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# Geophysical and Geotechnical Investigations of a proposed Site for Afijio Local Government Stadium Ilora, Southwestern Nigeria.

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***Abstract***- Stadium disasters due to inappropriate multiple engineering/geological errors have been part of history of the world necessitating pre construction site investigation using geotechnical and geophysical evaluation of a proposed Site for Afijio Local Government Stadium Ilora, Southwestern Nigeria. gGeotechnical aspect of this research involved, diging of three trial pits and seven samples were taken per pit at interval of 0.5m. The samples were taken to the laboratory for grain size analysis and consistency limits determination following the standards specified by ASTM D6913-04. Furthermore, five points on the proposed site were occupied employing Schlumberger electrode array, with a maximum current electrode spacing (AB/2) of 100m. The data obtained were interpreted using partial curve matching technique and RESIST software. Results of the geotechnical investigation revealed that the soil samples from the proposed site have plastic limit that ranged from 50 – 95 (av. 69), liquid limit from 5 – 25 (av. 15.43) while the plasticity index ranged between 30 and 70 (av.53.57). The soil samples from the proposed site are in the intermediate to high plasticity class, poorly graded and with high percentage finer passing 0.075 mm (av. 96.12%).. Electrical resistivity survey of the study area revealed three geoelectric curves (H, QH and Q) indicative of the preponderance of the combined weathered and fractured layer (unconfined) aquifers system. Five different subsurface lithologic sequences namely; lateritic topsoil, sandy clay, weathered basement, fractured basement and fresh basement were delineated with overburden thickness ranging from 1 to 60m. Geo-electric layers of the VES stations revealed generally, partially weathered/fractured subsurface

Geotechnical assessment revealed that, the average percentage of the finer exceeded 35% approved maximum standard for a foundation material and also the site being underlain by poorly graded soil that did not meet engineering specification for foundation render the site unsuitable such massive structure while the electrical resistivity survey revealed partially weathered/fractured terrain which further confirmed its unsuitability. Except, there is constrain of space, if this site must be used, further investigation must be done using other geotechnical approaches to better understand engineering strength characteristics of the underlying soil for well engineered foundation design to ensuring safety of the proposed structure.

***Index Terms***- Trial pits, Schlumberger arrays, plasticity index, poorly graded, geoelectric curves.

## I. INTRODUCTION

The main purpose of a stadium is to provide entertainment to humans apart from Socio-economic incentive as it provides jobs for its construction and operation. Stadium disasters have been part of history of the world. In 1902, Ibro Stadium in Glasgow constructed using wooden frame terrace collapsed during a Scotland versus England international leading to the death of 26 people. The incident led to the prohibition of wooden scaffold type terraces in favor of solid earth banking (www.stadiumguide.com/timelines/stadium-disasters**).** Burden Park in Bolton collapsed in 1946 due to overloading resulting from high population with estimated crowd of 85,000 people. Thirty five (35) Fans were reported dead while about 400 people were injured. The top of a temporary stand of Stade Furiani in Bastia collapsed in 1992 before the start of a Coupe de France semi-final between SC Bastia and Olympique de Marseille. Eighteen (18) people died and hundreds more were injured [1]. The causes of the collapsed stadia include amongst others; multiple engineering/geological errors, safety breaches, poor planning and poor safety management.

Safety of life and property is paramount in stadium location and construction. The need for pre-foundation studies has therefore become necessary so as to prevent loss of valuable lives and properties that always accompany stadium collapse due to structural failure. Geophysical and Geotechnical investigations have acquired substantial importance in preventing human and material damage due to foundation cracks and other geo-hazard features from deficient geologic structures. The scope of this research encompasses determination of the geotechnical suitability and land stability in the context of the proposed Stadium. The principal objectives of the investigation are to develop an appropriate geotechnical model of the site so that recommendations with regard to land stability and geotechnical constraints to the proposed development are identified. Vertical electrical sounding technique was employed to determine the depth to bedrock, structural mapping and evaluation of subsoil engineering characteristics to assess its competence.

## II. LOCATION AND GEOLOGY

The study area is located at the outskirt of Ilora, along Agricultural Settlement in Afijio Local government area, Oyo State. The study area is just by the side of the road (Fig.1).

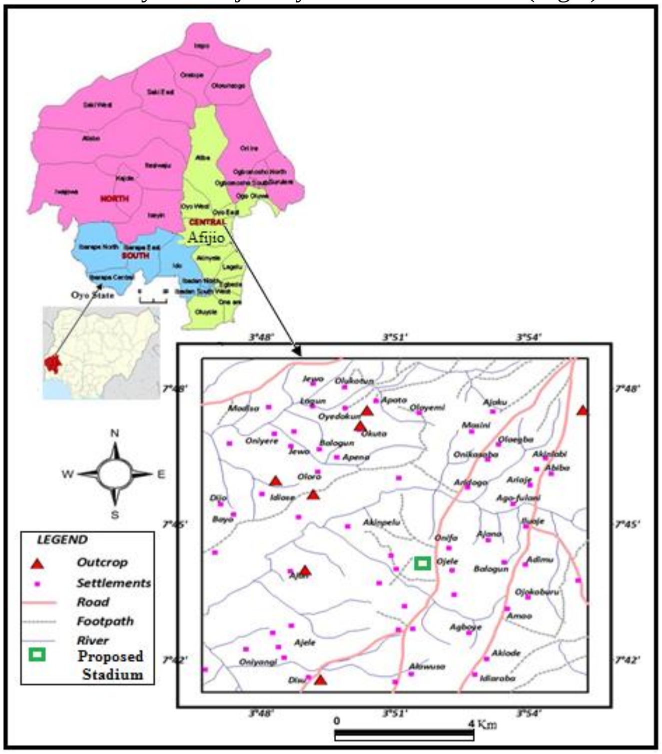


Figure1: Location of Study

The study area has a tropical derived savannah climate with average temperature of $26^0$C and up to $29^0$C during the peak of the dry season. Lower night-morning temperature of 12-18$^o$C is possible during the brief cold period in the harmattan season. The climate is characterized by dry and wet seasons with the dry season covering mid-October to March while the rainy season is from March to mid October. The area has an average annual precipitation of about 1500mm. The local physiography of the proposed stadium site revealed flat relief or topography generally characteristic of derived savannah. The site is a farm land which has suffered a lot of human activities mainly farming and overgrazing by animal. The notable plants in the area include the cassava plantation, cashew and mango trees.

Geologically, the area falls within the Basement Complex of southwestern Nigeria. The evolution of the Basement complex of Nigeria is associated with the general evolution of the African continent. The oldest rocks is the migmatites gneiss with supralcrustal relics which have yielded Archean (c. 2700Ma), and Proterozoic (c.2000Ma) ages [3]. The Principal rock units in Afijio local government include Migmatite gneiss, Banded gneiss and quartzites belonging to the Migmatite gneiss complex. Other minor rocks are the intrusion of quartz pegmatite, and dolerites. There is no outcrop within the vicinity of the proposed stadium site. However, the degree of weathering of the soil as well as any structural deficiency will be determined employing electrical resistivity survey and other necessary geotechnical index properties.

## III. METHODOLOGY

The geotechnical aspect of this study entailed digging of 3 trial pits, each of 3.5m deep. Figure 2 represents sample trial pit in this research. At each pit, disturbed samples were collected at interval of 0.5m. A total of seven samples were collected per pit and taken to the laboratory for further geotechnical tests (grain size analysis and consistency limits) following the standards specified by [2].

Figure 2: Sample Trial Pit dugged during Sampling Operations

Vertical Electrical Sounding (VES) was employed to probe the subsurface of the study area. The extent of pore spaces, joints or fractures as well as the nature of the associated fluid/liquid are said to have significant control on the resistivity of rock/subsurface medium [4]. Five points on the proposed site (one at the centre and one at each angle of the rectangular site) were occupied for fair coverage using Ohmega Ω Resistivity Meter. Schlumberger arrays were employed with the electrodes expanded from a minimum current electrode spacing (AB/2) of 1.0 m to a maximum of 100m. Thus with maximum current electrode separation (AB) of about 200m and potential electrode separation (MN) of 1-10m with geometric relationship between the potential electrodes and current electrodes maintained at MN ≤ 1/5AB, sufficient subsurface current penetration was guaranteed. The focus of such VES operation is primarily on the evaluation of the vertical variation within the subsurface in the selected locations. Subsequent to field survey measurements and data collection, data from VES measurements were subjected to data processing and evaluation as the basis for interpretation of the results of the field measurements. The VES field data were plotted on bilogarithmic paper and processed using the usual manual curve matching technique. This entails the use of a two-layer model master curve alongside with auxiliary curves. For the above-mentioned curve matching techniques, the principle of conversion of geo-resistivity field data to layer or stratified subsurface was upheld in the course of interpretation of the

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processed data. For quantitative interpretation, the result of the manual curve matching interpretation was used as in-put model for computer-assisted RESIST software version 1.0. [5].

## IV. RESULTS AND DISCUSSION

### 4.1. Geotechnical Result

The results of the geotechnical properties of soil samples from the study area are presented in Table 1. The results revealed that the plastic limit ranged from 50 – 95 (av. 69), liquid limit from 5 – 25 (av. 15.43) while the plasticity index ranged between 30 and 70 (av.53.57). In accordance with the plasticity classification of [6], the soil samples are in the intermediate to high plasticity class. Samples D and E were in the intermediate plasticity class, while the remaining samples fell into high plasticity class. Plasticity index is used to know the workability of soil, the lower the plasticity index of a soil the better it is for construction purpose. Plasticity of fines affects engineering properties such as compressibility and shear strength and with the high plasticity of soil samples as indicated in Table 1, the proposed site is considered unsuitable for the location of a stadium. Moreover, the representative particle size distribution curves (Fig.3) of soil samples in this research indicate that the soil is poorly graded. Particle-size distribution curve shows not only the range of particle sizes present in a soil but also the type of distribution of various size particles which affect the engineering properties of soil. Poorly graded soils, with their lack of one or more sizes, leave more or greater voids and therefore a less-dense mass. The soil samples under consideration are fine-grained, clayey with high plasticity index and will require considerable treatment if the stadium is to be sited at this location. The tested soils have percentage finer (percentage passing 0.075 mm) ranging from 94.60 – 97.50% (av. 96.12%). Generally, the tested soil samples have percentage passing 0.075 mm of more than 35% recommended by [7] for a foundation material. The soils can be generally rated as poor sub-grade foundation material. The soils that are largely made up of fine particle are likely to impacting the building with differential settlement as the clay changes volume especially during the change in weather from wet to dry season or vice vasa. Such soil is therefore termed to having poor geotechnical properties as foundation materials than soils that are largely made up of coarse particle.

Table 1: Results of geotechnical properties of soil samples from the study area

| Sample | % Passing sieve no 200 (0.075mm) | $W_p$ | $W_L$ | Plasticity Index (PI) | $D_{10}$ | $D_{30}$ | $D_{60}$ | $C_U$ | $C_C$ | PC | AC | RS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **A** | 96.30 | 60.00 | 5.00 | 55.00 | 0.25 | 0.68 | 2.20 | 8.80 | 0.840 | HP | $A_7$ | Poor |
| **B** | 96.20 | 60.00 | 8.00 | 52.00 | 0.20 | 0.60 | 2.40 | 12.00 | 0.750 | HP | $A_{7-6}$ | Poor to fair |
| **C** | 96.20 | 70.00 | 10.0 | 60.00 | 0.19 | 0.50 | 1.80 | 9.47 | 0.731 | HP | $A_{7-6}$ | Poor to fair |
| **D** | 96.8 | 50.00 | 20.0 | 30.00 | 0.23 | 0.42 | 0.82 | 3.57 | 0.935 | IP | $A_{7-6}$ | Fair |
| **E** | 97.50 | 68.00 | 22.00 | 46.00 | 0.18 | 0.35 | 1.60 | 8.89 | 0.425 | IP | $A_{7-6}$ | Poor to fair |
| **F** | 95.25 | 80.00 | 18.00 | 62.00 | 0.20 | 0.40 | 0.80 | 4.00 | 1.000 | HP | $A_{7-6}$ | Poor to fair |
| **G** | 94.60 | 95.00 | 25.00 | 70.00 | 0.05 | 0.15 | 0.40 | 8.00 | 1.125 | HP | $A_7$ | Poor |
| **Min** | 94.60 | 50.00 | 5.00 | 30.00 | 0.05 | 0.15 | 0.40 | 3.57 | 0.43 | | | |
| **Max** | 97.50 | 95.00 | 25.00 | 70.00 | 0.25 | 0.68 | 2.40 | 12.00 | 1.13 | | | |
| **Mean** | 96.12 | 69.00 | 15.43 | 53.57 | 0.19 | 0.44 | 1.43 | 7.82 | 0.83 | | | |
| **Stdev** | 0.96 | 14.84 | 7.70 | 12.91 | 0.06 | 0.17 | 0.77 | 3.03 | 0.23 | | | |

HP = High plasticity, IP = Intermediate Plasticity, Wp = Plastic limit, WL = Liquid limit, $D_{10}$ = % Finer is 10%, $D_{30}$ = % Finer is 30%, $D_{60}$ = % Finer is 60%, $C_u$ = Uniformity Coefficient, $C_C$ = Coefficient of Curvature, PC = Plasticity Class, AC = AASHTO Class, RS = Rating as subgrade material.

Table 1 revealed that the tested soil samples are of high consistency limits indicating high percentage of clay content in the soil. Generally, soils having high values of liquid and plastic limits are considered poor as foundation materials and as such the location proposed for the siting of the stadium is not likely to be suitable and would otherwise warrants significant modification to upgrade its engineering strength characteristics. The plastic index of all the soil samples are higher than 20% maximum recommended by Federal Ministry of Works and Housing [7], hence it shows a poor engineering property since the higher the plastic index of a soil, the less the competency of the soil as a foundation material. Furthermore, the plasticity chart (Fig. 4) revealed that the soil samples are inorganic clay (lean clay) as PI > 7 and plots above "A" line.

### 4.2. Geophysical Result

Vertical Electrical Sounding (VES) method was adopted to determine vertical variation in geo-resistivity parameter in order to gain insight into the variations in litho-units with depth. Five (5) vertical electrical soundings were carried out to determine the variation of electrical properties of the subsurface with depth. The summary of the interpreted results of the vertical electrical soundings (VES) are presented in Table 1 while the geoelectric curves are presented in Fig. 5. In addition, the geoelectric sections are as shown in Fig 6. The qualitative analysis of the VES interpretation shows that three main curves (H, QH and Q) (Fig.5) predominate the study area. The geo-electric curves are generally indicative of the preponderance of the combined weathered and fractured layer (unconfined) aquifers system in the study area [8]. Furthermore, the geoelectric sections (Fig. 6) that show the variations of resistivity and thickness values of layers within the depth penetrated in the study area at the indicated VES stations, revealed five different subsurface lithologic sequences namely; lateritic topsoil, sandy clay, weathered basement, fractured basement and fresh basement. The topsoil thickness is relatively thin with average resistivity and thickness values of 1201Ω-m and 1m respectively. Sandy-clay was encountered in two locations with resistivity ranging between 76 and 124Ω-m and thickness values from 15 – 60m.

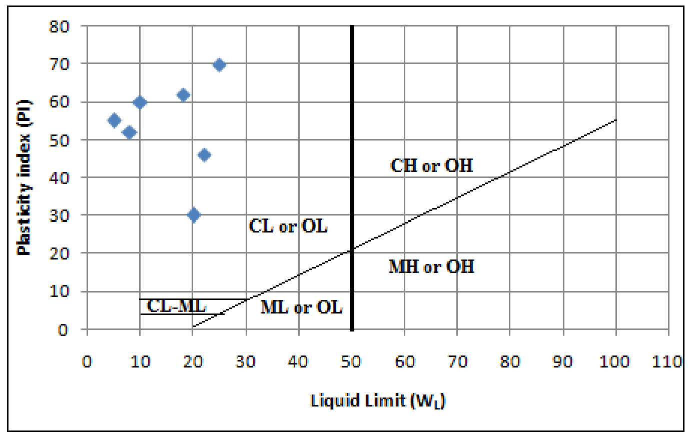
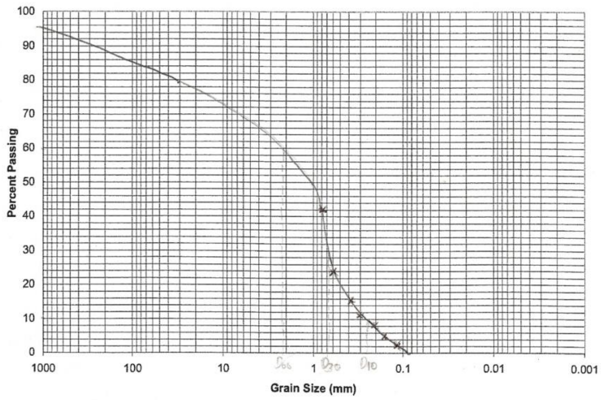
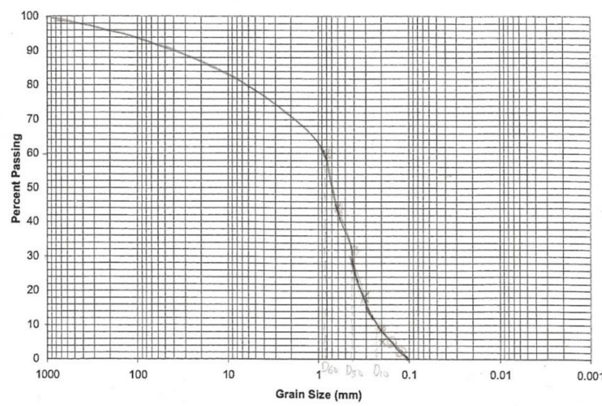



Figure 4: Plasticity Chart indicating the soil type of the study area.

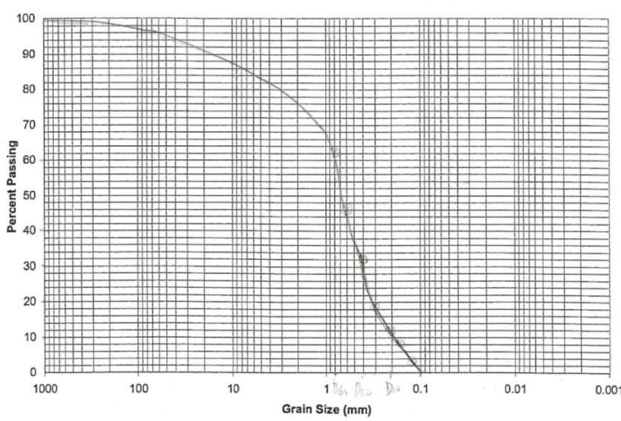
Variation in the estimated overburden thickness ranged from 1 to 60m. This is a clear indication of varied thickness of the weathered regolith across the study area, with bedrock topography reflecting varied degree of weathering of the basement rock units. Weathered Basement was encountered in all the five VES locations and the resistivity and thickness values for the Weathered Basement ranged from 395 - 968Ω-m and 3 - 7m respectively. The Fractured Basement encountered in 3 locations (VES 2, 3 and 5) was characterized with low resistivity (av. 111 Ω-m) and average thickness value of 25m while the Basement which was encountered in only two locations (Fig. 6) has average resistivity and depth of 9820 Ω-m and 31m respectively. Geo-electric layers of the VES stations revealed generally, partially weathered/fractured subsurface units. The thickness of the saturated layer is highest around VES 1 and 4. VES 3 is partially weathered and highly fractured. Though, in term of groundwater potential, virtually, all the VES locations can be drilled for water development but VES 1, 2, and 3 are more promising in the proposed stadium. However, based on the results of geophysical survey under consideration this site is not suitable for stadium location as the area is highly fractured and weathered.




Sample A




Sample D




Sample G

Figure 3: Representative particle size distribution curves of soil samples from the study area

## V. CONCLUSION

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This research was conducted to establish the suitability of a site at Ilora in Afijio local government, Oyo state Nigeria for stadium location. The soil samples from the proposed stadium location are in the intermediate to high plasticity class. The soil is poorly graded with high percentage finer passing 0.075 mm (av. 96.12%).

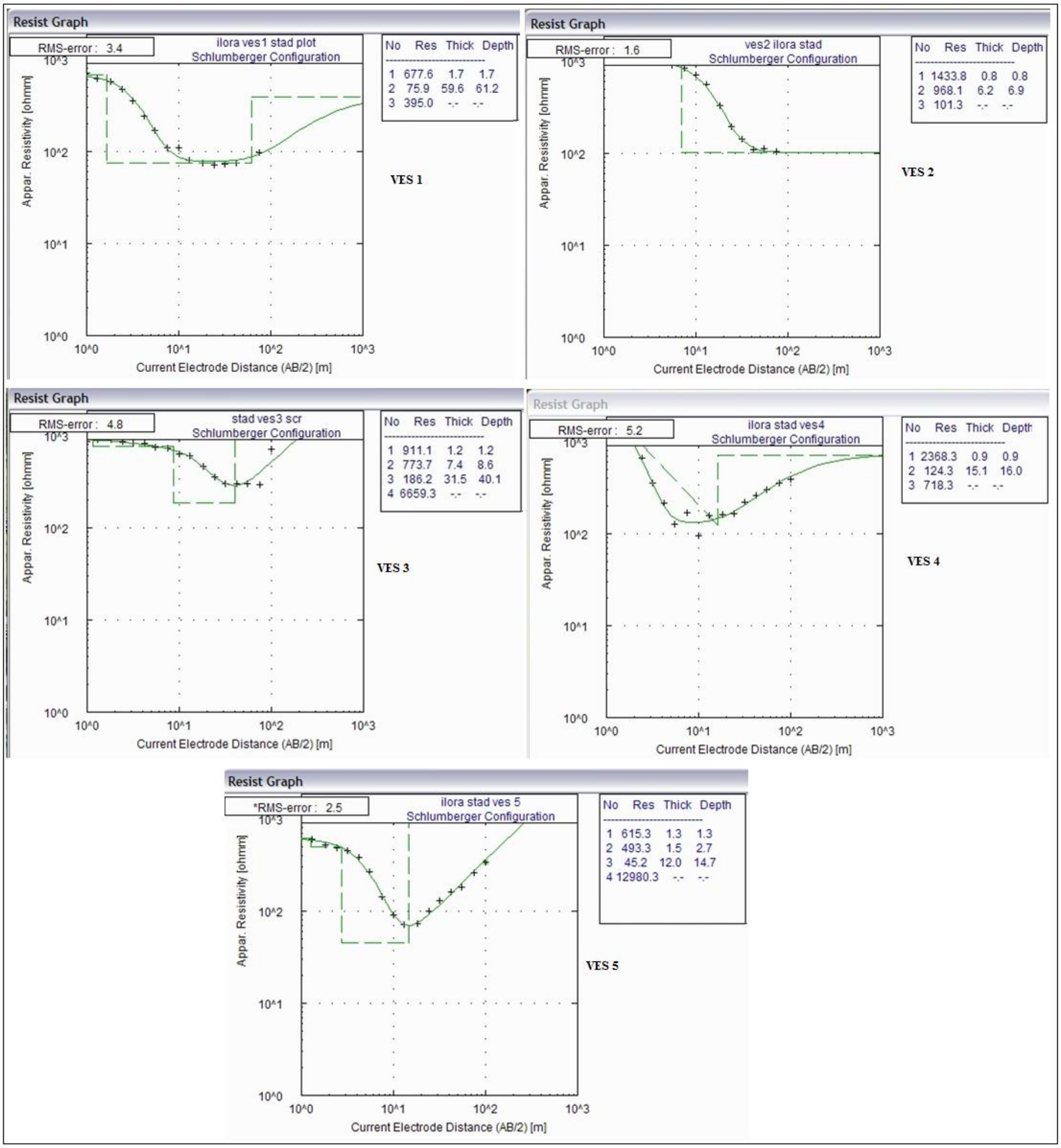


Fig. 5. Geo-electric curves of VES in the study area.

Geophysical survey of the study area revealed three geoelectric curves (H, QH and Q) indicative of the preponderance of the combined weathered and fractured layer (unconfined) aquifers system. Five different subsurface lithologic sequences namely; lateritic topsoil, sandy clay, weathered basement, fractured basement and fresh basement were delineated in the area with overburden thickness ranging from 1 to 60m.. Geo-electric layers of the VES stations revealed generally, partially weathered/fractured subsurface units while the geotechnical evaluation indicated poorly graded soil with high percentage finer. Based on the poor engineering properties of the soil as well as unfavorable result of resistivity survey, the site is not suitable for the stadium location. However, if this location must be used as already proposed, further Geotechnical test such as CPT, Compressive Strength and XRF and Geophysics approach such as ERT and GPR must be carried out to better understand engineering characteristics such as bearing capacity, compressibility in the presence of water, clay minerals and fracture and Joint spacing / orientation for a well engineered foundation design that will ensure safety and stability of the proposed structure.

| VES point | | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| Curve Type Lithology | | H | Q | QH | H | QH |
| Lateritic top soil | Top | 0 | 0 | 0 | 0 | 0 |
| | Base | 2 | 1 | 1 | 1 | 1 |
| | Thickness | 2 | 1 | 1 | 1 | 1 |
| | Ωm | 677.6 | 1434 | 911 | 2368 | 615 |
| Sandy Clay | Top | 2 | - | - | 1 | - |
| | Base | 62 | - | - | 16 | - |
| | Thickness | 60 | - | - | 15 | - |
| | Ωm | 76 | - | - | 124 | - |
| Weathered Basement | Top | 62 | 1 | 1 | 16 | 1 |
| | Base | - | 7 | 8 | - | 4 |
| | Thickness | - | 6 | 7 | - | 3 |
| | Ωm | 395 | 968 | 772 | 718 | 493 |
| Fractured Basement | Top | - | 7 | 8 | - | 4 |
| | Base | - | - | 42 | - | 19 |
| | Thickness | - | - | 34 | - | 15 |
| | Ωm | - | 101 | 186 | - | 45 |
| Fresh Basement | Top | - | - | 42 | - | 19 |
| | Base | - | - | - | - | - |
| | Thickness | - | - | - | - | - |
| | Ωm | - | - | 6659 | - | 12980 |

Table 2: Summary of the VES Interpreted Results

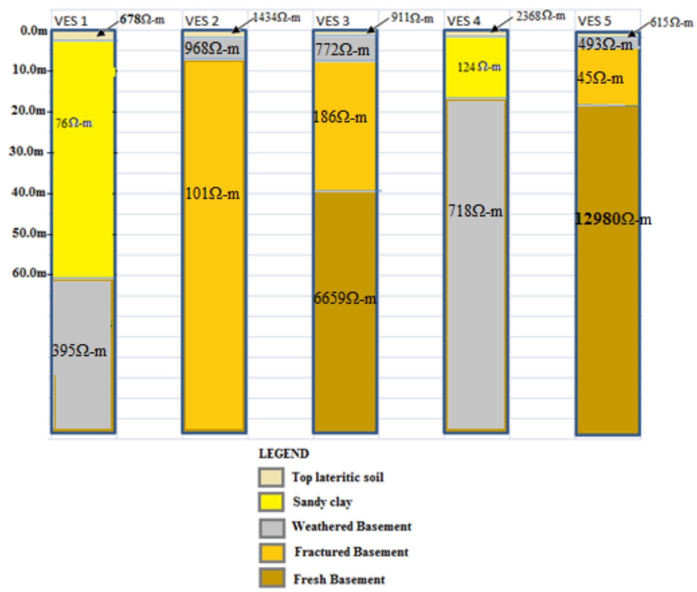


Figure 6: Geo-electric Sections across the VES in the study area.

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