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Geophysical Investigation of Pavement Failure on a Portion of Okene-Lokoja Highway, North Central Nigeria

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Abstract

Non-destructive geophysical methods involving electrical resistivity sounding and very low frequency electromagnetic profiling were used in investigating the cause of pavement failure on a portion of Okene-Lokoja highway North Central Nigeria. Seventeen (17) soundings were acquired and very low frequency electromagnetic profiling data were taken at 10m intervals along 2 traverses. The geoelectric section shows that the unstable portion of the highway is characterized by thin topsoil and low resistivity weathered layer(clay) between 58Ωm-125Ωm and partly weathered/fractured bedrock with resistivity between 69Ωm-140Ω, while the VLF-EM profile and 2-D VLF-EM pseudosection indicate the presence of conducting bodies with (> 50%) positive peak of the filtered real amplitude (anomalous high current density) which is indicating clayey material or linear geological structures such as faults, fractures, joints and lithological contacts . Low resistivity weathered layer (clay), partly fractured bedrock and linear geological structures have been identified as the cause of pavement failure in the study area.

Keywords: Geological structures, Geophysical method, Pseudosection, Non-destructive, fractured bedrock.

1. Introduction

Improved road transport facilities in any developing nation provides economic and social opportunities and benefits that result in a multiplier effects such as better accessibility to markets, employment and additional investments. But if they are deficient in terms of capacity and reliability, they can have an economic cost such as reduced or missed opportunities and lower quality of life.

Road network system has sewed Nigeria together than any form of integration scheme and has contributed to her economic growth. However, it has been observed that over the years her road often deteriorates few months after they are reconstructed and maintained. These pavement failures are often seen as cracks, ruts, depression, potholes and bulges on our roads which have adverse effect on both vehicles and passengers.

Studies of past road failures showed some major causes; usage, poor design and construction problems (Levik, 2002), use of substandard material for road construction (Momoh etal 2008), bedrock depressions (Adeyemo etal, 2012) and presence of undetected linear features, such as fractures and rock boundaries (Akintorinwa etal, 2010). The present study is carried out to unravel the cause of pavement failure in the study area using environmental benign, cost effective and efficient geophysical methods.

2. Location of the Studied Highway

The Okene-Lokoja highway in Kogi State, North central Nigeria is the major link from the north to east, west and south of Nigeria and vice-versa. It is also the main entrance to Abuja and exit route from the federal capital territory, with heavy presence of vehicular movement.

The road under study is about 500m long and lies between latitude $7^{0} 35^{1} 334^{11}$N and $7^{0} 36^{1} 709^{11}$ N, and longitude $6^{0} 15^{1} 479^{11}$ E and $6^{0} 16^{1} 408^{11}$ E. The area falls within the guinea savannah belt with shrubs and tall trees alongside two distinct seasons; dry and wet. It usually rains from April to November; the topography of the area is rugged with a sloppy land scape characterized by poor drainage system.

3. Geologic Setting

The study area falls within the basement complex of south western Nigeria and is underlain by the following rock units: migmatite-gneiss complex, slightly migmatised to unmigmatised para-schists and meta-igneous rocks; Charnockitic, older granite suites and dolerite dykes (Rahaman, 1976).

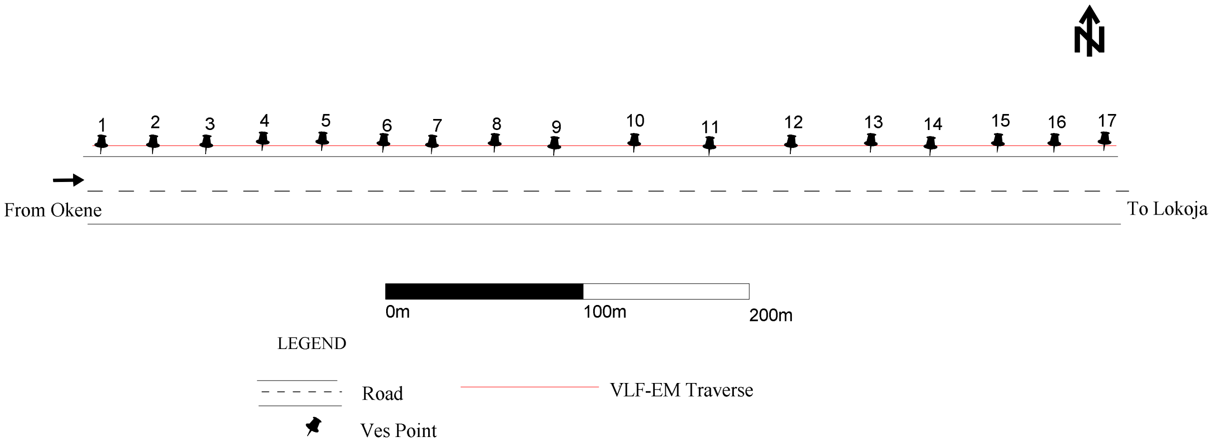


Figure 1: Typical field layout

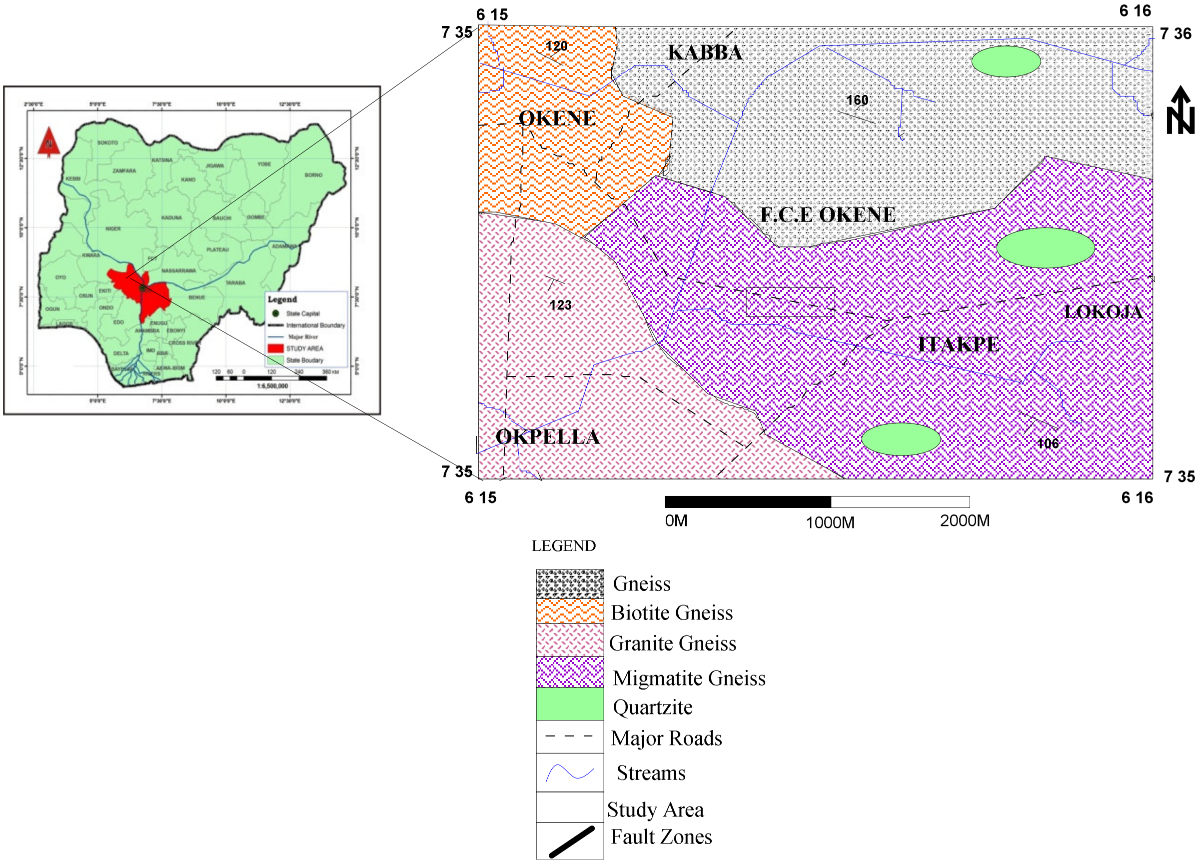


Figure 2: Geological Map the Okene Area showing the studied highway (modified after Adewale, 2011).

4. Material and Method

Integration of surface geophysical methods namely; the Electrical resistivity and Very Low Frequency Electromagnetic (VLF-EM) methods were used on 2 traverse along the road with each traverse about 250 m in length.

The Electrical resistivity method utilized the vertical electrical sounding (VES) involving the Schlumberger array, ABEM SAS 1000 Terrameter was used to acquire resistivity data. Seventeen (17) sounding stations were occupied with not more than 30m station-station interval and the current electrode spacing(AB/2) was varied from 1m to 65m with maximum spread length of 130m.

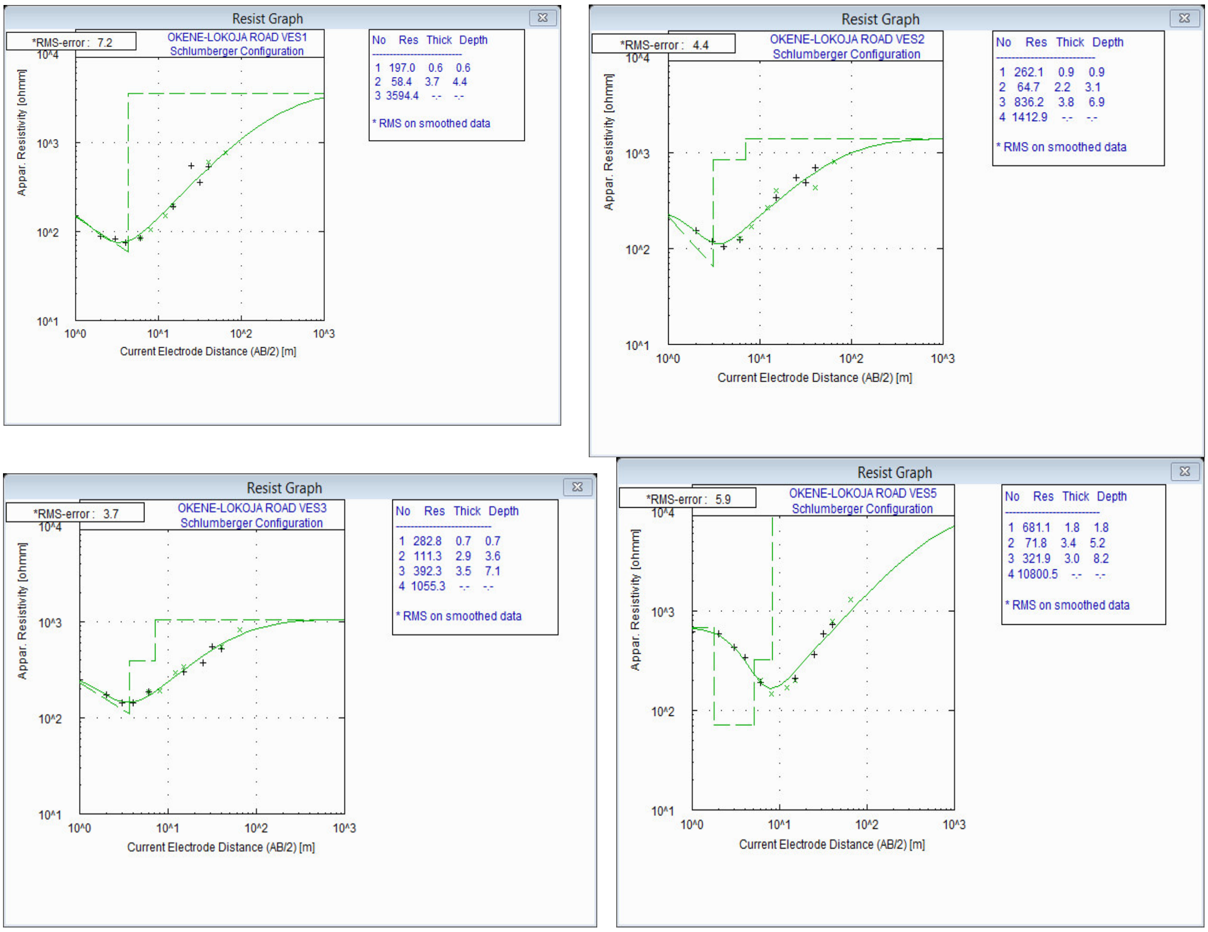
The data obtained from each station were plotted on transparent bi-logarithmic graph sheet to generate a smooth curve for interpretation by manual partial curve matching. The partial curve matching techniques involves the matching of successive segment of the field curve by a set of theoretical curves (Orellana and Mooney, 1966) and auxiliary curves. The geoelectrical parameters obtained from the partial curve matching were smoothened by computer iteration technique using Win Resist software (Vander Velpen, 1988).

The Very Low Frequency Electromagnetic (VLF-EM) method which was used to compliment the electrical resistivity method in this study makes use of the profiling technique. VLF-EM measurements were taken 10m interval along each traverse with ABEM Wadi portable VLF-EM surveying equipment. This equipment makes no contact with the ground, but utilizes very low frequency band of 15-30 KHZ with a fixed transmitter measuring the raw real and filtered real components of the vertical to horizontal magnetic field ratio (Karous and Hjelt, 1983). The raw and filtered real values (%) are plotted against station positions (m) using 'KHFILT' software and a 2 D pseudosection is obtained after processing the data.

5. Results and Discussion

The result of the processed electrical resistivity and Very Low frequency electromagnetic profiling data are presented as sounding curves (fig 3), geoelectric section (fig 4c), VLF-EM profile (fig 4a) and 2 D VLF-EM pseudosection (fig 4b).

The interpreted VES curve result obtained from the study area is summarized as shown in table 1. Three curve types were identified and these include H, HA and KH type, with the numbers of layers delineated ranging from 3 to 4.



Resist Graph

*RMS-error : 7.2

OKENE-LOKOJA ROAD VES1
Schlumberger Configuration

No	Res	Thick	Depth
1	197.0	0.6	0.6
2	58.4	3.7	4.4
3	3594.4	-.-	-.-

* RMS on smoothed data

Resist Graph

*RMS-error : 4.4

OKENE-LOKOJA ROAD VES2
Schlumberger Configuration

No	Res	Thick	Depth
1	262.1	0.9	0.9
2	64.7	2.2	3.1
3	836.2	3.8	6.9
4	1412.9	-.-	-.-

* RMS on smoothed data

Resist Graph

*RMS-error : 3.7

OKENE-LOKOJA ROAD VES3
Schlumberger Configuration

No	Res	Thick	Depth
1	282.8	0.7	0.7
2	111.3	2.9	3.6
3	392.3	3.5	7.1
4	1055.3	-.-	-.-

* RMS on smoothed data

Resist Graph

*RMS-error : 5.9

OKENE-LOKOJA ROAD VES5
Schlumberger Configuration

No	Res	Thick	Depth
1	681.1	1.8	1.8
2	71.8	3.4	5.2
3	321.9	3.0	8.2
4	10800.5	-.-	-.-

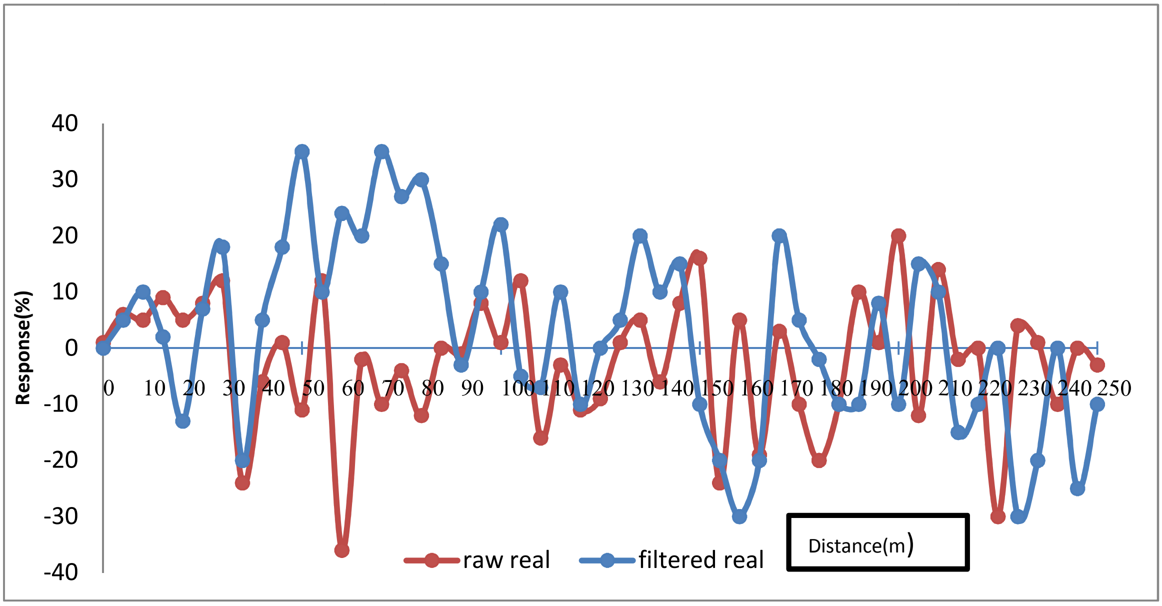
* RMS on smoothed data

Figure 3: Typical VES curve obtained from the study area.

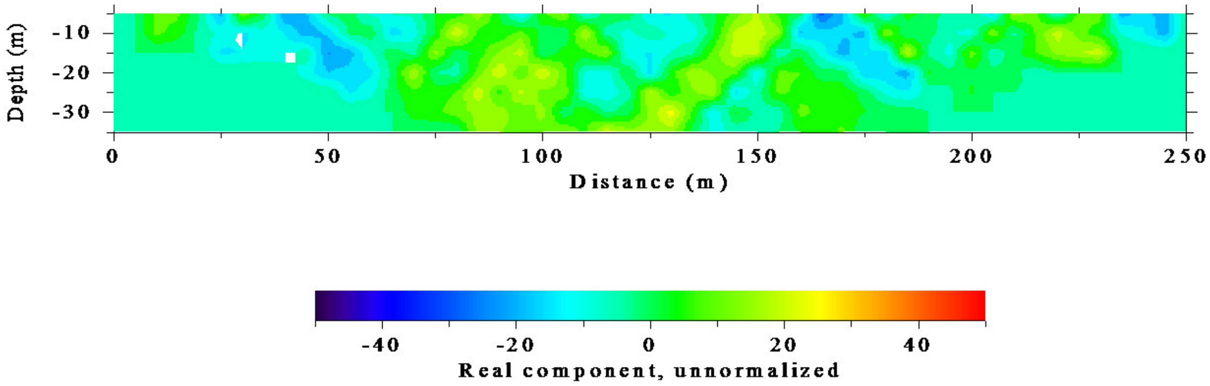
TABLE 1: Interpretation of VES result obtained from the study area.

VES NO	RESISTIVITY (ρ) (Ω-m)				THICKNESS (m)				CURVE TYPE
	ρ_1	ρ_2	ρ_3	ρ_4	h_1	h_2	h_3	h_4	
1	197	58	3594		0.6	3.7	-		H
2	262	65	836	1413	0.9	2.2	3.8	-	HA
3	283	111	392	1055	0.7	2.9	3.5	-	HA
4	221	125	2546		0.3	4.9	-		H
5	681	72	322	10800	1.8	2.4	3.4		HA
6	102	76	4667		0.5	3.2	-		H
7	115	59	5094		0.6	3.3	-		H
8	232	97	2156		0.4	10.6	-		H
9	341	87	3012		1.1	5.2	-		H
10	321	124	4235		0.2	7.1	-		H
11	125	387	88	5412	0.1	2.8	10.4	-	KH
12	118	349	140	7367	0.6	8.1	10.2	-	KH
13	178	297	69	3645	1.3	2.8	8.9	-	KH
14	207	360	92	7861	0.5	3.2	10.1	-	KH
15	510	127	3123		0.3	6.4	-		H
16	707	158	8023		0.6	7.1	-		H
17	688	132	4369		0.9	4.8	-		H

(a)



(b)



(c)

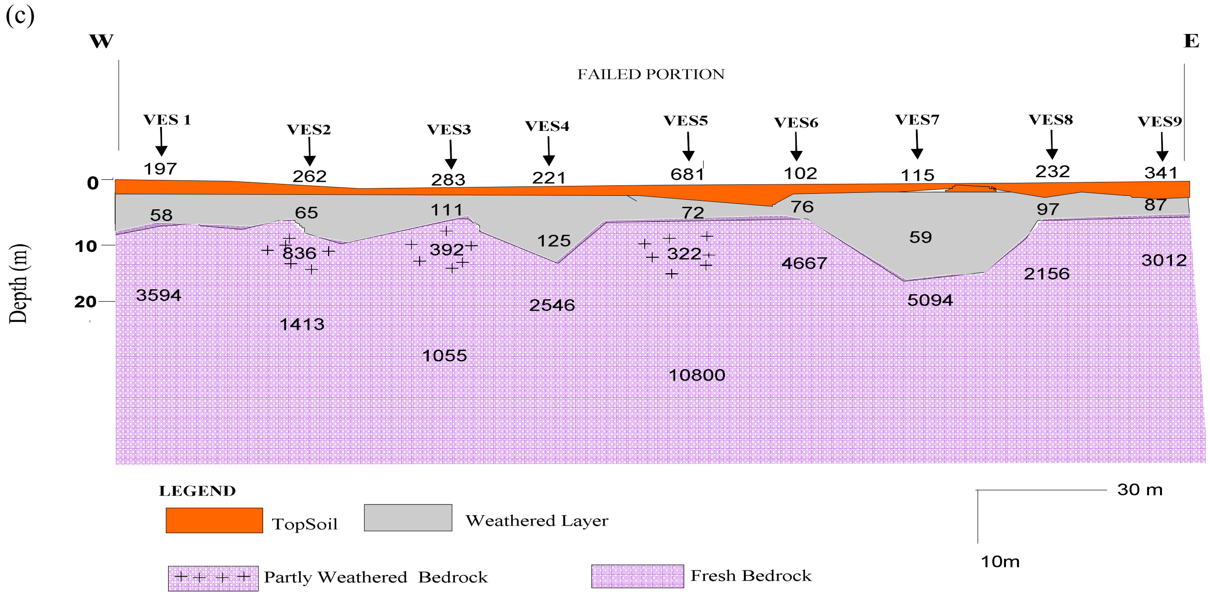
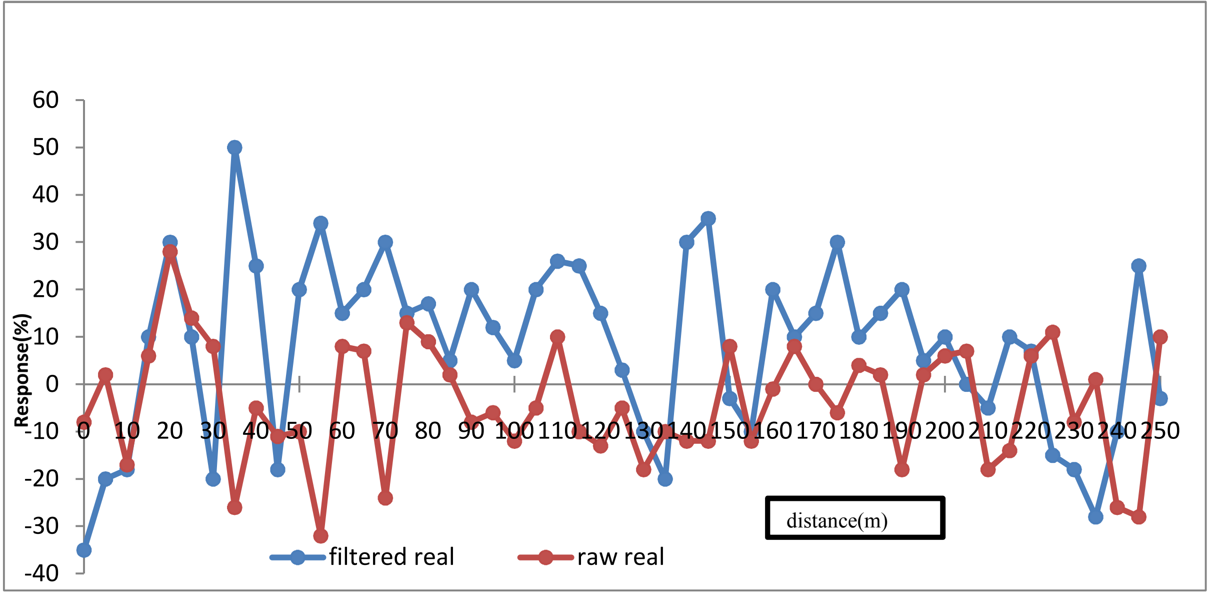


Figure 4: (a) Correlation of VLF-EM profile (b) 2-D VLF-EM Pseudosection and (c) Geoelectric section along traverse 1 of the study area.

The failed portion of the road on travere 1 (fig 4c) is underlain by thin topsoil (clayey sand) with a resistivity value between 102Ωm-681Ωm and weathered layer (clayey material) with low resistivity value ranging from 58Ωm-125Ωm and thickness between 2.4m-10.6m. The maximum positive peak (>20%) of filtered and raw real components (anomalous current density) of the VLF-EM profile and conductive zones observed from the pseudosection (fig 4a&b) at stations 30m-70m, 120m-180m and 220-250m are indicative of clayey materials at depth of between 10m-20m.

(a)



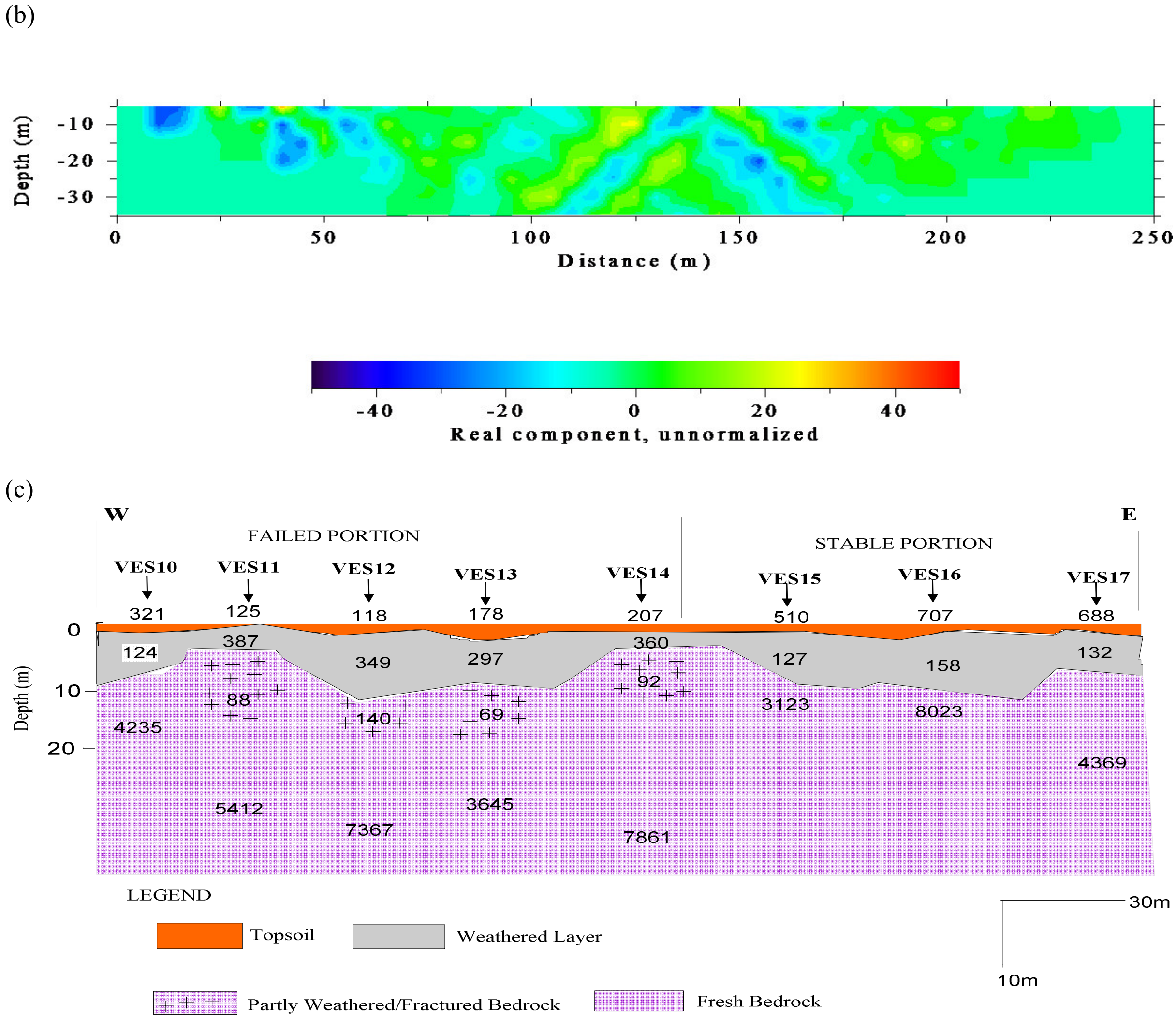


Figure 5: (a) Correlation of VLF-EM profile (b) 2-D VLF-EM Pseudosection and (c) Geoelectric section along traverse 2 of the study area.

Traverse 2 comprises both the failed and stable portions of the road as shown in (fig 5c). The failed portion is on a suspected near surface geological features as shown in the low resistivity partly weathered/fractured bedrock ranging between 69Ωm-140Ωm.The presence of conductive bodies was observed as the maximum positive peak (> 30%) of the filtered and raw real coponents (anomalous current density) on the VLF-EM profile (fig 5a) at stations 20m-60m, 100m-160m as shown on the pseudosection (fig 5b) dipping southwest and southeast direction which is suggestive of linear geological features such as fault, fracture and lithological contact. The stable portion of the road is underlain by topsoil/subsoil with moderate to high layer resistivity value (>500Ωm) in (fig 5c), the VLF-EM profile and the coresponding pseudosection are devoid of linear geological structures such as fault, fracture and lithological contact at 230m-250m (fig 5b).

6. Conclusions

Integration of cost effective and efficient geophysical methods involving electrical resistivity and very low frequency electromagnetic profiling had been used to investigate the causes of pavement failure on a portion of Okene-Lokoja road in Kogi State, North Central Nigeria.

The result obtained from the study area reveals that low resistivity weathered layer (clay) which have the ability of absorbing water which makes them swell and fail under heavy movement of vehicles, partly fractured bedrock and linear geological structures such as faults, fractures, joints and lithological contacts have been identified as the cause of pavement failure in the study area. Also during the reconnaissance survey that preceded geophysical survey in the study area, it was observed that surface water and ground water did not drain freely and quickly away from the road causing soil erosion, weaken pavement, destruction of road shoulders and wash out of culverts and embankments.

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