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To cite this article: G. B. Egbeyale *et al* 2019 *J. Phys.: Conf. Ser.* **1299** 012064

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The Electrochemical Society
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240th ECS Meeting ORLANDO, FL

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Abstract submission due: April 9

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Geophysical Investigation of Building Foundation in Part of Ilorin, North Central Nigeria Using Electrical Resistivity Method

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Abstract. Electrical resistivity method has been performed using Vertical Electrical Sounding (VES) technique at a Bishop Smith Memorial College, Ilorin, Kwara State to examine the geophysical parameters that can be used to evaluate the subsurface competency. Eight VES stations were sounded, using Schlumberger configuration for data acquisition with current electrode spacing varying from 1.0 to 140.0 m. The VES data obtained were interpreted using ipi2win+ip Software. The field data acquired was presented as geoelectric sounding curves and geoelectric section. The interpretation of the field results revealed heterogeneous subsurface geologic sequence probed to 34.6 m and beyond. It also showed presence of near surface linear geologic structures of varying lengths, depths and attitude which suggest the competent zones for foundation laying. The major subsurface layers are the top soil which consists of interlocking and concretionary lateritic stones and clayey sand, weathered basement, fractured basement and fresh basement. For building development in the study area, the topsoil must be excavated to at least the Fresh basement (competent layer) to avoid building deformation.

Keywords: Basement, Schlumberger array, bedrock, subsurface competency, foundation failure

1. Introduction

In the last decade, the interest of geophysics in civil and environmental engineering has become a promising approach. The incessant failures of engineering structures such as bridges, roads and building collapse in Nigeria has reached an alarming rate that both Federal and State Government are worried and have instructed their town planning department to come up with regulatory code for any building above a storey [1]. Engineering design and construction of foundation, especially of buildings, dams, highway routes, and bridges requires a sound knowledge of the subsurface. Information are needed on the nature/competence of the soil, the configuration of the subsurface layers, the bedrock topography, and its structural disposition to enable structures to be designed and located to



suit the variable character of the bedrock. Civil engineers need this information to determine the load bearing capacity of the soil in order to decide on the suitable type of foundation for an engineering structure in these areas [2]. In engineering geophysics, the question of the quality of building foundations is frequently addressed in the very late stages, when earthquake damage is either observed or expected [3, 4]. In the case of building construction, geophysics can be applied for exploration purposes to provide useful information regarding the early detection of potentially dangerous sub-surface conditions [5, 6]. Geoelectric methods are thus often used in engineering foundation investigations to evaluate the depth to competent subsurface geologic layers that are stable and suitable for the development of engineering foundations that usually show a distinct contrast in geoelectric characteristics of subsurface geologic materials [7]. More also, this method is faster and cost effective compared to other geophysical methods and provides a comprehensive means by estimating apparent resistivity, depth and thickness of the subsurface layers with a view of defining conductive zones. It is also important to understand the geological basement of an area [8]. Proceeding to this research work, the study area is noted for common cases of foundation failures with dearth of information on the existing literature of subsurface features that may be responsible for the foundation failure. Therefore the current effort is directed at unveiling the situation with a view to find an enduring solution to the existing problem of foundation failure in the area. The aim of this paper presents the use of surface geophysics to determine the cause of foundation failure on some buildings within Bishop Smith Memorial College, Ilorin which manifests in form of tilting and cracks, in Ilorin, Kwara State.

1.1 Location and Geology of the Study Area

The area of study is within Bishop Smith Memorial College, along Admiral Drive, Off Ajase-Ipo/Ilorin way, G.R.A, Ilorin Kwara State. The area is situated on Latitude $08^{\circ}28.359^1$ N- $08^{\circ}29.59^1$ N and Longitude $004^{\circ}34.222^1$ E- $004^{\circ}367.54^1$ E (Figure 1). It is area is situated in the tropical/humid rain forest region, with a climate characterised by wet and dry seasons. The wet season usually occurs from March to October and is dominated by a heavy thunderstorm. The dry season occurs from November to march when the area is under the influence of north-easterly winds. The annual rainfall ranges between/about 1000 and 1500 mm. the annual temperature varied from about 18 °C for a very cold day and 34 °C for very hot day [9]. The geology of the study area is characterized mainly by the presence of older granite and undifferentiated basement complex [10]. There are no visible outcrops in the study area. Locally, granitic and gneissic basement rocks overlain by relatively thick covering of weathered materials underlie the area.

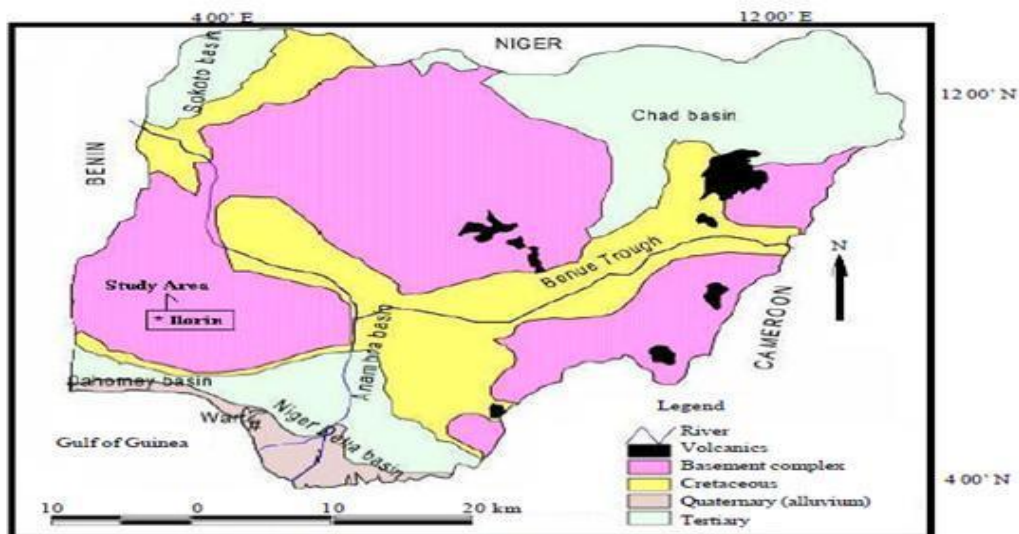


Figure 1: Geological Map of Nigeria revealing the study area, Ilorin, Kwara State [11].

1.2 Theory

Usually, during a resistivity survey electrical current is applied to a pair of current electrodes and the potential difference (voltage) is measured between one or more pairs of potential electrodes. The commonest array types include, Schlumberger, pole-pole, dipole-dipole, pole-dipole and Wenner array. The apparent resistivity is the bulk average of all soils and rock influencing the applied current. It is calculated by dividing the measured potential difference by the input current and multiplying by a geometric factor specific to the array being used, as well as electrode spacing [12]. Vertical Electrical Sounding (VES) employs collinear arrays designed to output a 1-D vertical apparent resistivity versus depth model of the subsurface at a specific observation point. In this method a series of potential differences are acquired at successively greater electrode spacings while maintaining a fixed central reference point. The induced current passes through progressively deeper layers at greater electrode spacing. The potential difference measurements are directly proportional to the changes in the deeper subsurface.

2. Materials and Methods

Measurement of resistivity were made using ABEM WADI (SAS 300B) terrameter, while Global positioning system (GPS) was used to measure or get the elevation above the sea level, longitude and latitude of the VES position. Measuring tape was used to measure inter-electrode spacing separation. Other accessories to the terrameter include the booster, four metal electrodes, hammers and cables for current and potential electrodes. The first step undertaken on the field was the reconnaissance study of the area to know the places to be sounded after taking permission from the land owner. Having established these points, they were marked and Vertical Electrical Sounding using Schlumberger array was carried out. Eight soundings with three traverses were performed in the study area. The maximum spacing of half current electrode $AB/2$ ($AB/2$ = current electrode spacing) ranges from 0.5 m to 70 m,

which was sufficient to achieve the study purposes. The field data and the obtained parameters were input into the system for computer iteration using Resist package [13], which in turn displayed the resultant theoretical curves. The parameters were subsequently varied until what was considered the best possible fit between the field curve and the theoretical curve was obtained for each of VES stations. The parameters of the final models give the layers resistivity and thickness for the VES stations.

3. Results and Discussion

The electrical resistivity method of geophysical prospecting using VES technique was employed to study the subsurface layers to a depth of 34.6 m and beyond. Data generated from the Vertical Electrical Sounding using schlumberger configuration was presented as geoelectric sounding curves. The major geoelectric sequences that were delineated were: topsoil (mostly clayey sand and laterite), weathered basement, fractured basement and fresh basement. The first layer is made up of topsoil (clayey sand and laterite) which has resistivity values ranging from 48.9 – 387 Ωm . The thickness of the layer is between 0.5 and 6.85 m. Beneath the topsoil is the Weathered formation with resistivity values vary from 28.5 – 492 Ωm . The thickness ranges from 0.986 – 4.52 m. The third layer is made up of the fractured basement that has resistivity values ranging from 14.8 – 442 Ωm . The thickness ranges from 4.52 – 34.6 m. The fourth layer with highly resistive fresh basement of 1106 – 26157 Ωm theoretically down infinitely. The summary of the interpreted results of the VES curves at each VES stations are presented in (Table 1). The characteristic curve types obtained in the area are HA, KH, KHA KHK and QH (Figure 2).

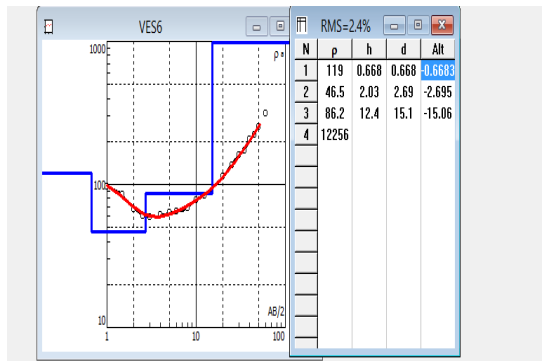
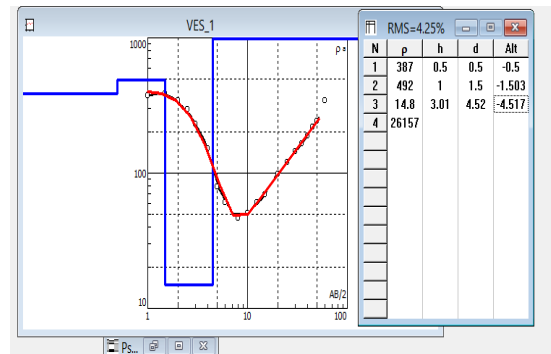
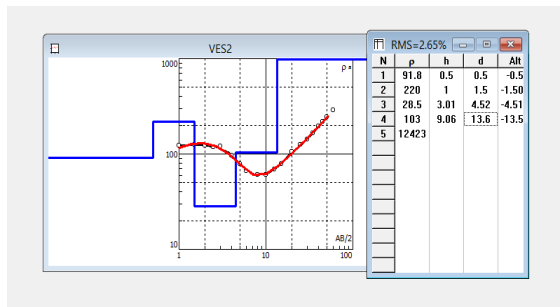
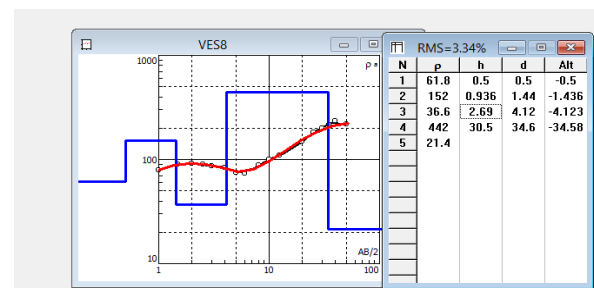
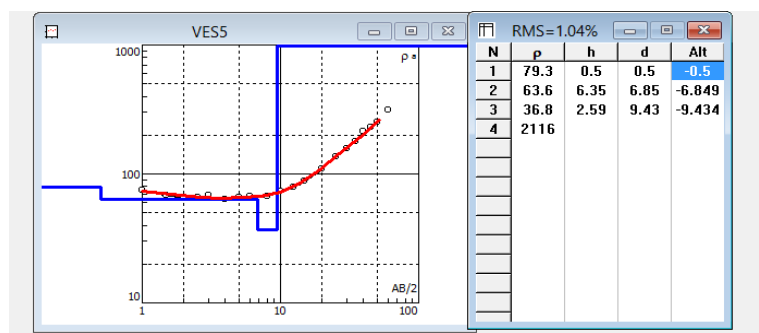
**HA** curve type. (VES 6)**KH** curve type. (VES 1)**KHA** curve type. (VES 2)**KHK** curve type. (VES 8)**QH** curve type. (VES 5)**Figure 2:** Samples of VES curve types of the study area

Table 1. Summary of VES results

VES Station	Layer	Resistivity (Ωm)	Layer thickness (m)	Depth (m)	Curve type	Infer Lithology
VES1	ρ_1	387	0.5	0.5	KH	Topsoil (Clayey sand)
	ρ_2	492	1	1.5		Weathered basement
	ρ_3	14.8	3.01	4.52		Fractured basement
	ρ_4	26157	-	-		Fresh basement
VES2	ρ_1	91.8	0.5	0.5	KHA	Topsoil (laterite)
	ρ_2	220	1	1.5		Clayey sand
	ρ_3	28.5	3.01	4.52		Weathered basement
	ρ_4	103	9.06	13.6		Fractured basement
	ρ_5	12423	-	-		Fresh basement
VES3	ρ_1	80.3	0.5	0.5	KH	Topsoil (laterite)
	ρ_2	198	1	1.5		Weathered basement (Clayey sand)
	ρ_3	29.6	3.01	4.52		Fractured basement
	ρ_4	3054	-	-		Fresh basement
VES4	ρ_1	99	2.78	2.78	KH	Topsoil (laterite)
	ρ_2	186	0.773	3.55		Weathered basement (Clayey sand)
	ρ_3	42.7	2.97	6.52		Fractured basement
	ρ_4	1106	-	-		Fresh bedrock
VES5	ρ_1	79.3	0.5	0.5	QH	Topsoil (Clayey)
	ρ_2	63.6	6.35	6.85		Fractured basement
	ρ_3	36.8	2.59	9.43		Fresh basement
	ρ_4	2116	-	-		
VES6	ρ_1	119	0.668	0.668	HA	Dry laterite
	ρ_2	46.5	2.03	2.69		Weathered basement
	ρ_3	86.2	12.4	15.1		Fractured basement
	ρ_4	12256	-	-		Fresh basement
VES7	ρ_1	48.9	0.5	0.5	KH	Topsoil (laterite)
	ρ_2	176	0.486	0.986		Weathered basement
	ρ_3	45.6	12.5	13.5		Fractured bedrock
	ρ_4	6153	-	-		Fresh basement
VES8	ρ_1	61.8	0.5	0.5	KHK	Topsoil (laterite)
	ρ_2	152	0.936	1.44		Clayey sand
	ρ_3	36.6	2.69	4.12		Weathered basement
	ρ_4	442	30.5	34.6		Fractured basement
	ρ_5	21.4	-	-		Weathered basement

4. Conclusion and Recommendation

Bishop Smith Memorial College, Ilorin, Kwara State was investigated using schlumberger array involving Vertical Electrical Sounding of electrical resistivity method. The VES interpretation reveals that the area is underlain by four major geoelectric layers, the top soil is mainly (clayey/ laterite sand), weathered basement, Fairly Hard (Fractured) basement and Hard (Fresh) basement this means that the top soil may be excavated to the fresh basement depending on the type of structure that is to be erected in the area. From the VES interpretation, it shows that the investigated area is good for foundation laying as a result of the soil composition and geoelectric section of the area (Table 1). The cracks on the buildings within Bishop Smith Memorial College, in Ilorin, may be as a result of poor construction or bad construction materials.

Geophysical survey to site investigation should take the utmost priority before laying foundation, because this measure shall prevent the structure from being collapse in the future. Skyscraper can be built in the study area because there is competent soil materials/rock underlain in the area, such as laterite, fresh basement except for VES6 and VES8. Shallow type of foundation such as strip footing in the competent area of high bearing capacity and raft foundation in the area of less competence are recommended.

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