -Asaba Formation (Eocene)

The Ogwashi-Asaba Formation is directly below the Coastal Plain Sands or Benin Formation is the Ogwashi – Asaba Formation of the Bende-Ameki Group of Formations. These were deposited in the Middle Eocene period. The lithology consists of lenticular siltstone, clays, shales and subordinate sandstones and lignite.

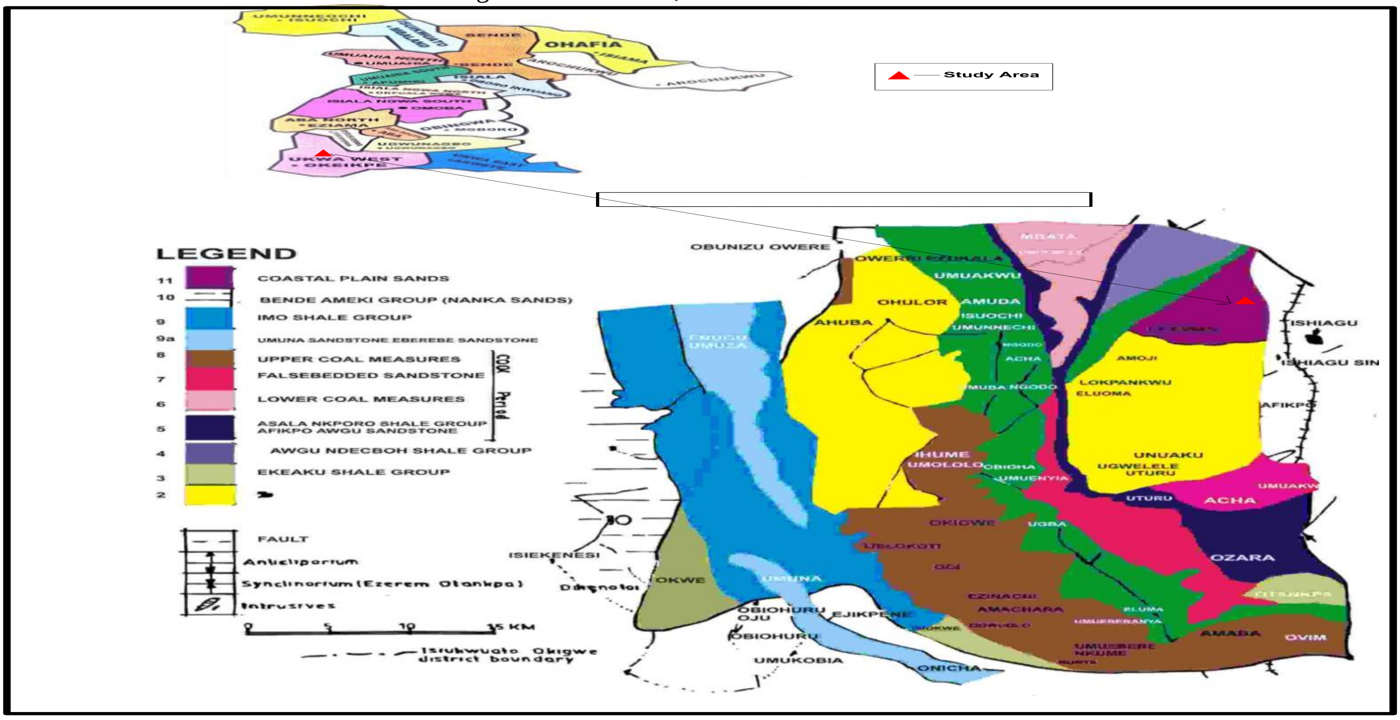

Figure 1: Geology of the Study Area. Source: Igbokwe et al, (2010).

3. Methodology

The mode of study includes:

i. Literature review of some previous work done in the study area and other works that were considered necessary for the present study.

ii Acquisition of 10 VES data across the study area, using the Schlumberger configuration. The Schlumberger configuration was adopted for the following reasons:

The method permits the acquisition of numerous data within a very short time.

The method allows for a clearer definition of the subsurface for a given outer electrode spacing.

It requires less manpower as only the current electrodes are moved.

3. Processing of the acquired data with the RES2DINV software.

4. Interpretation of results.

3.1 Vertical Electrical Sounding

VES furnishes information concerning the vertical succession of different conducting zones and their individual thicknesses and resistivities. For this reason, the method is practically valuable for investigations on horizontally or near horizontal stratified earth. In the electrical sounding method, the midpoint

of the electrode configuration is fixed at the observation station while the length of the configuration is gradually increased

(Ekwe et al, 2006). As a result, the current penetrates deeper and deeper, the apparent resistivity being measured each time the current electrodes are moved outwards (Koefoed, 1977). For Schlumberger array, apparent resistivity is given by:

$\rho a = \pi R\ (a2/b - b/4)$ (Keller et al, 1979)

where a = half current electrode separation and b = potential electrode spacing.

3.2 Borehole Drilling

Ten (10) numbers of holes were bored through clay, silts, sand and similar soft materials to depth not exceeding 10m vertically. Soil sampling at 1.5m depth interval were carried out on each borehole to a depth of 10m. Both disturbed and undisturbed samples were taken from the borehole at this interval, the core catcher method for the undisturbed samples and the hand auger method for the disturbed samples. Necessary guidelines and precautions were observed in the handling and storing of samples, adequate containers were provided to protect the samples from further disturbance after collection. Two large labels giving the location, depth and date were written for every sample. One label is placed inside the container, the other attached to the outside of it and the sample numbers recorded in a diary. These samples were later taken to the laboratory for analysis to determine their Engineering properties.

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Plate 1: One of the point where vertical electrical sounding (VES) was carried out**.**

3.3 Groundwater Condition

From the boring records shown on the borehole logs, no groundwater was encountered during boring from the ground surface to 10m. This agrees with the hydrogeology of the study area which has water table at considerable depths. The borehole points are then geo referenced using a GPS. The coordinates of the borehole points are shown in the Table 1.

Table 1: Borehole Coordinates

S/N	Borehole	Northing	Easting	Elevation (m)
1	BH1	$04^o 59^I 18.1^{II}$	$007^o 17^I 16.9^{II}$	62.0
2	BH2	$04^o 59^I .341^{II}$	$007^o 17^I .51.6^{II}$	56.0
3	BH3	$04^o 59^I 16.9^{II}$	$007^o 17^I 22.6^{II}$	44.0
4	BH4	$04^o 59^I 27.3^{II}$	$007^o 17^I 24.3^{II}$	38.5
5	BH5	$04^o 59^I 34.7^{II}$	$007^o 17^I 30.1^{II}$	41.2
6	BH6	$04^o 59^I 32.3^{II}$	$007^o 17^I 31.1^{II}$	37.8
7	BH7	$04^o 59^I 29.4^{II}$	$007^o 17^I 31.0^{II}$	47.2
8	BH8	$04^o 59^I 26.3^{II}$	$007^o 17^I 30.0^{II}$	63.3
9	BH9	$04^o 59^I 22.1^{II}$	$007^o 17^I 26.1^{II}$	45.4
10	BH10	$04^o 59^I 20.7^{II}$	$007^o 17^I 22.4^{II}$	48.4

3.4 Geotechnical Survey

The field investigation involves the use of a GPS to geo-reference the borehole points, trial pits points, cone penetrometer test points, collection of soil samples from the borehole and the geophysical surveys. CPT can be utilized for a wide range of geotechnical engineering applications. Sanglerat (1972) and De Ruiter (1981) reviewed the application of the method in geotechnical practice. The CPT is a means of ascertaining the resistance of the soil. A total of ten CPT tests, coinciding with VES locations were carried out at a depth 1.5m as shown in Fig. 2. The tests were performed using a ten (10)-ton nominal capacity manually powered CPT machine. Penetration resistance (qc), sleeve friction (fs) and the depth of penetration were recorded at each station and processed into plots. Most of the test reached refusal before the anchors pulled out of the subsurface. The layer sequences were interpreted from the variation of the values of the cone resistance with depth. The layer sequences were interpreted from the variation of the values of the cone resistance with depth. On the basis of the expected resistance contrast between the various layers, inflection points of the Penetrometer curves were interpreted as the interface between the different lithologies. The cone penetration test is economical and supplies continuous records with depth.

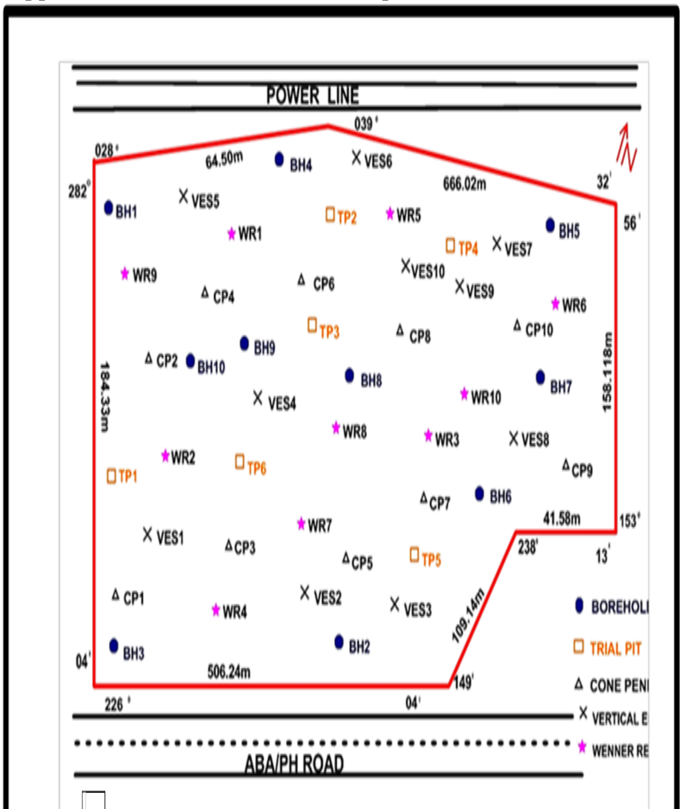

FIGURE 2 A SITE PLAN SHOWING VARIOUS SAMPLING POINTS

3.2.1 Trial Pit

A total of six (6) number trial pits were dug. These pits serve as control to the borehole samples. The pits are 1.8m by 1.5m by 2m. They were constructed not exceeding 2m depth as shown in Plate.2. The coordinates of the trial pits and depth at which both disturbed and undisturbed samples are taken are shown below in (Table.2)

PLATE 2: Construction of Trial Pit

TABLE 2: Trial Pits Coordinates

S/N	TRIAL PIT	NORTHINGS	EASTINGS	DEPTH (m)	REMARK
1	TP1	$04^o\ 59^1\ 18.1^{11}$	$007^o\ 17^1\ 16.9^{11}$	1.0	Disturbed
				1.3	Undisturbed
2	TP2	$04^o\ 59^1.403^{11}$	$007^o\ 17^1.440^{11}$	1.6	Disturbed
				1.5	Undisturbed
3	TP3	$04^o\ 59^1\ 30.8^{11}$	$007^o\ 17^1\ 31.3^{11}$	1.2	Disturbed
				1.4	Undisturbed
4	TP4	$04^o\ 59^1\ 33.9^{11}$	$007^o\ 17^1\ 29.8^{11}$	2.0	Disturbed
				2.0	Undisturbed
5	TP5	$04^o\ 59^1\ 25.9^{11}$	$007^o\ 17^1\ 31.3^{11}$	2.0	Disturbed
				1.7	Undisturbed
6	TP6	$04^o\ 59^1\ 22.7^{11}$	$007^o\ 17^1\ 25.3^{11}$	1.6	Disturbed
				1.5	Undisturbed

3.2.2 Dutch Cone Penetrometer Test

A total of ten (10) tonne Dutch Cone Penetrometer Machine was employed for this investigation. This machine has the capacity for probing up to 40 metres depth. The test was carried out to ten (10) meters depth at each point. This test enables us to determine the strength of the soil. A total of ten (10) Dutch cone Penetrometer test were carried out. The (Table 3) below show the different cone test with their corresponding coordinates.

Table 3: co-ordinate and elevation of Cone Penetrometer Test

	PENETROMETER TEST	NORTHINGS	EASTINGS
1	CPT1	$04^o\ 59^1\ 17.0^{11}$	$007^o\ 17^1\ 22.5^{11}$
	CPT2	$04^o\ 59^1\ 18.1^{11}$	$007^o\ 17^1\ 21.3^{11}$
3	CPT3	$04^o\ 59^1\ 18.6^{11}$	$007^o\ 17^1\ 23.6^{11}$
	CPT4	$04^o\ 59^1\ 20.8^{11}$	$007^o\ 17^1\ 21.8^{11}$
5	CPT5	$04^o\ 59^1\ 22.7^{11}$	$007^o\ 17^1\ 26.9^{11}$
	CPT6	$04^o\ 59^1\ 26.4^{11}$	$007^o\ 17^1\ 23.6^{11}$
7	CPT7	$04^o\ 59^1\ 26.6^{11}$	$007^o\ 17^1\ 31.3^{11}$
	CPT8	$04^o\ 59^1\ 30.0^{11}$	$007^o\ 17^1\ 27.3^{11}$
9	CPT9	$04^o\ 59^1\ 31.3^{11}$	$007^o\ 17^1\ 31.3^{11}$
	CPT10	$04^o\ 59^1\ 33.4^{11}$	$007^o\ 17^1\ 31.0^{11}$

3.2.3 Bearing Capacity Calculation

The Bearing Capacity calculation was done using the two methods of in-situ and laboratory tests carried out. These are:

1) Dutch Cone Penetrometer Method
2) Triaxial Test Method

Bearing Capacity calculation was done using the three methods listed above. In each case, the soil strength below 3m depth was used since this will form the foundation base. Above this depth the values were quite low. The in-situ tests were averaged up to 2m below since it would be within the foundation influence zone. The bearing pressures obtained from these three methods were averaged to obtain the recommended allowable bearing pressure. The effect of water table was not considered, since the water table is deep seated. For all these calculations, footing width of 2.0m and depth of 3.0m were used for calculations. For triaxial method, the Terzaghi was used and for the other methods, the Meyerhof equations were used. A Safety of 3.0 was used in the Terzaghi method to obtain the allowable bearing Pressure, while in the Dutch Cone Penetrometer Method (DCPT) and Standard Penetration Test Method (SPT) calculation had Allowable Bearing Pressure with 25mm maximum settlement calculated from the given formulae. All these methods serve for a maximum settlement of 25mm. The Square Footing Method is employed in the calculation of the Bearing Capacities of the Soil using Terzaghi's Bearing Capacity Factor for Shear Failure.

$$\text{Bearing Capacity} = \frac{1.3C\,(Nc) + \gamma z(Nq) + 0.4\gamma\beta(Ny)}{3}$$

Where C = Cohesion (KN/m^2). Nc, Nq and Ny are Terzaghi's Bearing Capacity Factors at Φ, 1. 3 and 0.4 are constants, γ = Unit Weight , z = Depth of Foundation, β = Width of Foundation

The depth of water table with respect to the base of the footing was not considered since the water table is quite deep from the surface. The Bearing Capacity used in the recommendation below is that obtained using the triaxial tests results, added to the other two methods and averaged.

4. Discussion

4.1 Geoelectric Sections

For VES 1 and 2 showed two and three layers respectively as shown in Fig. 4a and 4b, VES 1 resistivity values ranges from 192.7-363.9 Ohm-m and its depth ranges from 0.00-22.62m. VES 2 resistivity value ranges from 403.57-704.93 Ohm-m and its depth ranges from 0.00-55.991m as shown in (Figure 4). While VES 3 and 4 showed three and five layers with VES 3 has resistivity value of 391.1-221.1m and depth of 0.00-56.586m as shown in Fig.4c and 4d. For VES 4 has resistivity value of 127.151-5.4295 Ohm-m and it depth ranges from 0.00-44.484 m. VES 5, 6, 7, 8 shows six, four, five and three layers respectively there resistivity values ranges from 25.25-1010.3 Ohm-m, 308.00-834.06 Ohm-m, 318.00-902.26 Ohm-m, 273.05-480.42 Ohm-m. While there depth ranges from 0.00-43.365m, 0.00-48.806m, 0.00-53.674m, 0.00-50.377m as shown in Fig 5a-5d respectively. VES 9 and 10 showed three layers with resistivity value ranging from 589.13-1016.20 and 698.81-545.67 Ohm-m respectively while there depth ranges from 0.00-35.119m and 0.00-51.489 Ohm-m respectively as shown in Fig. 6.

Table 4: Summary of Undrained Triaxial Test Result for Trial Pits.

TRIAL PITS	DEPTH (m)	REMARKS	MOISTURE CONTENT %	BULK DENSITY Mg/m^3	ANGLE OF FRICTION Φ	COHESION KN/m^2	BEARING CAPACITY KN/m^2
TP1	1.0	Disturbed	9.2	1.90	24	53	453
	1.3	Undisturbed	9.0	1.92	24	58	502
TP2	1.6	Disturbed	8.7	1.88	25	55	507
	1.5	Undisturbed	7.6	1.91	21	52	365
TP3	1.2	Disturbed	13.5	2.11	18	44	257
	1.4	Undisturbed	7.6	1.79	26	79	778
TP4	2.0	Disturbed	9.3	1.71	24	52	446
	2.0	Undisturbed	7.5	1.78	25	80	731
TP5	2.0	Disturbed	9.3	1.70	23	108	854
	1.7	Undisturbed	7.5	1.76	24	53	447
TP6	1.6	Disturbed					
	1.5	Undisturbed					

Table. 5: Summary of Atterberg Limits and Mechanical Sieve Analysis for Boreholes.

MALL BH1	DEPTH (m) 2.0	REMARKS	LL %	PL %	PI %	SIEVE No. 200 %	SIEVE No. 100 %	SIEVE No. 72 %	SIEVE No. 52 %	SIEVE No. 36 %	SIEVE No. 25 %	SIEVE No. 14 %	SIEVE No. 7 %
		Disturbed	26	11	15	94.05	5.35	0.6	-	-	-	-	-
BH2	1.8	Disturbed	36	24	12	90.0	5.23	1.76	0.59	-	-	-	2.35
BH3	1.5	Disturbed	35	24	11	96.57	2.29	1.14	-	-	-	-	-
BH4	1.6	Disturbed	33	20	13	91	7.34	1.13	-	-	-	0.56	-
BH5	2.0	Disturbed	26	10	16	96.42	2.98	0.6	-	-	-	-	-
BH6	1.5	Disturbed	33	20	13	90	8.34	1.66	-	-	-	-	-
BH7	1.6	Disturbed	25	17	8	94.05	4.5	1.45	-	-	-	-	-
BH8	1.3	Disturbed	26	12	14	94.5	3.5	2.0	-	-	-	-	-
BH9	1.4	Disturbed	33	19	14	84.0	11.43	2.86	-	1.14	0.57	-	-
BH10	0.75	Disturbed	35	24	11	95.6	2.3	2.1	-	-	-	-	-

Table. 6: Summary of Atterberg Limits and Mechanical Sieve Analysis for Trial Pits.

MALL	DEPTH (m)	REMARKS	LL %	PL %	PI %	SIEVE No. 200 %	SIEVE No. 100 %	SIEVE No. 72 %	SIEVE No. 52 %	SIEVE No. 36 %	SIEVE No. 25 %	SIEVE No. 14 %	SIEVE No. 7 %
TP1	1.0	Disturbed	26	11	15	94.05	5.35	0.6	-	-	-	-	-
	1.3	Undisturbed	36	24	12	90.0	5.23	1.76	0.59	-	-	-	2.35
TP2	1.6	Disturbed	35	24	11	96.57	2.29	1.14	-	-	-	-	-
	1.5	Undisturbed	33	20	13	91	7.34	1.13	-	-	-	0.56	-
TP3	1.2	Disturbed	26	10	16	96.42	2.98	0.6	-	-	-	-	-
	1.4	Undisturbed	33	20	13	90	8.34	1.66	-	-	-	-	-
TP4	2.0	Disturbed	25	17	8	94.05	4.5	1.45	-	-	-	-	-
	2.0	Undisturbed	26	12	14	94.5	3.5	2.0	-	-	-	-	-
TP5	2.0	Disturbed	33	19	14	84.0	11.43	2.86	-	1.14	0.57	-	-
	1.7	Undisturbed	35	24	11	95.6	2.3	2.1	-	-	-	-	-
TP6	1.6	Disturbed											
	1.5	Undisturbed											

Geotechnical Interpretation.

As evident from the Geology of the area already discussed earlier two different geological formation exist, one lying above the other. The local Geology is the Coastal Plain Sands or Benin Formation. From the samples tested in the laboratory and classified with the Unified Classification System (UCS) showed mostly Clay-Sand or Sand-Clay mixtures, mostly with low plasticity. All of these are inorganic sand, silt clay mixtures. From the observed Standard Penetration test result as well as the Dutch Cone Penetrometer Test, the strength of the soil area was observed to be increasing downwards. From ground level to about 4.0m depth, loose to medium dense to firm soil was noticed with SPT ranging from 2-6 blows/300mm. Thereafter however, firm to very firm soil went into dense and very coarse sand up to the termination of boring at 10m.

From the Dutch Cone Penetrometer Test Result, observable increase that is in strength was noticed from about 4.0m depth and progressed to the point of termination. From the boring records shown on the borehole logs, no groundwater was encountered during boring from the ground surface to 10 metres. This agrees with the local hydrogeology (geophysical survey) which has water table at considerable depths. The Liquid Limit ranged between 25% and 40% with an average of 32.5% while the Plastic Limit ranged between 10% and 24% averaging 17% as shown in (Table 5). The Plasticity Indices ranged between 7% and 17% with an average of 12% as shown in (Table 5). The Percentage Passing of Sieve No.200 ranged between 71.3% and 96.6% averaging 84% indicating that the soil is homogenous of Clayey Silt. The Moisture Content ranged between 7.5% and 13.5% with an average of 11.5% while the Bulk Density ranged between 1.70 mg/m^3 and 2.11mg/m^3 with an average of 1.9mg/m^3 as shown in (Table 4). The Angle of Internal Friction ranged between 16% and 26% with an average of 21% as shown in (Table 4). The Cohesion ranged between 44 KN/m2 and 108 KN/m2 averaged 76 KN/m2 as shown in (Table 4).

5. Conclusion

From the above investigations, laboratory tests and discussions, ground beam with isolated footings at the column positions are recommended to be adopted for foundation. Foundation width of 2.0m taken to a depth of about 3.0m is suggested to be adopted. The allowable bearing pressure of 189KN/m^2 is hereby recommended to be adopted. Test results have shown that the soil is loose at the surface. For this reason, adequate measures are suggested to be taken to prevent erosion that might undermine the substructure and hence the super structure. Adequate drainage should therefore form an integral part of the construction of this project site.

6. Recommendation

- From the foregoing, it is recommended that 90-95% degree of compaction should be reached or achieved. Sheep foot roller, making 2-4 passes on a thickness of 150mm, should be employed. The OMC 11% and the MDD is 2.00gm/cm^3. however to ensure compliance, on-site in-site density test using replacement method is recommended to be employed.
- From the geophysical investigation carried out using Wenner the soil profile from surface to 40m, are consist of fine sand based on the apparent resistivity of different rock layers.
- There is no treat from ground water table since the depth to water table is about 40m to 55m around the site.
- Excavation of sand from construction should be 500m away from the site, this will help to prevent flooding and environmental hazard.

Pavement design.

- The soil in the project area is considered stable, considering results of the sample tested as well as the in-situ test carried out. To enhance durability, take the following pavement design is suggested. Flexible pavement is also suggested to be adopted for the road construction.

The following pavement design is suggested to be adopted thus;

- Wearing course: 150mm asphaltic concrete
- Base-course: 180mm burrow materials of CBR 80% and above.
- Sub-base course: 190mm borrow material of CBR out less than 50%.

In addition, adequate drains should be constructed to keep the road free from flooding.

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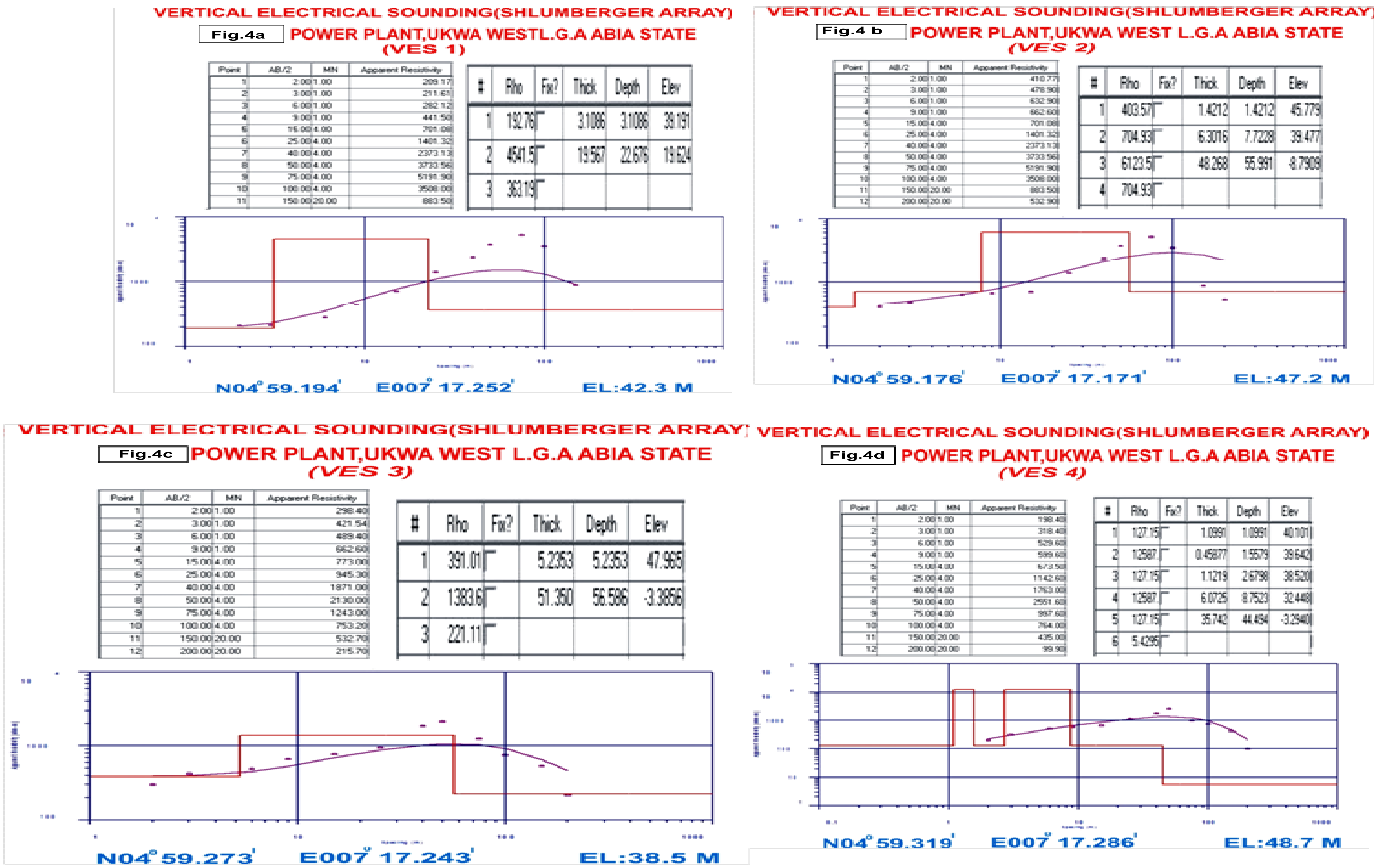

Figure 4: Interpretation of Subsurface Resistivity Values for VES 1, 2, 3 and 4.

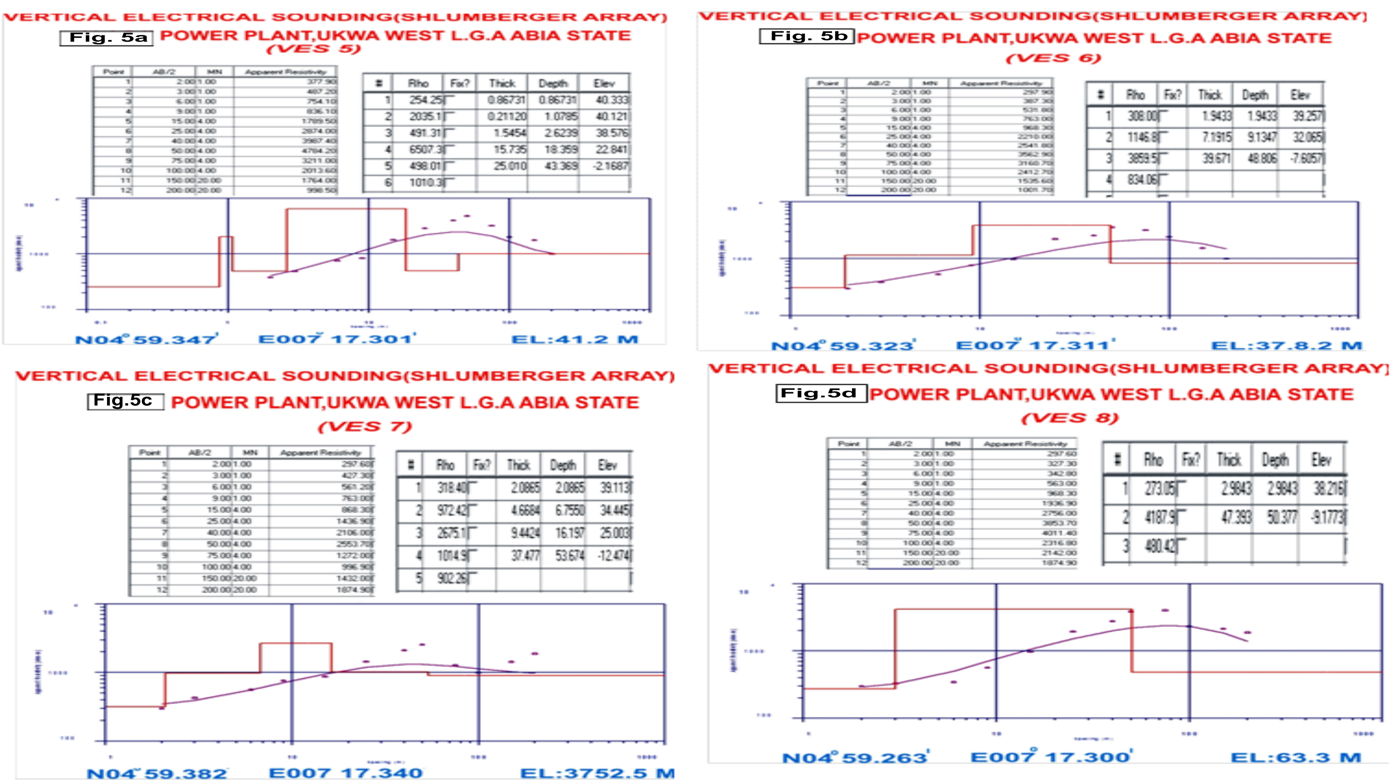

Figure 5: Interpretation of Subsurface Resistivity Values for VES 5, 6, 7 and 8.

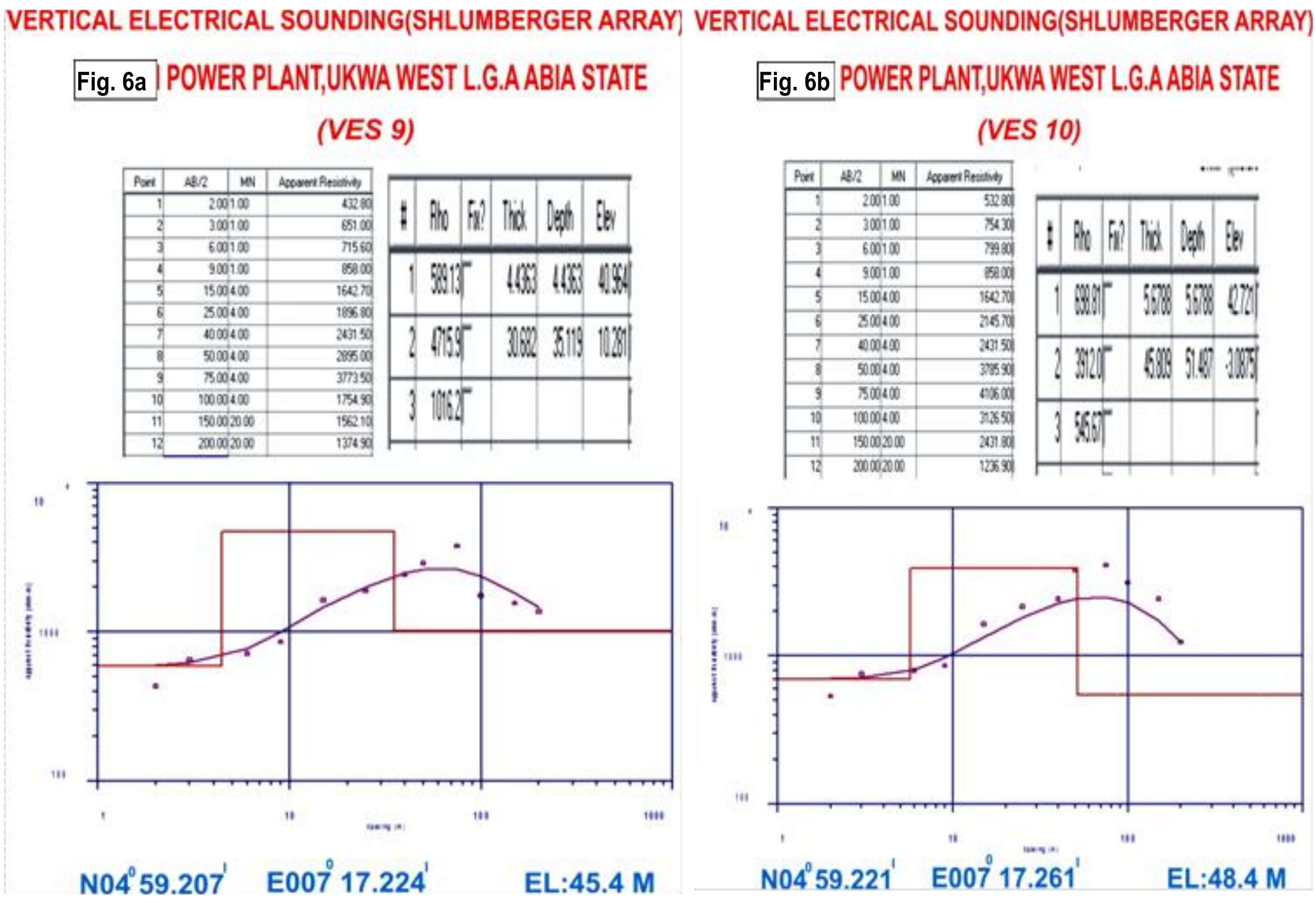

Figure 6: Interpretation of Subsurface Resistivity Values for VES 9 and 10.

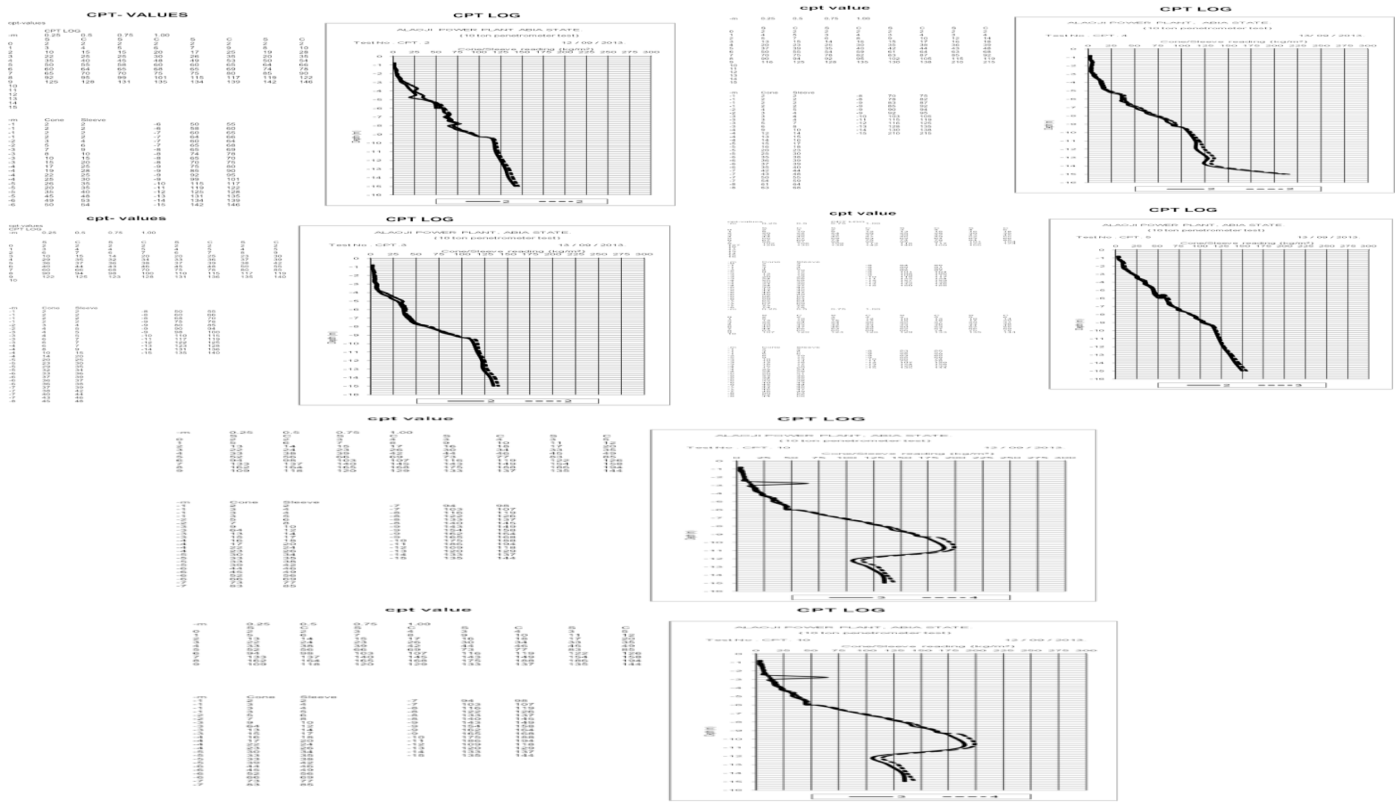

Figure 5: Cone Pentrometer Test for CPT 2, 3, 4 and 5.