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HIGHWAY PAVEMENT FAILURE INDUCED BY POOR GEOTECHNICAL PROPERTIES AT A SECTION ALONG THE F209 OKITIPUPA – IGBOKODA HIGHWAY, SOUTHWESTERN NIGERIA

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Abstract

Failure of highway pavement is a common feature on many major highways in Nigeria. Extensive field and laboratory investigations on kilometer 20 to kilometer 25 along the F209 Okitipupa– Igbokoda highway, Southwestern Nigeria, revealed that the road was deformed by the development of potholes resulting from poor physical properties of the pavement subsoil materials.

Laboratory soil mechanics tests carried out on the disturbed soil samples collected from the failed sections of the road showed that the natural soil moisture ranges from 7.10% to 9.7%, liquid limit from 22% to 43.50%, linear shrinkage from 2.30 to 5.20, and the specific gravity from 2.60 to 2.66.

The California bearing ratio (CBR) value was 55% showing a considerable reduction in strength as a result of surface water ingress into primary cracks that later developed into potholes. X-ray diffraction studies showed the presence of abundant kaolinite peaks and a subdued goethite peak without any trace of montmorrilonite. The presence of excess fines in the pavement construction materials (soils) contributed to the failure of the highway pavement at this locality. The low CBR value is also a noted cause of highway pavement failure.

Keywords: Kaolinite, potholes, pavement failure.

1. Introduction

As far back as the pre-independence times, highway pavement failure had been a common phenomenon on Nigeria roads (Pollit, 1950; Jegede, 1998). The rate, frequency and magnitude of pavement deformation in virtually all major highways in Nigeria have reached an alarming proportion. Various forms of road deformation features characterise most major highways in Nigeria, particularly Southwestern Nigeria. However, the most common of these road deformation features include, cracking, corrugation; potholes, pavement incision; routing and rutting.

Occasionally, flooding of highways resulting from "bathub" on the road surface and defective road shoulder due to lack of drainage facility constitute some of the major deformation features on Nigerian highways (Chukweze, 1988; Jegede, 1998).

There is no gainsaying the fact that transportation systems in general and the highway network in particular are indispensable physical infrastructure. Over 80% of Nigeria's peoples are agrarian and most of the food and cash crops produced need to be transported from the locality to another, either for sale or for consumption purposes. The railway network is poor especially in the Southwest and air travel is very expensive. Therefore, the highway system still constitutes the primary mode for movement of passengers and freight (Jegede, 1998, 1999, 2000).

Good roads will certainly create a tremendous multiplier effect on the Nigerian national economy. There is therefore the need for the highways to be in good motor-able condition at all times. The development of good roads in Nigeria is a pre-requisite to the overall economic growth and technological advancement of the nation in all ramifications (Jegede, 1999).

Okitipupa is a recognized commercial centre in Ondo State of Nigeria. Ondo State is so richly blessed with vast commercial deposits of various minerals and very large forest resources. There is a very large plantation of palm trees at Okitipupa where the State Government had long established a palm oil, palm kernel etc company. Ondo state, in which Okitipupa is situated is poised for an industrial boom given the limitless presence of virtually all kinds of raw materials to support most of industries. In the section of the F209 highway, precisely in between kilometer 20 to 25 along Okitipupa – Igbokoda stretch of the road, are found potholes of various geometry and dimension including different types of cracks. All these pavement deformation features constitute dangers for motorists trafficking the road. Several motor accidents claiming many precious lives and valuable properties have occurred along this section of the road. There is therefore the need for thorough geotechnical investigation into the main causes of the failure of the road pavement in this section of the F209 Okitipupa –Igbokoda highway.

2. Materials and Methods

The investigation involved both field and experimental work. The field work aspect involved extensive road travel and trekking in order to observe and record highway pavement failure features, such a potholes, corrugation, pavement routing, rutting and incision. The geological settings of the immediate environment of the road including drainage conditions were also investigated (see Fig. 1).

Bulk disturbed representative soil samples were collected from under the failed sections of the road including the base level material; because the base is the most vitally important layer of highway prism or configuration.

The geotechnical tests carried out on the representative soil samples collected include natural moisture content, Atterberg (consistency) limits, linear shrinkages, specific gravity, compaction, the California bearing ratio, and X–ray diffraction (XRD) analysis.

The tests were performed in accordance with the procedures specified by the American Society for Testing and Materials and the British standards Institution (ASTM 1289, 1979; BS 1377, 1975).

The test results are presented in Table 1. The laboratory tests were carried out at both the Universita Degli Studi di Milano, Italy and the Federal University of Technology, Akure, Nigeria.

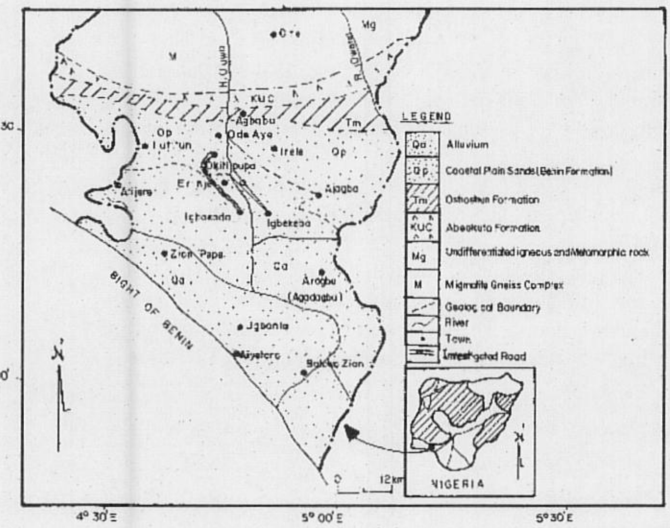

Fig.1: Geological map of the study area (after GSN 1974)

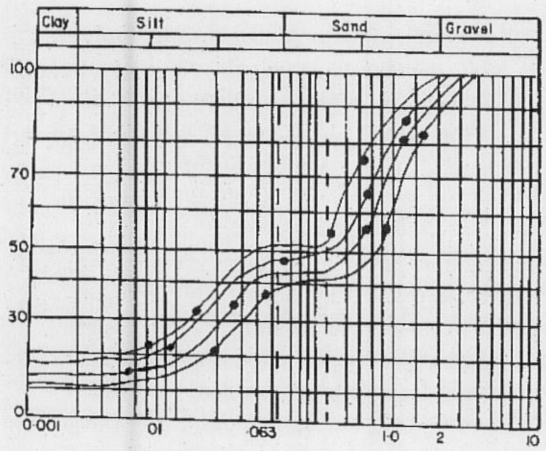

Fig. 2: Gap graded curves for Okitipupa subsoils

3. Discussion

The geotechnical properties of the subsoil materials that were used in constructing the road are presented in Table 1. The soil textural analysis indicated that it classified as gap graded silty clay. The percentage fine is well above 25% (Fig. 2). There is clear deficiency of coarse fraction especially gravelly fraction in the soil profile. The definite increase in the soil natural moisture content may be best explained by decreasing evaporation trend from surface to subsurface along a soil profile in the crust. High plasticity and high in situ moisture content imply that a soil will take longer periods to dry after the heavy rains associated with the wet season (Jegede, 1995, 1997, 1998, 2000).

The consistency (Atterberg) limit values plot in the region of CL – CI and ML – MI groups (Fig. 3). This indicates that the soil contains both clay and silt fractions. It also implies that they may both be regarded to consist of clay of low to intermediate plasticity and silt of low to intermediate plasticity (Casagrande, 1974; Jegede, 1994, 2000). The liquid limit values of the soil may be considered high, ranging from 22% to 43.50%. This further supports the lack of high plasticity in the soil. Therefore, the soil with regard to the extremely high liquid limit values may be considered too weak in strength. The linear shrinkage values because of their relatively low values indicated a non-shrinking, non-heaving soil (Brink *et al.*, 1982).

Table 1: Geotechnical properties of a section along the F209 Okitipupa-Igbokoda highway.

Sampling Index Number	Depth (m)	Natural Moisture (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index	Linear Shrinkage	Specific Gravity	Soil Description
OK 1	0.6	7.10	44	34.10	9.40	5.0	2.60	Reddish brown silty clay
OK 2	1.0	8.90	37	28.73	8.27	4.0	2.61	
OK 3	1.5	9.00	41	24.20	11.80	3.0	2.61	
OK 4	2.0	9.30	40	28.57	11.443	4.1	2.62	
OK 5	2.5	9.70	33	30.90	2.10	5.2	2.66	
OK 6	3.0	9.60	22	10.38	11.62	2.3	2.65	

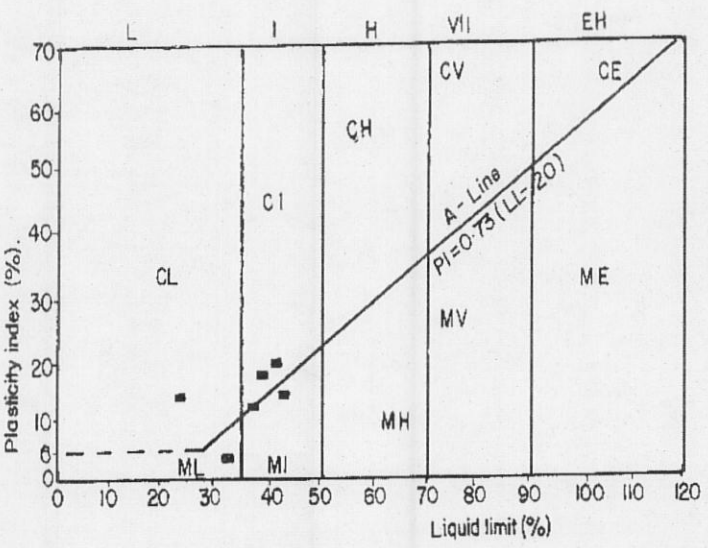

Fig.3: Casagrande's plasticity chart for studied soil samples (Okitipupa).

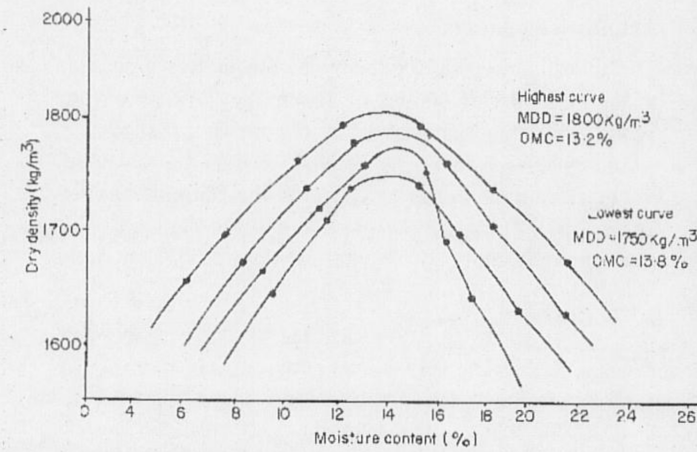

Fig.5: Moisture / density relationship for Okitipupa subsoils

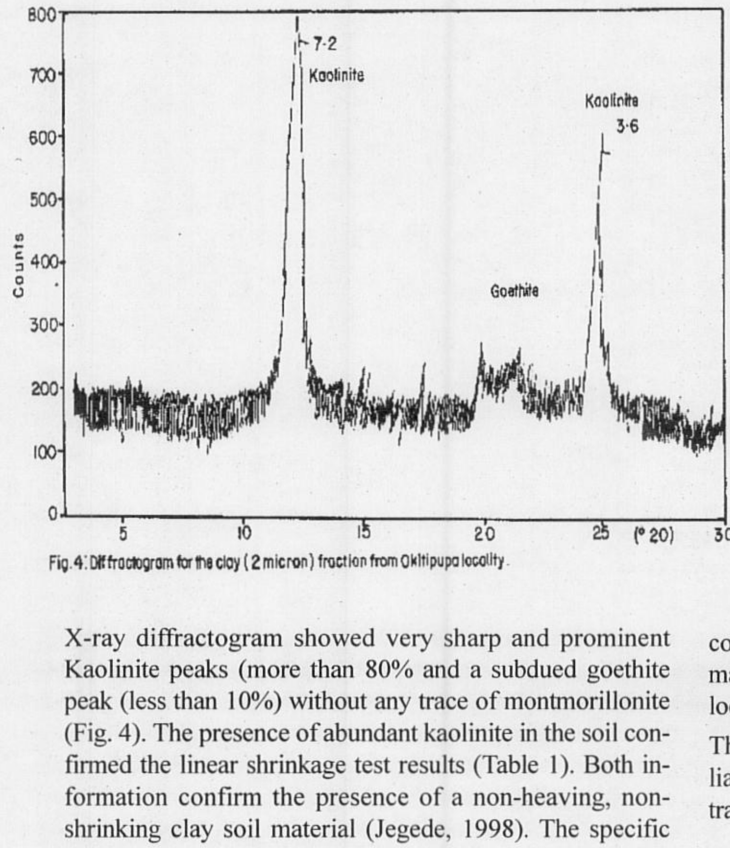

Fig.4: Diffractogram for the clay (2 micron) fraction from Okitipupa locality.

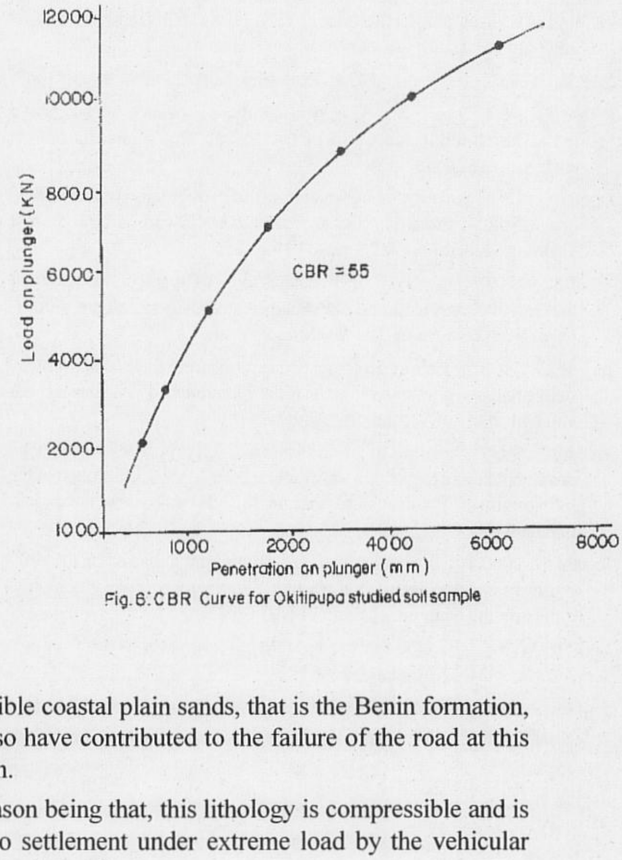

Fig.6: CBR Curve for Okitipupa studied soil sample

X-ray diffractogram showed very sharp and prominent Kaolinite peaks (more than 80% and a subdued goethite peak (less than 10%) without any trace of montmorillonite (Fig. 4). The presence of abundant kaolinite in the soil confirmed the linear shrinkage test results (Table 1). Both information confirm the presence of a non-heaving, non-shrinking clay soil material (Jegede, 1998). The specific gravity values range from. 2.60 to 2.66.

The moisture density relationship, i.e. the compaction curves (Fig. 5) showed a maximum dry density raging from 1750 kg/m^3 for the lowest curve and 1800 kg/m^3 for the highest curve at an optimum moisture content of 13.8% and 13.2% respectively. The CBR value of 55% (Fig. 6) is indicative of a strong reduction in the strength of the soil (pavement) materials. The extremely low value of 55% may be best explained as being due to the possible incursion of surface water through tiny openings which are mainly cracks and joints of differing geometry. The downward percolation or infiltration of this moisture into the base layer of the road prism further aggravates weakening and destruction of the road pavement (Jegede, 2000). It should be noted that the collapsible coastal plain sands, that is the Benin formation, may also have contributed to the failure of the road at this location.

The reason being that, this lithology is compressible and is liable to settlement under extreme load by the vehicular traffic on the road.

4. Conclusion

Highway pavement failure at a section along the F209 along Okitipupa – Igbokoda highway had been mainly induced by very poor soil properties as revealed by the excess fines (above 25%), high liquid limit values and very low California bearing ratio value of just 55%. The very low CBR value was mainly induced by surface water ingress into lower layers of the road prism including the base elevation, which resulted into failure of the highway pavement at this locality. The strength of the soil may be improved by soil stabilization techniques while cracks and joints may be sealed during road maintenance programme. The collapsible coastal plain sands at this location also contributed to pavement failure.

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