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The Use Of Very Low Frequency Electromagnetic (VLF-EM) In Road Failure Investigation Along Auchi – Ibillo Road In Edo State, Nigeria

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Abstract

A shillow investigation of the subsurface underlying the road pavement along a segment of the Auchi – Ibillo road was carried out. This was done with a view of delineating the geoelectric sequence of the bedrock as a means of establishing the probable causes of pavement failures along the highway. Two profiles (I and II) were mapped out for the investigation. The Very Low Frequency – Electromagnetic (VLF – EM) method was employed and the data obtained were interpreted qualitatively. Features suspected to be basement fractures were delineated along profile I at 60 m, 110 m, 230 m and 460 m. On profile II, the distances between 20 to 220 m delineated of a region of near surface lateral inhomogeneities: occurring due to the presence of highly weathered geologic materials beneath the pavement. It was therefore established from the results that the most probable cause of pavement failures along the Auchi – Ibillo road is as result of structural displacement of bedrock due to the presence of near surface features such as faults and fractured zones; the presence of highly weathered geologic materials and closeness of some part of the pavement to an aquifer zone.

The Nigerian Inland waterways and Railways are inefficient, hence the heavy reliance of the nation's economy on road transportation. Unfortunately, the problems of bad roads in the country have become an embarrassing stigma. The provisions of efficient road transport facilities are fundamentally important to the development of Nigeria as well as the well-being of its inhabitants. Nigerian roads need urgent attention considering that an average of 50 people die every day by road accidents as claimed by a survey (Adewumi, 2009).

Several factors including geological, geomorphological, geotechnical, road usage, construction practices, and maintenance are responsible for road failures (Ajayi, 1987). The geological factors influencing road failures include the nature of the soils and near surface geologic sequence, existence of geologic structures such as fractures and faults, presence of laterites, existence of ancient streams channels and shear zones. The collapse of concealed subsurface geological structures and other zones of weaknesses 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).

Study Area Description

Two profiles/traverses (I and II) were established along the Auchi – Ibillo road. Profile I was taken from the front of Agor junction in Aiyegunle, stretches Northwestwards towards Ibillo and terminated at a point, a few kilometers from Ikpesa village. Profile I covers a distance of about 650 m and is located between the geographical grid of latitudes 7° 21' 06.60'' N and 7° 21' 52.04'' N, and longitudes 6° 04' 48.46'' E and 6° 04' 52.55'' E (Fig. 1.0).

Profile II (covering a distance of 1000 m) starts from the front of Akoko - Edo Mixed Grammar School Uneme – Nekhua to the front of the Uneme – Nekhua main market and is located between the geographical grid of latitudes 7° 20' 12.02'' N and 7° 20' 41.97'' N and longitudes 6° 05' 06.74'' E and 6° 05' 03.82'' E.

EM field Methods/Procedures

i. Establishment of Profiles

ii. Taking GPS Readings:

iii. ***Geophysical Data Collection***: The *VLF-EM* readings were then taken using the *ABEM WADI* VLF equipment at station interval of 10 m along each profile. The instrument measures the in-phase (Real) and quadrature (Imaginary) components of the induced vertical magnetic fields as a percentage of the horizontal primary field. At the end of the fieldwork, the field data which have been stored in the machine were retrieved and recorded on a data recording sheet. The obtained data were tabulated under the following headings; Station position, Distance, Raw Real, Filtered Real, Raw Imaginary and Filtered Imaginary.

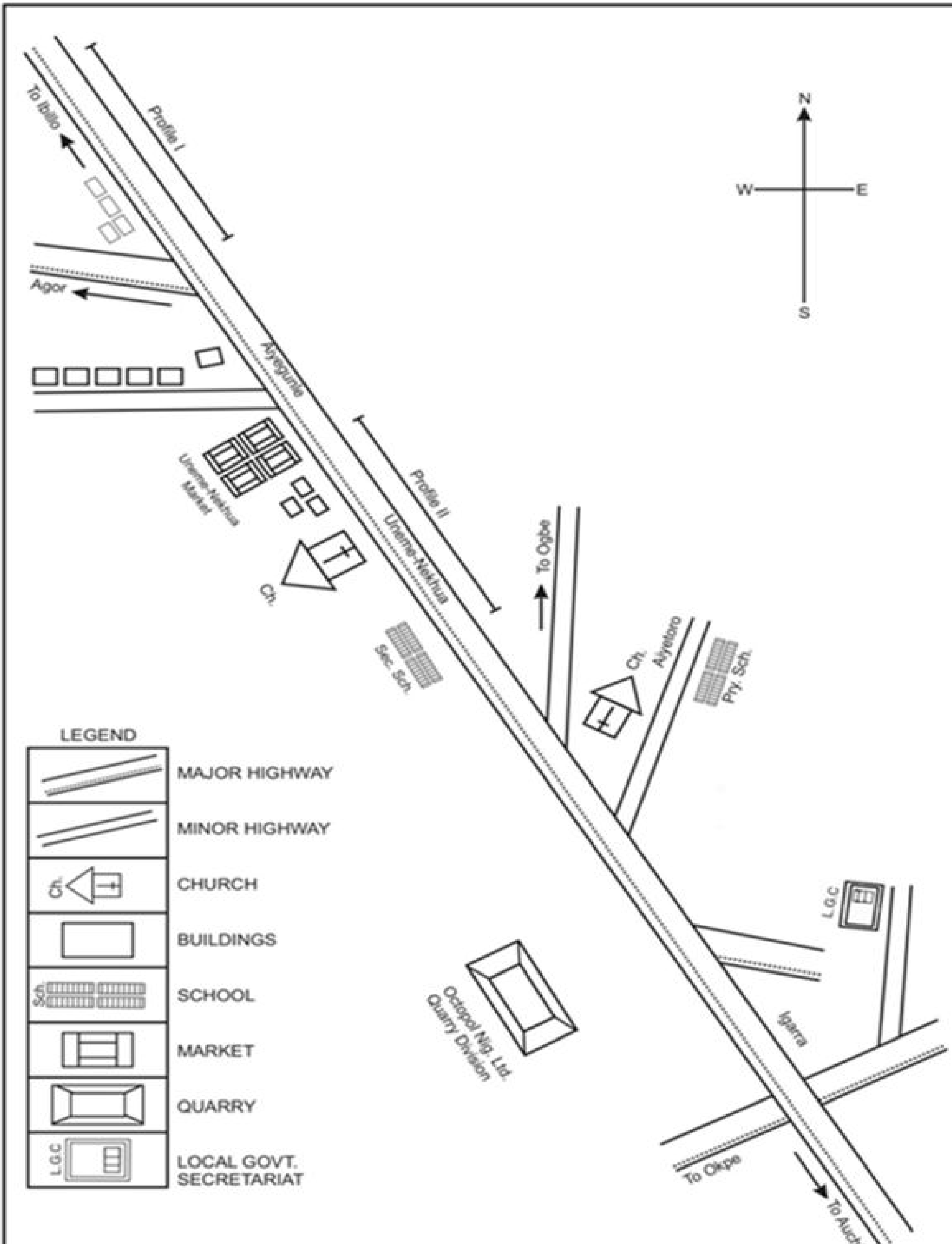


Fig 1.0: **LOCATION SKETCH OF STUDY AREA**

Presentation and Discussion of Results

The data displayed in Tables 1.1 and 1.2 were obtained along profiles I and II respectively with the aid of the ABEM WADI VLF equipment. Also, the VLF graphs for profiles I and II corresponding to the data in Tables 1.1 and 1.2 are displayed in Fig. 1.1 and 1.2 respectively.

Table 1.1: Electromagnetic (VLF) Readings for Profile I.
Station Spacing: 10 m. Signal Strength: 15
Co-ordinate: 0003/0000. Frequency: $15.2 KHz$

Station Number	Distance (m)	Raw Real	Filtered Real	Raw Imaginary	Filtered Imaginary
0	0	0	1.7	8.5	-4.1
1	10	-2.2	0.9	7.3	-2.2
2	20	0.8	2.0	21.7	-3.8
3	30	-3.3	4.1	10.9	-3.0
4	40	-1.1	2.1	-18.4	3.5
5	50	-0.9	1.0	22.1	-2.9
6	60	4.4	-2.1	25.5	-1.9
7	70	3.1	-0.9	21.3	0.9
8	80	-2.3	-1.0	27.0	-2.7
9	90	-5.6	1.1	18.8	5.3
10	100	-4.3	2.2	11.1	5.4
11	110	-2.1	6.7	7.7	2.1
12	120	-2.1	10.1	19.7	-17.7
13	130	-0.7	7.1	5.0	8.7
14	140	0	3.3	-3.4	1.4
15	150	-3.0	-1.0	-9.9	6.0
16	160	-1.6	-3.2	-7.0	-6.2
17	170	-0.3	-2.0	3.6	-10.1
18	180	1.1	0	0.9	-2.0
19	190	2.2	1.1	0	-11.5
20	200	0.9	2.3	7.5	4.0
21	210	0.3	2.3	-5.1	-7.7
22	220	2.7	3.1	5.5	-5.1
23	230	3.5	12.3	0.9	6.1

24	240	3.5	7.7	2.9	-4.3
25	250	4.9	0.7	4.5	-4.1
26	260	-1.1	1.2	7.0	-5.5
27	270	5.2	4.6	13.2	9.0
28	280	-0.2	1.1	-0.2	5.3
29	290	2.3	0.3	6.9	6.7
30	300	-1.8	-1.4	-2.8	6.1
31	310	0	1.0	-11.5	3.0
32	320	0.5	0.3	13.3	-0.7
33	330	0.6	-1.7	-20.2	-3.1
34	340	-2.6	-0.7	4.4	-0.7
35	350	1.5	0.9	-12.9	1.9
36	360	-0.7	-1.1	-5.4	-8.3
37	370	0.6	-2.8	7.5	-3.2
38	380	-3.7	-2.4	-6.3	10
39	390	0.6	-0.1	-12.8	3.0
40	400	-0.6	-2.0	2.4	-8.1
41	410	-1.8	0.7	0.1	-3.2
42	420	-4.0	3.0	-22.2	22.1
43	430	-5.4	4.2	-99.9	1.4
44	440	-3.1	7.1	-99.9	-32.3
45	450	-0.2	2.9	88.0	-61.3
46	460	0.7	0	-17.3	29.9
47	470	6.7	-1.6	-10.1	9.9
48	480	0	1.1	-15.6	6.3
49	490	0.3	-2.6	-27.3	-6.2
50	500	5.1	-6.4	-1.4	5.1
51	510	-6.8	-0.3	-31.9	3.0
52	520	-0.3	-3.2	-1.5	0.7
53	530	-2.8	1.3	-2.9	-1.3
54	540	7.1	5.5	-3.5	-1.6
55	550	-1.0	1.2	5.7	2.2
56	560	1.8	-1.2	-16.6	-10.7

57	570	2.6	-6.8	2.3	-2.3
58	580	-0.4	-11.0	-9.7	1.9
59	590	-5.5	-0.9	-3.6	-0.9
60	600	-6.9	-4.7	-9.8	-11.1
61	610	6.8	-7.4	21.1	-5.9
62	620	4.4	5.6	3.1	11.1
63	630	1.1	2.3	66.5	-22.1
64	640	-3.1	1.0	67.5	-4.3
65	650	-1.7	-2.2	44.9	-1.7

Table 1.2: Electromagnetic (VLF) Readings for Profile II.
Station Spacing: 10 m. Signal Strength: 15
Co-ordinate: 0002/0000. Frequency: $18.2 KHz$

Station Number	Distance (m)	Raw Real	Filtered Real	Raw Imaginary	Filtered Imaginary
0	0	-6.4	-3	-4.5	-4.8
1	10	-2.2	-0.7	17.7	-2.3
2	20	-0.1	7.1	6.3	8.0
3	30	5.9	10.3	-18.3	0.3
4	40	2.2	-1.5	4.2	-4.8
5	50	2.1	-7.9	0	21.3
6	60	-3.9	10.9	-99.9	20.2
7	70	-9.1	-0.8	-99.9	4.1
8	80	4.5	-3.4	-99.9	-28.5
9	90	2.3	2.2	71.0	-52.7
10	100	3.8	0	-15.1	38.7
11	110	1.2	7.6	-11.2	8.8
12	120	-1.0	1.1	-14.5	3.8
13	130	-5.5	4.7	-26.3	-2.6
14	140	4.8	13.9	-4.1	1.5
15	150	0.6	7.5	-29.1	0.3
16	160	9.0	-2.9	-9.3	-7.1
17	170	11.7	8.0	4.0	-2.2
18	180	6.6	-4.4	-1.5	1.3
19	190	3.3	10.1	-2.9	0.7

20	200	-0.5	0.6	-4.8	-1.6
21	210	-8.4	8.8	2.1	2.0
22	220	-5.2	-9.9	-15.4	-1.1
23	230	7.3	-8.1	3.2	-0.2
24	240	-10.7	-9.4	-11.6	1.6
25	250	-13.1	-5.0	-6.3	-0.9
26	260	-10.4	-4.1	-8.9	-12.1
27	270	-7.7	-5.9	33.1	-5.9
28	280	-9.8	-2.4	15.3	10.7
29	290	-5.0	-1.9	-11.2	1.0
30	300	-6.0	-4.0	3.8	-8.9
31	310	-0.7	0	32.4	3.1
32	320	-1.1	1.2	-5.2	3.9
33	330	5.6	4.7	-8.2	-26.7
34	340	-0.3	1.3	81.1	-26
35	350	2.3	0.5	-24.2	-9.9
36	360	-2.0	-1.4	15.2	-0.7
37	370	-1.1	-3.0	-24.6	7.6
38	380	1.7	-5.0	-14.1	1.3
39	390	-1.0	-0.7	-25.8	4.6
40	400	0.6	-2.1	-26.0	-0.8
41	410	-3.0	-1.4	-22.7	0.8
42	420	1.1	3.5	-23.3	2.4
43	430	-3.2	0.4	-39.3	-12.1
44	440	1.1	1.3	-1.0	-33.4
45	450	0.5	-0.1	66.5	-23.1
46	460	-0.8	1.6	68.4	-2.4
47	470	1.7	3.6	49.5	-1.9
48	480	2.3	0.8	62.7	-3.1
49	490	0	-2.8	-35.7	-12.3
50	500	-4.4	1.6	-0.9	-13.7
51	510	5.1	4.9	8.7	-2.7
52	520	6.4	7.2	0.5	1.2

53	530	10.3	2.2	-2.7	1.1
54	540	5.0	3.0	-2.9	0.6
55	550	3.1	1.1	9.9	4.3
56	560	-2.2	-4.8	-4.1	3.1
57	570	0	-3.1	-0.7	-0.5
58	580	-1.8	-2.0	-1.0	-0.3
59	590	-1.0	-0.7	2.3	-1.0
60	600	0.6	-2.1	1.9	0.5
61	610	-3.0	-3.4	0.9	0.5
62	620	1.1	3.8	0	-0.2
63	630	-0.7	-2.3	0.7	-1.3
64	640	3.3	4.3	4.3	-1.9
65	650	-2.9	-0.1	6.3	-2.3
66	660	-0.8	1.6	8.2	-2.9
67	670	1.7	3.6	13.6	-1.8
68	680	2.3	0.8	11.9	-2.0
69	690	0	-2.8	-17.9	-3.3
70	700	-3.2	-1.3	20.1	-2.7
71	710	1.1	0.1	26.4	-1.8
72	720	-1.0	-1.3	23.1	0.8
73	730	3.4	-3.6	23.0	1.7
74	740	-4.4	-3.5	20.8	4.1
75	750	-0.2	-5.7	11.3	4.2
76	760	0.3	-2.1	8.2	1.9
77	770	-1.5	-1.0	18.6	5.2
78	780	-1.1	-0.9	3.0	7.3
79	790	2.3	0.3	-2.3	4.1
80	800	-1.8	-1.4	-8.4	0.6
81	810	0	1.0	-2.6	-2.6
82	820	0.5	0.3	2.7	-1.1
83	830	0.6	-1.7	0.1	-0.2
84	840	-2.6	-0.7	0.3	-1.1
85	850	1.5	0.9	6.3	0.4

86	860	-0.7	-1.1	-4.0	-6.6
87	870	0.6	-2.8	8.5	-1.5
88	880	-3.7	-2.4	0.9	1.6
89	890	0.6	-0.1	1.9	-1.0
90	900	-0.6	-2.0	3.5	-1.4
91	910	-1.8	0.7	4.9	-2.2
92	920	1.6	2.7	12.8	0.9
93	930	1.7	-0.3	-0.3	1.5
94	940	-1.7	-2.4	7.7	1.6
95	950	1.3	-7.8	-1.8	6.1
96	960	-10.3	-4.4	-11.9	2.0
97	970	5.1	6.1	-7.1	-0.5
98	980	2.7	1.6	-18.8	-1.3
99	990	0.4	0.3	3.3	-0.1
100	1000	0.7	-2.1	-11.7	1.7

Fig. 1.1: VLF – EM Graph for profile I

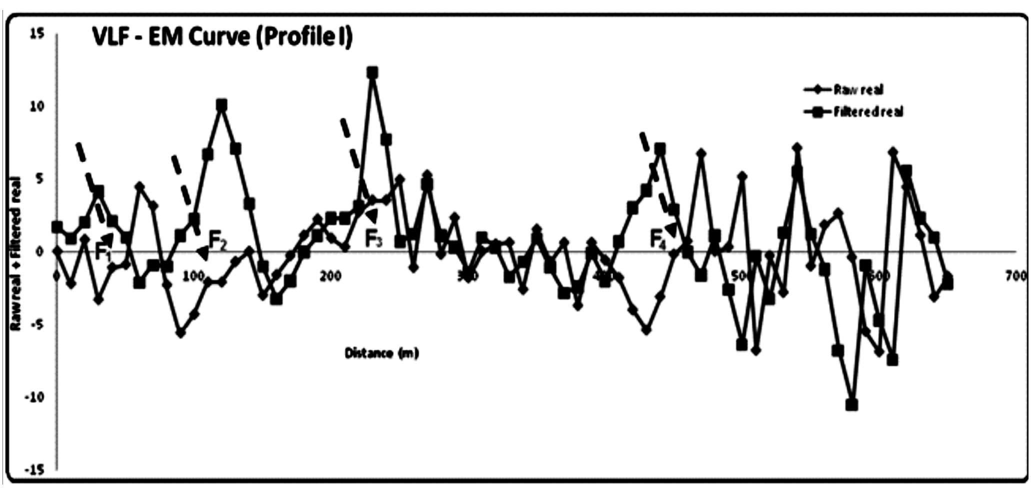
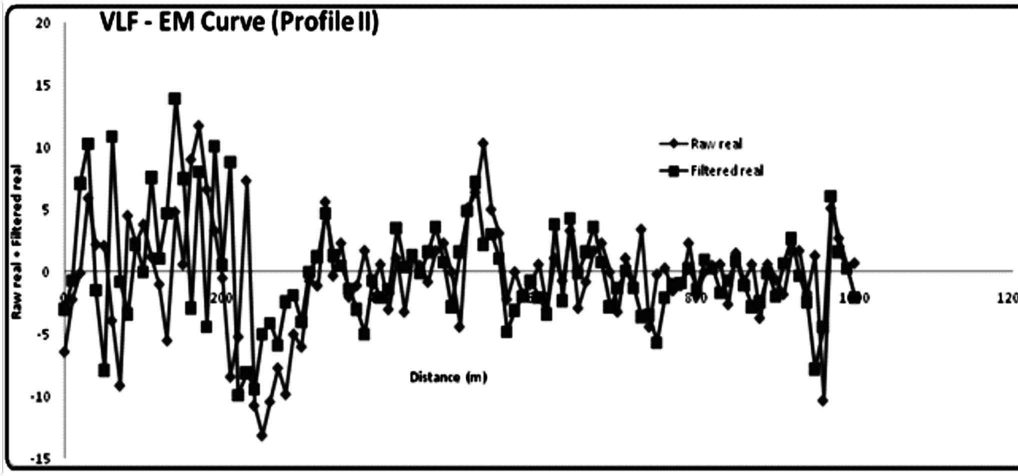


Fig. 1.2: VLF – EM Graph for profile II



Interpretation and Discussion

The VLF – EM geophysical method is a quick and powerful tool for the study of shallow conducting lineament features in the near earth surface (Telford, King, and Becker, 1977). The VLF – EM profiles (Fig. 1.1 and 1.2) are plot of the Filtered real and Raw real components against distance. The interpretation of these profiles is merely qualitative and allows for the delineation and mapping of the conductive zones. The interpretation of these profiles involves visual inspection for points of interests, which are

i. points where the peaks of the Filtered real curve coincides with the points of inflection of the Raw real curve and,
ii. points where positive amplitude of Filtered real curve crosses over the inflection points of Raw real.

Such points are usually suggestive of the presence of conductive (weak) zones. The VLF – EM anomaly curves vary significantly; some are sharp while others are broad, and are characterized by varying width extent.

On profile I, the identified zones of interest are the points labeled F_1, F_2, F_3 *and* F_4 corresponding to distance 60 m, 110 m, 230 m and 460 m respectively (Fig. 1.1). These zones are inferred conductive, typical of water filled fissures, fractures or faults (Alvin, Kelly and Melissa, 1997) or effect of appreciable depth to bedrock (White, Huston and Baker, 1988). These zones are considered priority areas for depth sounding. These features are suspected to be basement fractures. Ademilua and

Olorunfemi (2000) emphasized that basement fractures contribute significantly to groundwater yield.

Profile II shows multiple peak positive filtered real anomalies between 20 and 210 m. These anomalies may be indicative of inhomogeneity in near surface materials as supported in Dobrin (1976) where it was pointed out that lateral inhomogeneities in the conductivity of subsurface materials causes distortions in the current flow pattern which give rise to corresponding irregularities. The other part of the profile between 220 and 1000 m is devoid of any significant structural feature, an indication that the substratum in this region is relatively homogeneous, stable and competent.

Conclusion

The VLF - EM have proven to be very useful in the delineation/mapping of subsurface anomalies precipitating the incessant failures along the Auchi–Ibillo road. The most probable causes of failures on the road pavement as elicited by the data obtained are;

i. structural displacement of bedrock underlying the road pavement. This is caused by the presence of near surface features such as faults, fractured zones, and joints in the subsoil beneath the pavement as this is capable of creating zone that are structurally weak and favourably disposed to groundwater seepage and accumulation hence, pavement failure as observed on profile I.
ii. the presence of non-homogeneous Earth materials which in due to highly weathered geologic materials in the underlying subsurface and the closeness of some part of the pavement to an aquifer layer.

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