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Engineering Geological Investigation of Pavement Failure along Emure Ekiti-Akungba Akoko Road, Southwestern Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Authors OAO and MMO designed the study, carried out the field sampling and the laboratory works. They also wrote the first draft of the manuscript. Author IAA carried out the literature review, proof read the manuscript and handled all correspondence with the editors. All authors read and approved the final manuscript.

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ABSTRACT

Aim: This engineering geological investigation work was carried to investigate the causes of persistence failure of a section of Emure Ekiti/Akungba Akoko road, Southwestern Nigeria.
Methodology: A total of 10 disturbed soil samples were collected from different locations at a common depth of 2 m. The samples were analyzed for natural moisture content, grain size analysis, Atterberg limits, standard compaction and California Bearing Ratio (CBR) test.
Results: The laboratory tests on the samples revealed that moisture content ranged from 4.10 - 6.20%, liquid limit from 29.01 - 41.13%, plastic limit from 18.05 - 22.30%, linear shrinkage from 4.8 - 8.7% and plasticity index from 10.96 - 20.03%. The grain size analysis showed that the amount of fines ranges from 15.0 - 33.0%. The specific gravity ranged from 2.67 - 2.77, maximum dry density from 1848 – 1888 kg/m^3 and optimum moisture content from 17.4 - 18.4%. California Bearing Ratio (CBR) test for the investigated soil samples range from 31 - 39%. The overall results obtained revealed that the subsoil materials have good engineering qualities for engineering purposes in accordance with the Federal Ministry of Works and Housing specification for roads and bridges.

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Therefore, the reduction in the apparent strength of the subsoil materials that led to the observed road failure is possibly as a result of water infiltration into the structural section of the road pavement, particularly at the base layer.
Conclusion: Therefore, the pavement needs to be strengthened through adequate drainage facilities to improve its capacity, durability and performance.

Keywords: Road failure; natural moisture content; grain size analysis; Atterberg limits; standard compaction and California Bearing Ratio (CBR) test.

1. INTRODUCTION

It is observed that in Nigeria and most developing countries in Africa, road transport remains the most widely used mode of transportation. The reasons for this are not far-fetched; its accessibility and relatively lower cost of maintenance are few of such reasons. The economic basis of a nation and her performance is highly dependent on the efficiency of their transportation systems. The development of any country is a measure of quality road network between her major cities, towns and villages.

The problem of bad roads in Nigeria has become a humiliating stigma [1]. In many parts of the country, normal communication has been cut-off by bad roads failure. Highway failure has been a common occurrence on Nigeria roads as far back as the pre-independence times [1]. Failures of these roads are partly due to inadequate investigation of the engineering geological properties of the roads by engineering geologist [2] before their construction.

The road that connects Emure-Ekiti and Akungba-Akoko is a major road which links several towns like Oka, Oko-Oka, Supare, Ikare-Akoko and other towns. The road is in a very bad condition and it is characterized by various forms of deformation structures such as intensely cracked surface and highly eroded surface (where in some cases the subbase and subgrade materials are already exposed). These phenomena are responsible for road instability along the studied section of the road. The deformations observed on this road section are in various forms, degrees and regularities (Plate 1). They often cut adequately deep into the structural section of the highway thereby restraining traffic flow. Enormous amount of money has been spent so far on the construction and rehabilitation of this road.

This investigation will help to reveals the geological nature and engineering properties of the subsurface materials underlain the study area. The result of this study will serve as a guide for proper road design of any future construction of the road. This study therefore employed in-situ geotechnical testing to provide information on the pavement materials and structural disposition of the area with a view to capture geo-engineering information of both the subgrade and sub-base materials that could be inimical to engineering projects.

Plate 1. Condition of the road at locality 4 (along Emure-Ekiti/Akungba-Akoko road)

2. STUDY AREA

2.1 Geographic Location, Physiography and Drainage

The study area is about 28 km long and located at the boundary between Ekiti and Ondo States, in south-western Nigeria. The road connects Emure-Ekiti and Akungba-Akoko and links the entire Ekiti and Ondo States. It lies between 5° 25' E to 5°44' E and 7°24' N to 7°32' N (Fig. 1). The area is accessible through both ends of the road and the two towns serve as links to other towns.

The study area falls within the humid tropic rain forest where the mean annual rainfall is 1375 mm and the rainfall pattern is bimodal in nature with an annual maximum in the month of June and a secondary maximum in the month of September [3], while the dry season is defined by little or no rainfall between November and April [4]. The average yearly temperature also varies from 22°C (wet season average) to 30°C (dry season average), while the humidity varies from 40% (December average) to 80% (July average). The vegetation is dense consisting of various tress including palms, teaks, evergreen etc. [5].

2.2 Geology and Structures

The area is located on a gently undulating terrain (Fig. 1) [6] and it lies within the Nigerian Basement Complex which is part of the remobilized zone of the West African Basement. The area around the study area is underlain by one of the six identified lithological units of the Basement Complex of Southwestern Nigeria [7,8,9]. This is the Migmatite-Gneiss-Quartzite (MGQ) Complex. The basement rocks exhibit varieties of structures such as foliation, schistosity, folds, faults, joints and fractures. Generally, the structural trends in the area are NNW-SSE and NNE-SSW. The rocks occur as low lying outcrops with some pockets of high vision outcrops around the area.

2.3 Soils

The surface soils in the study area composed of brownish, loose medium to coarse-grained material with some clayey materials. The soils in some area contain silt, which are considered to be formed insitu as a result of the decomposition of the parent rock.

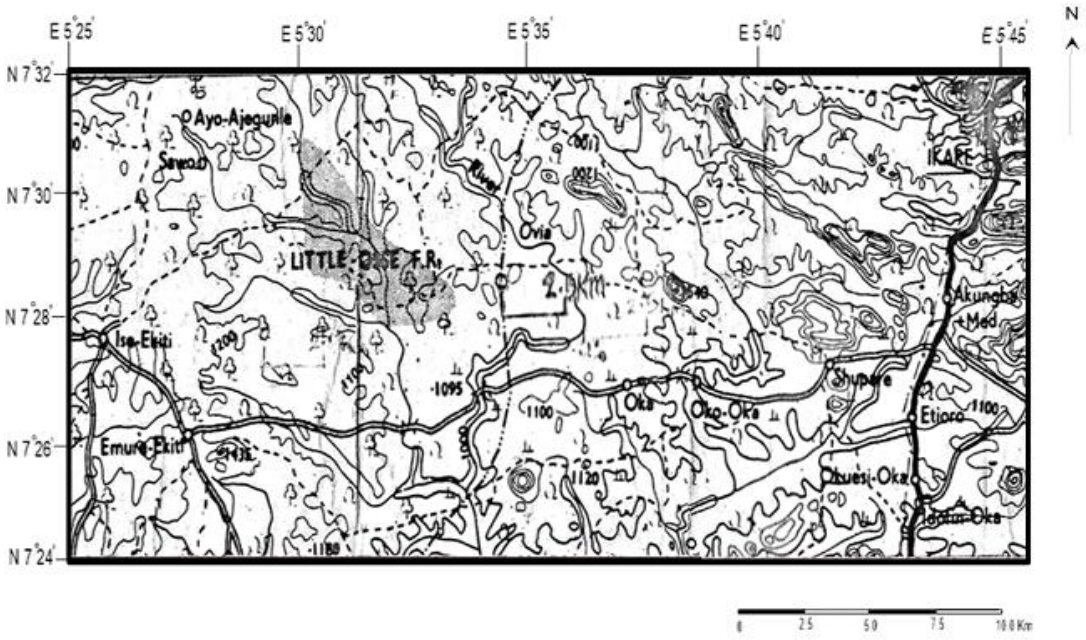

Fig. 1. Topographical map showing Emure-Ekiti to Akungba-Akoko the study area [3]

3. MATERIALS AND METHODS

Soil samples were collected at common depth of 2 m from ten (10) geo-referenced locations from the study area. The samples were analysed for natural moisture content, specific gravity, grain size

analysis, Atterberg limits, Standard compaction and California Bearing Ratio (CBR). The test procedures were in accordance with [10] and Unified Soil Classification System (USCS). All these engineering geological tests have been used successfully in road investigation in different parts of Nigeria [11-15].

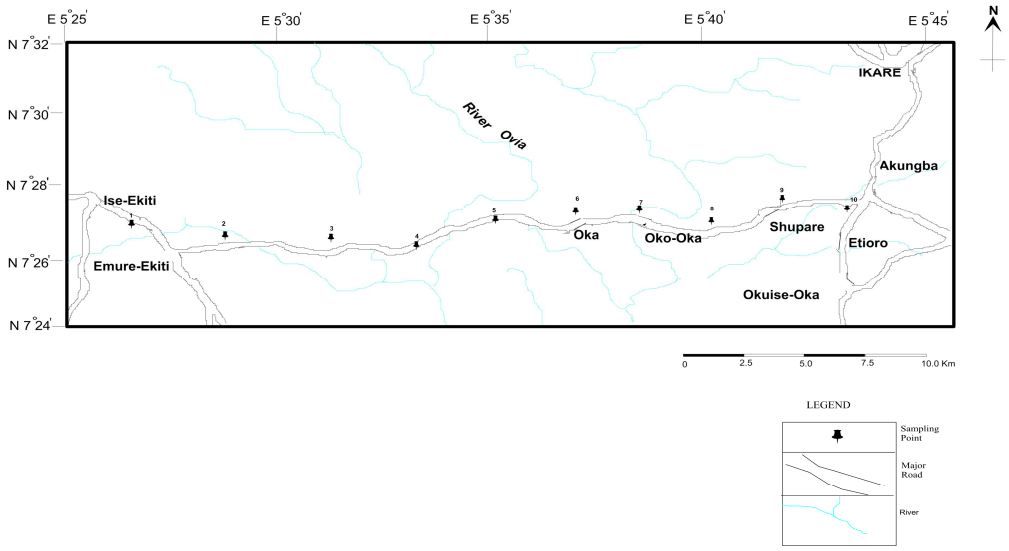

Fig. 2. Geological map of the study area showing the soil sampling points

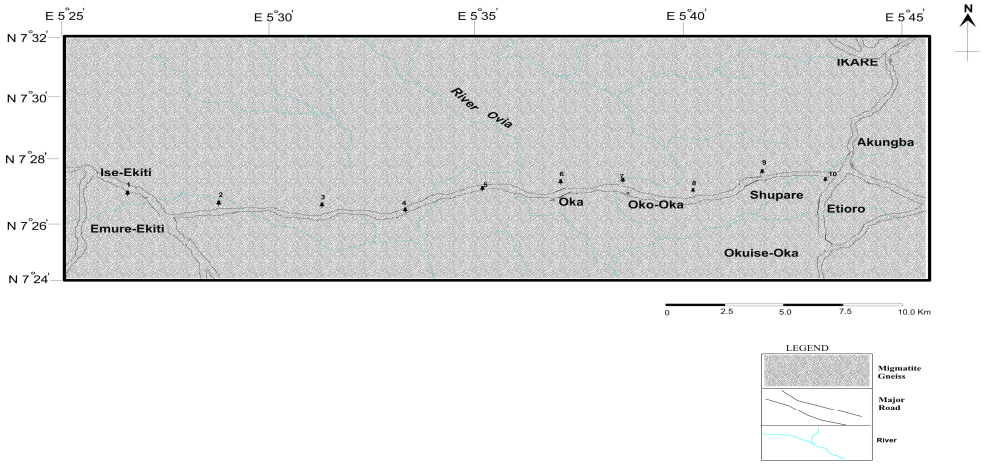

Fig. 3. Geological map of the study area

The base map of the study area was pre-processed for geometric correction, haze reduction and re-sampling. The sampling points (Fig. 2) were super-imposed on the geological map of the area (Fig. 3).

4. RESULTS AND DISCUSSION

Their grain size distribution pattern and the consistency limits enhances the classification of soils. The moisture content obtained from the soil samples range from 4.10 - 6.20% (Table 1). Though most of the soil samples are clayey sand and the percentage of fines in the soils range from 15.0 - 33.0% (Table 1). These show that the soils are generally matured residual materials with sufficient binders for the coarse constituents to attain high shear strength. The tested soils are generally well-graded (Fig. 4 and Table 1) and can serve as good sub-grade and sub-base materials when subjected to the prevailing moisture content.

Table 1. Summary of tested soil samples

Sampling point	Location		Depth (m)	NMC (%)	Specific gravity	CBR (%)	Compaction			Grain size (%)			Atterberg limits (%)			
	Longitude	Latitude					Kg/m^3	OMC (%)	Class	Gravel (%)	Sand (%)	Fines (%)	LL	PL	PI	LS
1	05° 26.42'	07 °27.05'	1.5	4.10	2.774	31	1888	17.4	Fair	25.0	54.0	21.0	29.01	18.05	10.96	5.3
2	05° 28.12'	07 ° 26.52'	1.5	4.80	2.682	32	1871	18.0	Fair	12.0	54.0	33.0	32.13	19.30	12.83	6.2
3	05° 31.47'	07 ° 26.51'	1.5	5.80	2.670	39	1873	18.2	Fair	13.0	57.0	30.0	31.65	17.10	14.55	8.7
4	05° 33.52'	07 ° 26.47'	1.5	5.81	2.741	34	1845	18.2	Fair	15.0	55.0	32.0	41.13	21.10	20.03	8.2
5	05° 35.03'	07 ° 27.12'	1.5	5.20	2.742	30	1868	18.4	Fair	10.0	60.0	30.0	39.34	20.25	19.09	6.2
6	05° 37.05'	07 ° 27.18'	1.5	5.50	2.690	34	1848	17.6	Fair	16.0	54.0	32.0	37.88	19.25	18.63	5.8
7	05° 38.49'	07 ° 27.19'	1.5	4.90	2.661	34	1874	18.0	Fair	15.0	60.0	25.0	29.65	18.30	11.35	6.5
8	05° 40.12'	07 ° 27.02'	1.5	5.20	2.720	33	1871	18.0	Fair	16.0	53.0	31.0	30.30	22.30	8.00	6.6
9	05° 41.42'	07 ° 27.48'	1.5	6.20	2.710	37	1848	17.6	Fair	10.0	58.0	32.0	32.32	17.30	15.02	7.8
10	05° 43.53'	07 ° 27.32'	1.5	5.20	2.685	34	1878	17.9	Fair	12.0	55.0	33.0	33.26	18.30	14.96	7.6

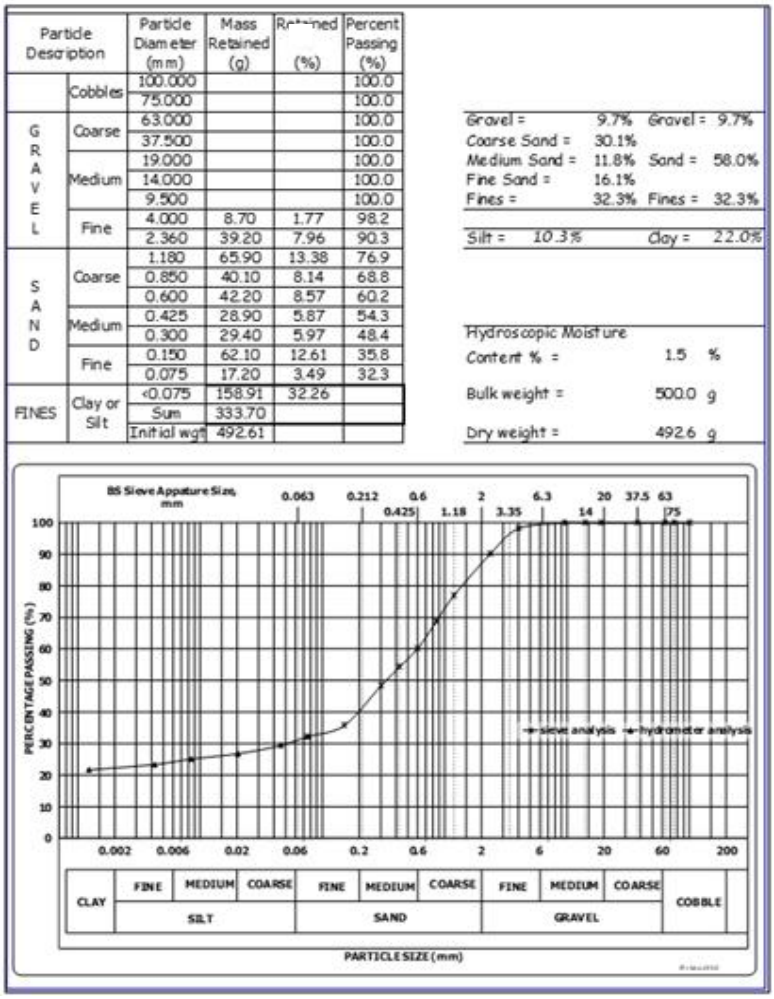

Fig. 4. Typical grainsize analysis chart from the study area (Location 9)

The specific gravity value is a very useful index in the identification and evaluation of laterite aggregates for construction. An increase in specific gravity has been found to be associated with a decrease in voids ratio [16]. The specific gravity values of the tested soils range from 2.67 - 2.77. The plastic limits range from 18.05 - 22.30%, the liquid limits also range from 29.0 - 41.13%, while the plasticity index range from 10.96 - 20.03 % (Table 1). These values fall within the typical values of soils within the Basement Complex of Southwestern Nigeria and can be used for road construction.

The moisture-density relationship (compaction characteristics) of the soils as indicated (Table 1) shows that the maximum dry densities of the studied samples are relatively moderate. A comparison of the values with [17] compaction characteristics shows that the soils fall within the fair classification. The optimum moisture content ranges between 17.4 - 18.4% while the maximum dry density ranges between 1848-1888 kg/m^3 (Table 1). The best soils are those with maximum dry density at low optimum moisture content.

Results of California Bearing Ratio (CBR) test (Table 1) for the investigated soil samples range from 31 - 39%, which can be classified as good subgrade materials [10]. The overall results obtained revealed that the subsoil material have good engineering qualities for engineering purposes.

5. CONCLUSION AND RECOMMENDATION

This research work involving engineering geological methods was carried to investigate the

causes of persistence failure of a section of Emure Ekiti/Akungba Akoko road, Southwestern Nigeria. A total of 10 disturbed soil samples were collected from different locations at uniform depth of 2 m. The following tests were carried out on the samples; natural moisture content, grain size analysis, Atterberg limits, standard compaction and CBR test. The results of the tests indicated that moisture content varied from 4.10 - 6.20%, liquid limit from 29.01 - 41.13%, plastic limit from 18.05 - 22.30%, linear shrinkage from 4.8 - 8.7%, and plasticity index from 10.96 - 20.03%. The grain size analysis revealed that the amount of fines varies from 15.0 - 33.0%. The specific gravity ranged from 2.67 - 2.77, maximum dry density from 1848 -1888 kg/m^3 and optimum moisture content from 17.4 - 18.4%. The CBR test for the soil samples range from 31 - 39%. The results indicated that the subsoil materials have good engineering qualities and are suitable for engineering purposes. The samples analyzed samples met with the specifications of the Federal Ministry of Works and Housing specification for roads and bridges in Nigeria. It can be concluded that the road pavement failure is as a result of water infiltration into the structural section of the road pavement [18].

It is therefore recommended that the road pavement along Emure Ekiti/Akungba Akoko road, Southwestern Nigeria needs to be strengthened through adequate drainage facilities to improve its capacity, durability and performance.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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