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GEOPHYSICAL INVESTIGATION OF CAUSES AND CHARACTERISTICS OF ROAD FAILURE ALONG PART OF ILARA-IPOGUN, ONDO STATE, NIGERIA.

Authors: Festus Olusola Eebo & Obaloluwa Abiodun
Federal University of Technology, Akure Nigeria.

ABSTRACT

Geophysical survey using electrical resistivity method involving Schlumberger Vertical Electrical Sounding, 2-D imaging dipole–dipole technique were carried out along part of Ilara-Ipogun road located in the Precambrian Basement Complex of Southwestern, Nigeria. This study is aimed at revealing the subsurface geoelectric sequence, mapping the subsurface structural features within the subsurface and delineating the bedrock relief as a means of establishing the cause(s) of the road pavement failure. The study represents the interpretation of nineteen vertical electrical sounding (VES) and single dipole-dipole profiles to access the possible causes of road failure along the Ilara – Ipogun road, Akure, south-western Nigeria. The geoelectric parameters obtained from the quantitative interpretation of the VES data were used to generate geoelectric section. The geoelectric section generated shows that the study area was underlain by three geoelectric layers namely the topsoil, the weathered layer and the fresh basement. Thus, Clayey composition of the weathered materials characterized by low resistivity values on the geo-electric section/Dipole-dipole pseudo section which is an indication to weak zones that are capable of undermining the stability of the proposed road. The resultant swelling and shrinkage is of the clayey material believed to be responsible for the various cracks/deformation noticed along the studied segment of the road. This therefore suggests that the layer is composed of incompetent materials that are unsuitable for engineering structures. Since fracture is a weak zone, its presence can facilitate failure of the proposed road especially when it is occurring at shallow depth. Although some parts of this segment is still stable, but they are still vulnerable to failed since they have same characteristic with the already failed section.

Keywords: Geophysical survey, Geological features, 2-D resistivity structure.

INTRODUCTION

Incessant failure of highways has become a common phenomenon in many parts of Nigeria. The present condition of most roads in southwestern Nigeria has stimulated the interest of various stakeholders in the usage and maintenance of the highways. Rehabilitating the roads has become a financial burden on the federal, state and local governments. Hence, there is need to identify the cause(s) of road failure and find a means of tackling the problem. Several factors are responsible for road failures, which include geological, geomorphological, geotechnical, road usage, construction practices, and maintenance. The geological factors influencing road failures include the nature of near surface soils, existence of geological structures such as fractures and faults, existence of ancient stream channels, and shear zones. The collapse of concealed subsurface geological structures and other zones of weakness controlled by regional fractures and joint systems along with silica leaching which has led to rock deficiency are known to contribute to failures of highways and rail tracks (Nelson and Haigh, 1990).

The geomorphological factors are related to topography and lack of drainage system by the road sides and which possibly leads to settlement and flow resulting from compressional forces as a result of heavy vehicular movement which weakens the base of the road and consequently resulted in the failure of the investigated segment of the roadway.

For the past decades, geophysics has proved quite relevant in highway investigations (Nelson and Haigh, 1990). Geophysical methods like electrical resistivity has been used in mapping subsurface geologic sequence and concealed structures. In this case, geophysical investigation of causes and characteristics of road failure along part of Ilara-Pogun road has been carried out.

Plate 1.0: Shows the failed segment of the road.

Geotechnical factors include; failure arising from differential settlements on road cut sections that intercept clayey saprolite with high moisture content (Adegoke-Anthony and Agada, 1980; Ajayi, 1987; Oladapo et al; 2008) and failure precipitated by differential settlement associated with significantly thick, low resistivity clay topsoil. The collapse of concealed structure and other zones of weakness are controlled by regional fractures and joint systems along with silica leaching which has led to rock deficiency are known to contribute to failures of highways and rail tracks (Nelson and Haigh, 1960).

Geomorphological factors include effect of topography, rainfall, weathering, surface and subsurface drainage system, erosion, temperature, overburden thickness and topsoil clay content.

Road usage in form of road abuse due to overloading, existence of landfill or waste dumps close to roadways, excavation across roadways for burial of utilities such as cables and pipes can all result in road failures. The application of geophysical methods is quite relevant in highway investigations because it can be used universally in mapping of all these hidden geologic structures and subsurface geologic sequences (Olorunfemi *et al*; 1986).

The road portion investigated in this study is along Ilara-Ipogun road in Ondo State. It has failed repeatedly over the years, despite efforts made to rehabilitate it by resurfacing it with bituminous materials.

1.3 LOCATION AND DESCRIPTION OF THE STUDY AREA.

Ipogun is a community opposite Ilara mokin town situated at Ifedore Local Government Area of Ondo State. It is located between the geogragraphic coordinates 7^{o} 18’ 53”N and 5 ^{o} 04’ 48”E, it is about 20km from Akure. The surveyed segment covers a length of 320m of Ilara-Ipogun road in the S-E to N-W direction, characterised by good (stable) sections, cracks, and some failing sections. The study section of the road falls within Easting 730433 are730601mE and Northing 810010 and 810241mN, Minna Datum and zone 32 (Fig.1.1).

1.3.1 Geomorphology Climate of the Study Area

The study road is characterized by gently to moderately undulating, with elevation ranging from 348m to 390m above sea level. The area is characterized by two seasons: the wet season; that spans through March and October, with an average annual rainfall of about 1800mm to 3700mm. The dry season is usually from November and early March, with an average maximum temperature of about 31^{o}C. The relative humidity is usually above 56% as a result of the laden moisture.

The major pattern of drainage is dendritic drainage pattern. Streams and water run-off are structurally controlled and it flows in a southwest direction with vegetation along its direction of flow.

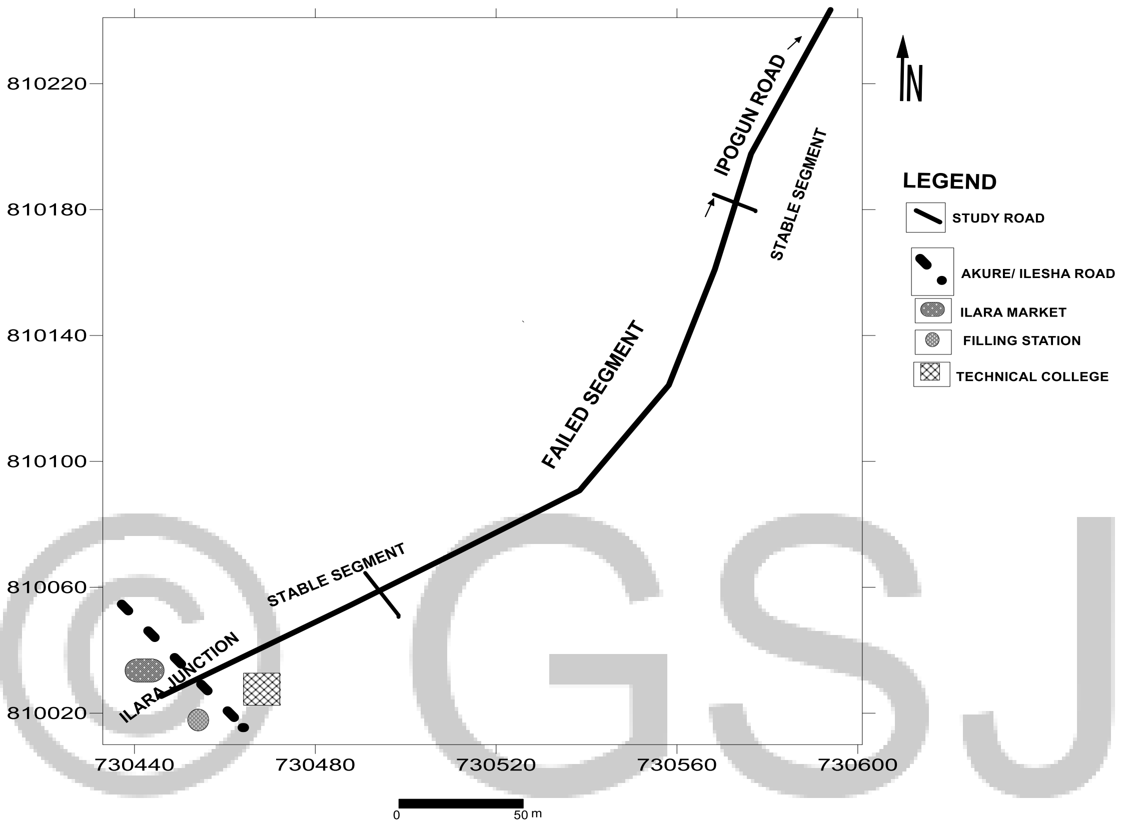

Fig 1.1: Base Map of Part of Ilara-Ipogun Road Showing the Study Stable (?) and Failed Segment.

2.1 GEOLOGICAL SETTING OF THE AREA AROUND THE STUDIED ROAD

The area where the road is located lies within the southwestern Nigeria Basement complex (Fig 2.1). The geology of the area underlain by southwestern Basement complex rocks which has been identified to five rock groups in choronological order, starting with the oldest as Migmatite-gneiss-quartzite complex, slightly Migmatised to unmagmatised paraschist and Metaigneous rocks, Charnockitic rocks, older Granites and minor rock types (Rahman, 1989).

Foliation, lineation and minor fields are the three principal structure elements in the Basement complex. The greater past of southwestern Basement is characterised by strike of foliation in a general N-S direction with distributions in the NW-SE and NE-SW direction.

2.1.1 Geology of the Area along the Studied Road

The geology of the study area (Ipogun Community) falls within the basement complex of south western Nigeria. The study road segment is located along Ilara-Ipogun road, Ondo state. Therefore, the major rock types in the area have been studied and classified by Adekoya et al; (2011).On the outcrops are occurrence of pegmatite, aplite and some quartz veins intrusions. The gneiss-migmatite-quartzite complex, (Fig.2.2), the schist belts which are low to medium grade supracrustal and meta-igneous rocks; The Pan African granitoids (Older Granites) and other related rocks such as charnockitic rocks and syenites; and Minor felsic and mafic intrusives. The charnockitic rocks of Akure constitute one of the petrologic units of the precambrian basement

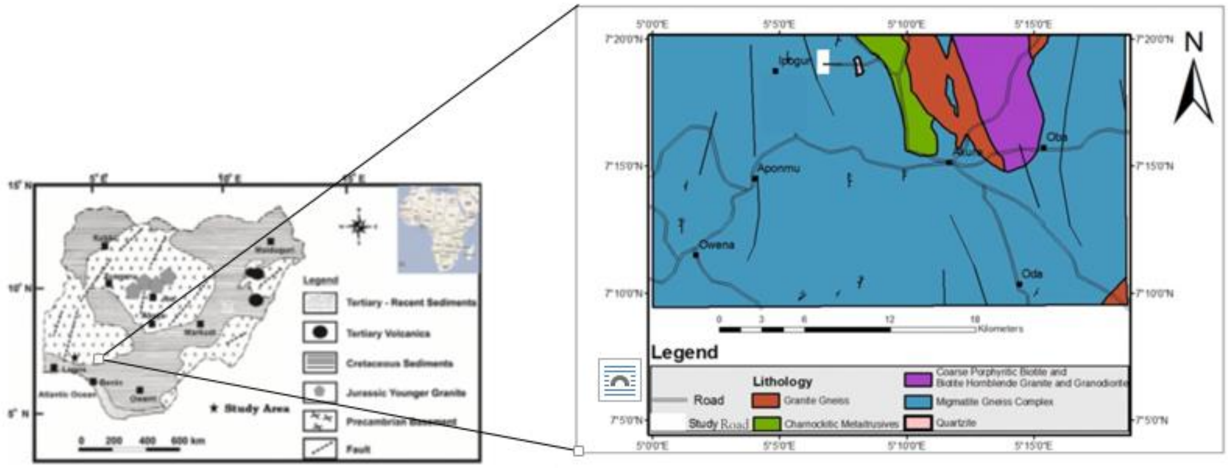

Fig 2.1: Geological Map of Akure Showing the Studied Road (Adapted from Ademeso, 2009) and Geological Map Of Nigeria Showing the Basement Complex (After Rahman, 1989).

3.0 MATERIALS AND METHODS OF STUDY

A traverse line was established along the study road segment in the N-S direction. The geophysical electrical resistivity method was utilized, using the ohmega resistivity meter employing both vertical electrical sounding (VES) and the combine Horizontal profiling and vertical electrical sounding (dipole-dipole profiling techniques).

3.1 Vertical Electrical Sounding (VES)

The geo-electric survey involves vertical electrical sounding (VES) using schlumberger array. In this technique, vertical variation in the ground's apparent resistivity were measured with a fixed centre of array, the survey is carried out by gradually expanding or increasing the electrode spacing about a fixed centre of the array. During this survey, sixteen vertical electrical sounding (VES) stations were occupied, with half electrode spacing (AB/2) varies from 1 to 65m. This was done at irregular interval along the traverse. (Fig.3.1).

The apparent resistivity values obtained at each station plotted against electrode spacing on bi-logarithm graph. The resistivity curves were processed with the aid of partial curve matching techniques. The results of the curve matching (layer resistivity and thickness) were fed into the completion as starting model parameter in an iteration forward modeling using WinResist. From the interpretation section along the traverse was generated.

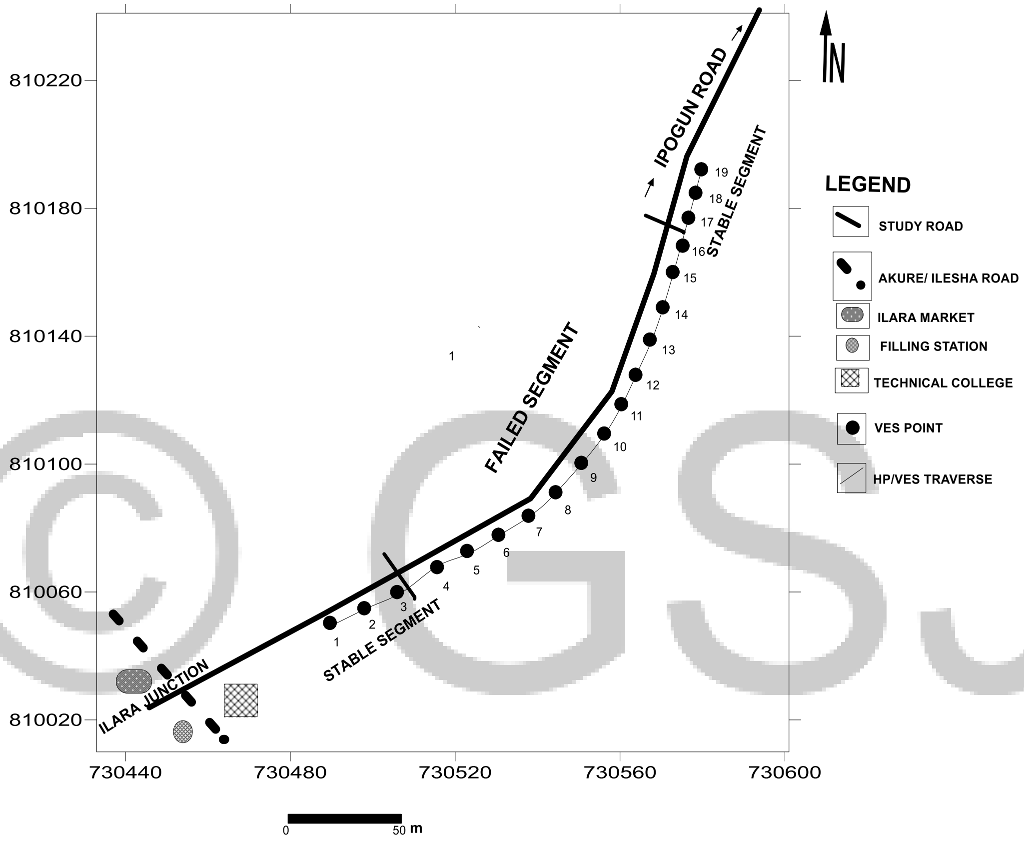

Fig 3.1: **Data Acquisition Map Showing the VES Stations and HP/VES Traverse.**

3.2.2 Combine Horizontal Profiling/Vertical Electrical Sounding (HP/VES)

The combine horizontal profiling/vertical electrical sounding technique involves the dipole-dipole array. The dipole-dipole array was adopted to determine both the lateral and vertical variation in ground apparent resistivity beneath the traverse line. This was carried out along a profile along the traverse (Fig 3.1). Currents were passed into the ground through the current electrodes and the potential difference between the potential electrodes was measured. The measurements were made at electrode spacing a=10m. The combine horizontal profiling / vertical electrical sounding (HP/VES) data generated using the dipole-dipole array was modelling using DIPPRO for window Software to generate the 2-D resistivity inversion.

4.0 RESULTS AND DISCUSSIONS

The interpretation results of the VES curves were presented as tables and geo-electric sections. The combine horizontal profiling/vertical electrical sounding data were presented as 2-D resistivity image.

The results of the interpreted VES curves are presented in Table 4.1. Depth sounding curves obtained from the study are presented in Figures 4.1 and 4.2 . The resistivity sounding curve types obtained along the traverse are the A and H curve types.

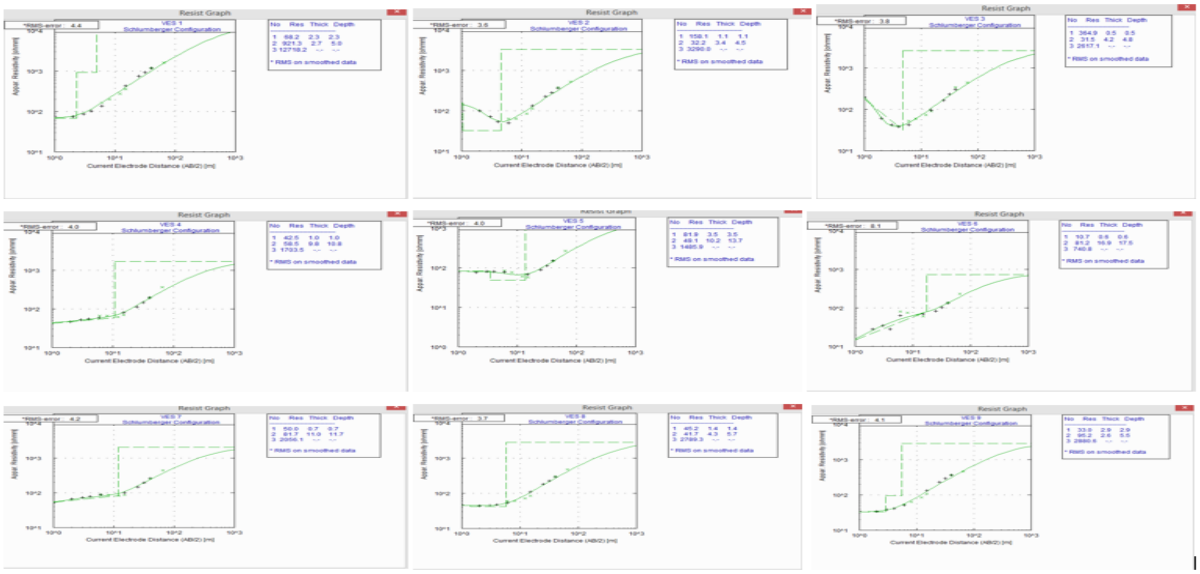

Figure 4.1: Shows VES Curves 1 to 9.

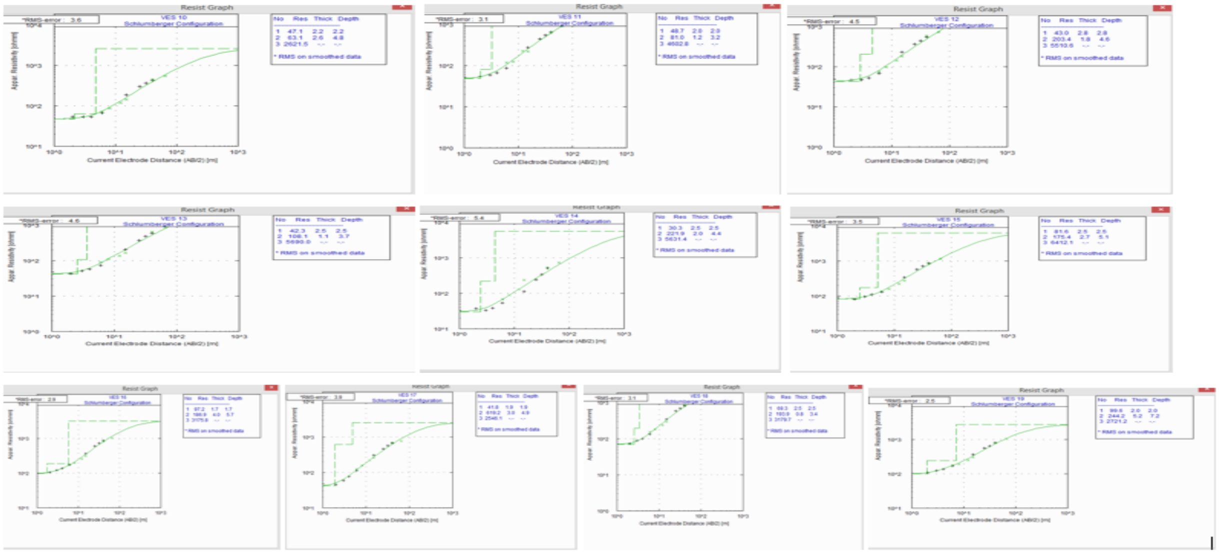

Figure 4.2: Shows VES Curves 10 to 19.

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Table 4.1: Summary of VES Interpretation Results

VES STATION	THICKNESS (m)	RESISTIVITY (Ωm)	CURVE TYPES	LITHOLOGY
1	2.3 / 2.7	68 / 921 / 12718	A	Top soil/Partially fractured rock/ Fresh basement
2	1.1 / 3.4	158 / 32 / 3290	H	Lateritic soil/Weathered rock/ Fresh basement
3	0.5 / 4.2	365 / 32 / 2617	H	Lateritic soil/Weathered Clayey rock/ Fresh basement
4	1.0 / 9.8	43 / 59 / 1704	A	Top soil/Weathered Clayey rock/ Fresh basement
5	3.5 / 10.2	82 / 49 / 1486	A	Top soil/Weathered Clayey rock/ Fresh basement
6	0.6 / 16.9	11 / 81 / 741	A	Top soil/Weathered Clayey rock/ Fresh basement
7	0.7 / 11.0	50 / 82 / 2056	A	Top soil/Weathered Clayey rock/ Fresh basement
8	1.4 / 4.3	45 / 42 / 2789	A	Top soil/Weathered Clayey rock/ Fresh basement
9	2.9 / 2.6	33 / 95 / 2881	A	Top soil/Weathered Clayey rock/ Fresh basement
10	2.2 / 2.6	47 / 63 / 2622	A	Top soil/Weathered Clayey rock/ Fresh basement
11	2.0 / 1.2	49 / 81/ 4603	A	Top soil/Weathered Clayey rock/ Fresh basement
12	2.8 / 1.8	43 / 203 / 5511	A	Top soil/Weathered Clayey rock/ Fresh basement
13	2.5 / 1.1	42 / 108 / 5690	A	Top soil/Weathered Clayey rock/ Fresh basement
14	2.5 / 2.0	30 / 222 / 5631	A	Top soil/Weathered Clayey rock/ Fresh basement
15	2.5 / 2.7	82 / 175 / 6412	A	Top soil/Weathered Clayey rock/ Fresh basement
16	1.7 / 4.0	97 / 187 / 3176	A	Top soil/Weathered Clayey rock/ Fresh basement
17	1.9 / 3.0	42 / 619 / 2546	A	Top soil/Weathered Clayey rock/ Fresh basement
18	2.5 / 0.8	69 / 194 / 3180	A	Top soil/Weathered Clayey rock/ Fresh basement
19	2.0 / 5.2	100 / 244 / 2721	A	Top soil/Weathered Clayey rock/ Fresh basement

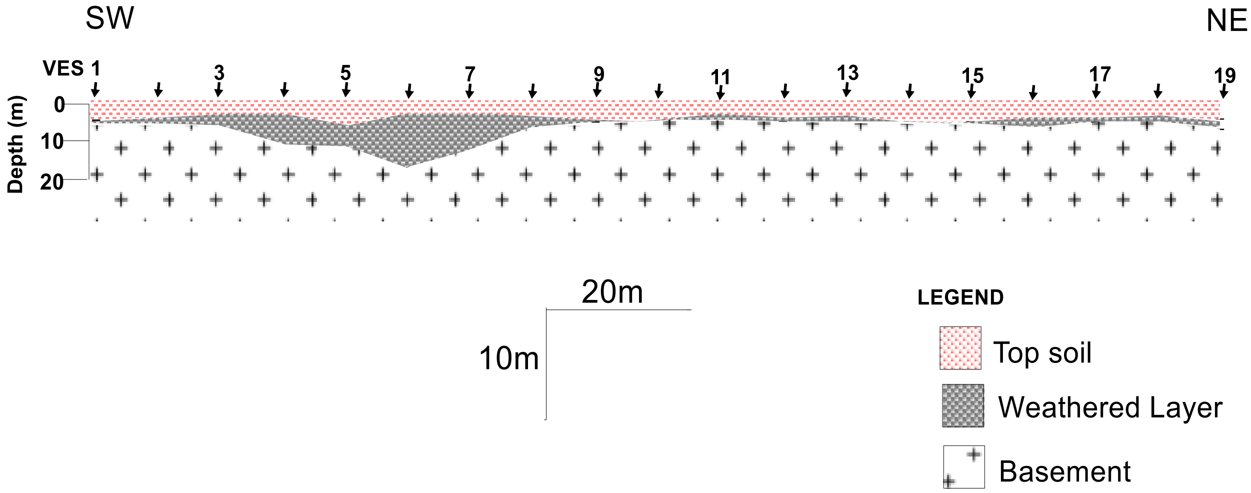

Fig 4.3: Geo-electric Section Along the Study Road.

4.1 Combined Horizontal Profiling (HP) and Vertical Electrical Sounding (VES) (2-D Electrical Imaginary)

The combine horizontal profiling/vertical electrical sounding data were presented as 2-D inverted resistivity structure. These models cover distance from 0-380m along the road segment under investigation. The 2-D resistivity structure shows subsurface sequence comprised of topsoil with the resistivity in the same range as the weathered layers usually merging into the latter (Fig 4.4). Low resistivity topsoil/weathered layers is virtually thick and up to 15m or more in places. Suspected steeply dipping common features are located at station between 24(240m) and 28(280m). The features have significant depth extent that is greater than 30m.

The 2-D inversion also shows a depression of station between 0(0m) and 15(150m). The 2-D inversion model has low percentage of correlation with the geo-section.

4.2 CORELLATION OF RESULTS

The results obtained from the two basic field techniques used (vertical electrical sounding/ dipole-dipole) in the electrical method of investigating the subsurface integrity of the investigated portions of the roadway in a view to determine the probable causes of road failure along the road, showed a similar relationship in terms of their lithology and stratigraphy.

It was observed on the 2-D resistivity structure and pseudo-sections that the major areas of the failed and stable(?) segment fall between the areas of relatively low resistivity which can also be compared to the areas which have a thick weathered layer or plastic clay lithologic unit on the geo-electric sections (Fig.4.5).

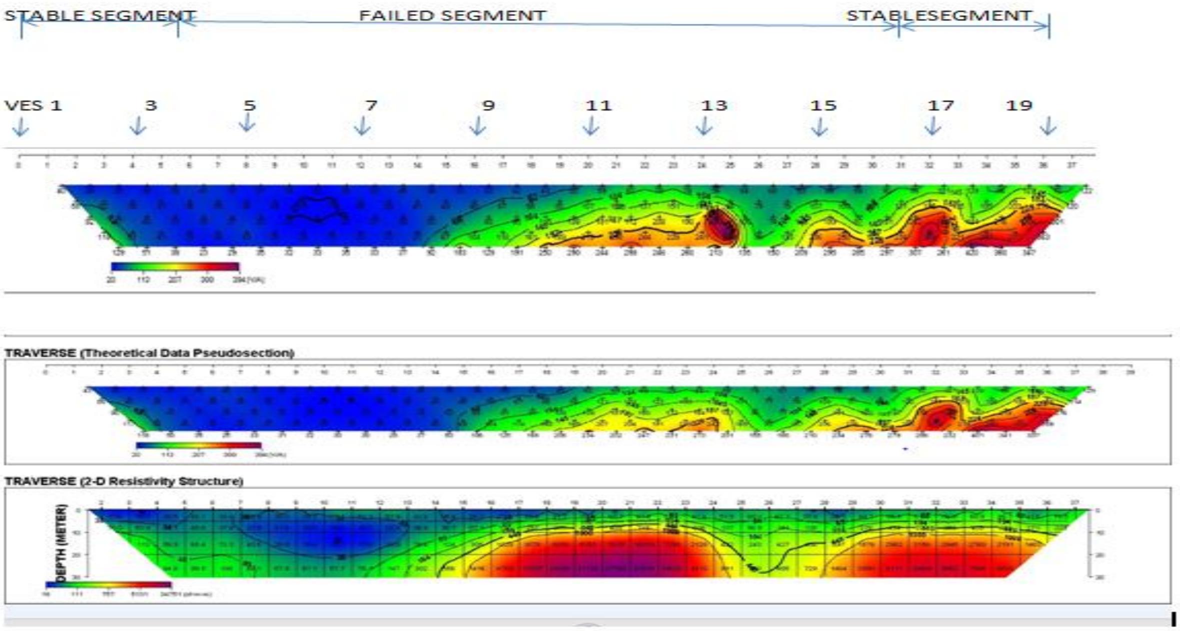

Fig 4.4: 2-D Modeling of Dipole-Dipole Data along the Investigated Road Segment.

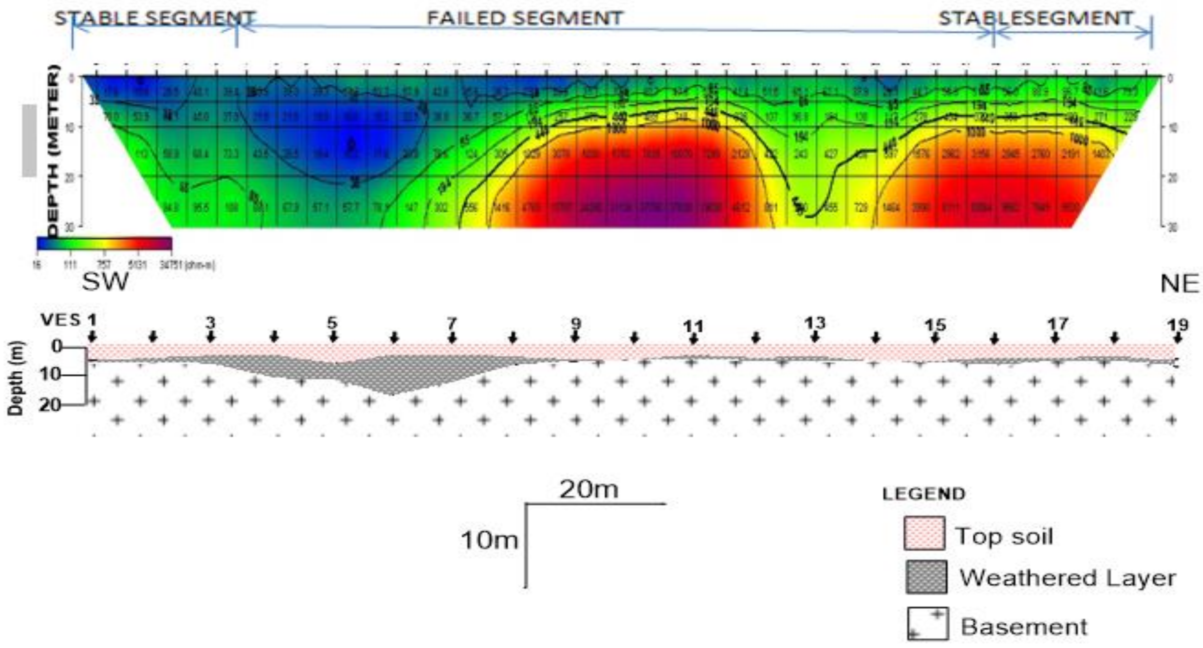

Figure 4.5: Correlations of Dipole-Dipole and Vertical Electrical Sounding Results

It is observed from the geo-electric section and the 2-D resistivity structure that there is a depression between stations 0-19 (0-190m) and 24-28 (240-280m) which could be indicative of a fracture/faulted Basement bedrock. The suspected geological features between station 24 (240m) and 28 (280) was not delineated by the geoelectric section

5.0 CONCLUSION

This study represents the interpretation of nineteen vertical electrical sounding (VES) and single dipole-dipole profiles to access the possible causes of road failure along the Ilara – Ipogun road, Akure, south-western Nigeria.

Clayey composition of the weathered materials characterized by low resistivity values on the geo-electric section/Dipole-dipole pseudo section. The resultant swelling and shrinkage is of the clayey material believed to be responsible for the various cracks/deformation noticed along the studied segment of the road. Although some parts of this segment is still stable, but they are still vulnerable to failed since they have same characteristic with the already failed section.

Conclusively, the underlying geological material (clayey materials) and linear geologic features are the factors responsible for pavement instability along the study segment causing the failure of this segment.

5.1 RECOMMENDATION

The results of this study have successfully shows the applied ability of geophysical method in post road investigation and would therefore like to recommend as follows:

(i) That geophysical investigation showed be undertake at all the failed segments noted along the road.

(ii) That if possible, road cut into clayey substructure should be avoided or evacuated and refil with competent materials like laterite..

(iii) That road pavement suspected to be underlain by bedrock with linear feature such as fractured, fault should be properly reinforced.

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