INFLUENCE OF GEOLOGY AND HYDROGEOLOGICAL CONDITIONS ON THE PERFORMANCE OF A ROAD PAVEMENT BETWEEN SHANGO AND CHANCHAGA ALONG MINNA –LAMBATA ROAD, CENTRAL NIGERIA

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Abstract

The dual carriageway along Shango – Chanchaga, in Minna, Central Nigeria, has continued to experience failure at a particular section, opposite the Public Works (PW) LTD yard, Tungan-Goro). This section of the road, which, unlike others, does not response to frequent and routine maintenance, is underlain by schist that is deeply weathered. Evidence shows that the failure experienced by the road is attributed to the geological/hydrogeological conditions underlying the road. This is because the frequently failed portion of this road is constructed on a fractured and deeply weathered schist as a subgrade material with low bearing capacity. The segment of this road is at a depression associated with concentration of groundwater discharge. Storage in the groundwater has increased as a result of blockage in most of the seepages culminating in fast disintegration of the base course materials. The schist under this portion of the highway is weathered to the depth of more than 10 meters into clay minerals with resistivity values as low as 21 Ohm. The clay minerals absorb water and swell in the wet season and compact at the dry season. The percentage of groundwater variation ranges between 154% - 2400% indicating medium to very high percentage of variation of groundwater fluctuation. These clay minerals absorb water and swell at the raining season and dries in the dry period. The road needs to be properly designed and provided with good drainage that will reduce the ingress of water.

Keywords:hydrogeologic conditions, instability, weathering, sub-base material

1. Introduction

The Nigerian government spends billions of Naira on road construction and maintenance and yet most of these roads are not found in stable and good conditions most of the time. In Nigerian highway construction, a lot of importance is attached to testing of the aggregates that are necessary for a sound and durable pavement and in very few cases, the geologic materials that provides support for the highway.

When considering a suitable route for the highway, the geological setting and the groundwater condition of the area are some of the important factors to be considered. Studies have shown (Weinert, 1960; Farquhar, 1980; Okabue and Uma, 1988) that geological and hydrogeological conditions underlying a highway route are important factors in the effective performance of the road. Analysis of the impact of geology on the effectiveness of a portion of a highway in Minna is been made in this paper. A particular point opposite the Public Works Nig. Ldt yard (Tungan-Goro-Chanchaga) experiences frequent failures as seen in figure 1.

Figure1 A failed portion of the studied road

The topography of the Minna and environs is largely affected by the geology that comprises of schist, amphibolites, gneisses and granites which constitute part of the Basement Complex rocks of Nigeria. The granitic hills are massive undulating terrains that range from 380m -850m high above mean sea level. The study area is within the middle belt of Nigeria and record a mean rainfall of about 1,000mm annually. Rainfall begins in April, August/ September records the maximum rainfall and stops in October. The months of August and September records low temperatures of about 24°C. High temperature is usually recorded during the months of February to March, at an average of 35^{0}C. The harmattan wind is experienced during December and January.

2. Literature Review

Research has shown that the stability of roads in tropical area is controlled by the geologic/ hydrogeologic, soil, climatic and drainage conditions among other factors (Clare and Beaven, 1962; Tanner, 1963; Gidigasu, 1974, 1983; *Okogbue C.O., 1988;*Okagbue and Uma, 1988). Deterioration of the materials that make up the base and sub-base and improper drainage that result to water having access to the pavement structure are among the causes attributed to road failure (Gidigasu, 1983). Base and sub-base materials disintegrate faster when water comes in to contact with it and areas that are not properly drained do not meet proper specifications on allowable plasticity and content of fines. Road failure could also result when inferior base and sub-base materials are used. Road failure also result when specifications for the pavement thickness is not followed. (Gidigasu, 1983) observed that breakdown of the road pavement increases when water percolate during the rainy period and reduce the strength of the highway material and when moisture suction occur from when the shoulder material loses moisture during the dry season.

Geology and hydrogeological conditions are considered critical when other factors are met in road construction. (Clare and Beaven, 1962; Okogbue and Uma, 1988) have observed that the patterns of road effectiveness in West Africa are controlled by geology, topography, soil and drainage conditions. (Russan and Croney, 1961; Gidigasu, 1983; Okogbue and Uma 1988), have noted that depth to water table tends to be the most prevalent of the climatic, physiography and drainage factors that control road effectiveness.

3. Methodology

Road grade elevations: A geographical Positioning System (GPS) was used in taking the road grade elevations.

Well water level fluctuation: Static water levels were measured from four hand-dug wells located very close to the road during the peak of the dry (April) and rainy (September) seasons. A water meter was used in taking the measurements while a GPS was used in taking the ground elevation as well as the co-ordinates of the wells. The total depths of the wells were also measured.

Geophysical survey: Vertical electrical sounding (VES) also referred to as electrical resistivity sounding was employed during this study. Current was sent into the subsurface by means of two current electrodes (C_1 and C_2) and a second pair of electrode (P_1 and P_2) measured the drop in potential. The electrode spacing interval was constantly changed while maintaining a fixed location from the center of the electrode spread.

laboratory tests: Atterberg Limits tests were conducted on five samples collected from five trial pits along the portion of the studied road. The liquid limit (LL) and plastic limit (PL) were each determined with about 300 grams of soil samples passing 0.425mm sieve in accordance with BS 1377 (1990). The difference between LL and PL gave the plasticity index (PI). The cone penetration method as described by (Brain, 1983) was used. A graph of cone penetration versus moisture content was plotted both on a linear scale and a straight line graph obtained. The LL was taken as the moisture content at which the standard cone penetrated 20mm into the soil paste.

4. Results and Discussion

The geology of Minna area reveals that the schist has been intruded in places by the older granite (figure 2). The emplacement of the older granite has led to intense jointing and fracturing of the schist. The schist is fine grained, foliated and dips at about 28^0W. Most of the drainages cut the narrow valley and water moves from the hills to the valley during raining season. The schist is mostly exposed along these river channels (River Chancgaga). Drainage pattern is the trellis while the major river found along the road is the Chanchaga River which is a tributary of the Kaduna River.

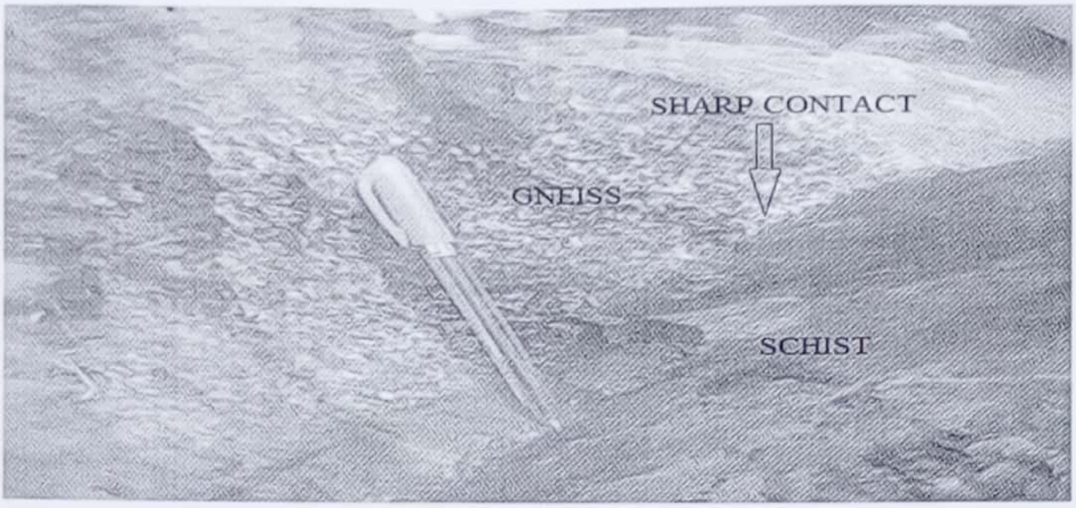
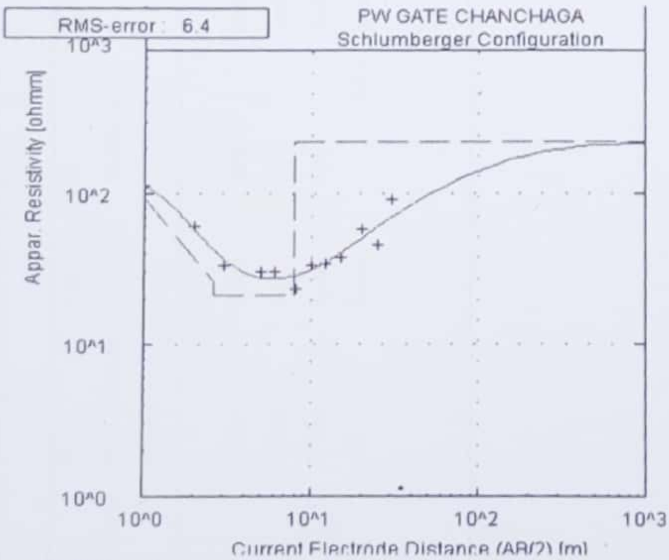


Figure 2: Schist intruded by granite gneiss in Minna area

The VES result is shown in figure 3, the groundwater fluctuation on table 1 while the Atterbege limits are presented on table 2.



No	Res	Thick	Depth
1	146.6	0.7	0.7
2	26.0	1.9	2.6
3	21.2	5.2	7.8
4	219.2	-.-	-.-

Figure3: Subsurface geology of the problem area

Table 1: Groundwater fluctuation along Shango-Chanchaga Road

Location	Well depth (m)	SWL Dry Season A (m)	SWL Wet Season B (m)	Variation (A – B)	% of Variation	Rock Type	Lat.(N)	Long.(E)	Elev. amsl (m)
CHANCHAGA1	2.1m	1.5m	0.5m	0.4m	300	Schist	9^0 32' 15.6"	6^0 34' 46.3"	230
CHANCHAGA 11	5.4m	4.5m	1.5m	3m	346	Schist	9^0 32' 33.5"	6^0 34' 53.5"	202
CHANCHAGA111	5.5m	5.1m	1.7 m	3.4m	300	Schist	9^0 47'.2"	6^0 39.7"	241
SHANGO	8.2	5.0m	1.9	3.1m	263	Schist	9^0 34' 25.9"	6^0 34' 18.4"	256

Table 2 Classification of the soils based on Atterberge Limits along Shango-Chanchaga Road

ATTERBEG LIMITS				*Plasticity*
LL %	PL	PI	*USSC classification*	*adjective*
33	4.0	29	CL	High
41	3.0	38	CH	High
39	3.5	35.5	CH	High
48	4	44	CH	Very high
38.5	15.4	23.1	CL	High

The geology as revealed affects the nature and ground in the area. The Basement complex rocks at their time of formation were none porous and highly impermeable. The rocks however, have been affected by tectonic activities that lead to the faulting and fracturing of the rocks (Ganduet *al*., 1986; Olayinka, 1992; Obaje, 2009) resulting in secondary porosity. The fractures provided access to rain water into the schist that has \resulted in weathering of the schist thereby making the overburden thick. The resistivity values recorded from this segment of the road is low (between 21and 26 Ohm) and the depth of weathering beyond ten meters (figure 3). The presence of water has further enhanced chemical weathering of the primary minerals to secondary minerals that are mostly clayey. The clayey weathered products of the schist absorb rain water but do not allow downward movement of the water, the clay being an aquiclude. This results in the rise of the water table to less than 1m thereby making the sub-base and subgrade materials permanently wet during the wet season. The percentage variation of groundwater fluctuation is between 263 and 340 as shown in table 1.

This is high and indicates that the under lying geologic materials are impermeable.

The Shango-Chanchaga Road was constructed using granite (which was sourced for locally) as base course. This possibly shows that the type of material used for the construction of the highway may not be mainly responsible for the failure. Swelling soils are a major constituent of the subgrade soils of the area as shown in (table 2). This type of soil is associated with natural low bearing capacity. The cause of the failure could be attributed to the groundwater condition that is being controlled by the geology of the problem area. Close observations of figures 1 and 2 show that the problem area is underlain by schist at a low elevation. It has already been shown that this schist was highly affected by fracturing and jointing that accompanied the intrusion of the older granites in the Minna area. Its intense fracturing and jointing have allowed the percolation of rain water and has considerably weakened the schist and led to its unsuitability as an underlying material. The performance of the subgrade of the failed portion of the highway is thought to have been influenced by the resulting lowered bearing capacity of the weathered schist. The studied rocks are composed of calcium-rich feldspars and dark minerals that are easily susceptible to high weathering (i.e., unstable).

Most of these rock components have weathered in to highly impermeable amorphous hydrous oxides and mostly clay-sized plastic soils. Some of the minerals identified in the metamorphic rocks in the study area include hornblende, biotite, chlorite and sericite. Because the mafic minerals (most weatherable) are concentrated in the schist, they have become more susceptible to weathering. This property has proved troublesome in engineering according to (Rahn, 1996).

The weathered rocks could have formed clay minerals mostly kaolonite and montm orillonite. According to (Okeke, 2008; Attewell and Farmer 1976), the active clay mineral that is responsible for the swelling in expansive soil is montmorillonite. The presence of secondary minerals (halloysite, illite and montmorillonite) is very important from the engineering point of view (Gidigasu, 1974; Townsend *et al.*, 1969). The granular structure (that makes the soils suitable for engineering purposes) in the study soils appears to have been lost upon working the soils resulting in an increase in the clay-size content and plasticity. This has resulted in the soils having lower strengths, high pore pressure, high swelling potentials and other undesirable properties.

5. Conclusion

The hydrogeologic conditions together with the poor drainage that have resulted to the lowered strength of the subgrade could be responsible for the failed pavement. The significance of understanding the geology/hydrogeology in selection, design, construction and wellbeing of highways therefore, should not be under estimated.

The incessant failures of the portion of the road opposite the PW gate along Shango –Chanchaga dual carriageway Minna is linked to the geology/hydrogeology of the area. This portion of the road is built on weak sub-grade (jointed, fractured and weathered schist) that has lost its ability to carry load. The road is at a low elevated area with an accumulation of groundwater seeping out. Majority of the seepages have become obstructed lea ding to rise in water table under the highway due to increased groundwater storage. This results in the base course being prone to fast disintegration. The schist has weathered to plastic clayey materials that absorb water, swells and expands in the wet period and contracts during the dry period. This has led to longtime wetting of the base and sub-base materials during the wet season. The provision of adequate sub-base drainage facilities will help minimize in the subgrade

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