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Research Paper

APPRAISAL OF PAVEMENT FAILURES ON ADO-EKITI – OGBAGI ROAD, SOUTH-WESTERN NIGERIA

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A detailed appraisal was carried out on the causes of road failure in Nigeria using the Ado-Ekiti – Ogbagi road as a case study. The various requisite controls to checkmate failures on Nigerian roads were also discussed. The type of failures observed on the road are depressions of diverse dimensions, disintegration, blow-up, sub-grade intrusion, pot-holes, surface stripping, cracking and sliding resulting from anomalous stress distribution due to excessive loading. Particle size analysis, Atterberg limits, compaction and C.B.R. tests were carried out on soil samples collected from road cuttings and pot-holes. The following average values were obtained from the analysis of the samples: liquid limit (25.07%), plastic limit (12.44%), plasticity index (12.63%) and maximum dry density (M.D.D.) of 19.68 g/cm^3. These values are within the approved standards for road construction materials. Nevertheless, poor road design or outright refusal by contractors to keep to the agreed industrial standard or specification may have contributed to the observed failures on the road. The need for effective design of roads and maintenance policy was therefore advocated.

Keywords: Pavement failure, Ado-Ekiti, Ogbagi, Nigerian roads

INTRODUCTION

Relevance and Aim of this Study

Roads are very important means of transportation of goods, services, persons and various utilities such as fuel, raw and finished products from one location to another. The importance of road transportation to our national economy cannot be over-emphasized. However, most Nigerian roads fail shortly after construction and commissioning. Against this backdrop of relevance, the aim of this paper is the appraisal of pavement failure on Ado-Ekiti – Ogbagi road and feasible remedies and measures to prevent pavement failures in Nigeria.

Types of Road Failures

The type of failures observed on the road are depressions of diverse dimensions, disintegration, blow-up, sub-grade intrusion, pot-holes, surface stripping, cracking and sliding resulting from anomalous stress distribution due to excessive loading.

Road failure may be functional or structural. Functional failure is caused by surface pressure

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of traffic movement over a road, topography and untimely and inadequate maintenance culture. On the other hand, structural failure results from elemental deterioration of the road materials in response to climatic and hydrogeochemical changes. Structural failure may also result from differential settlement, poor road design and shear failure.

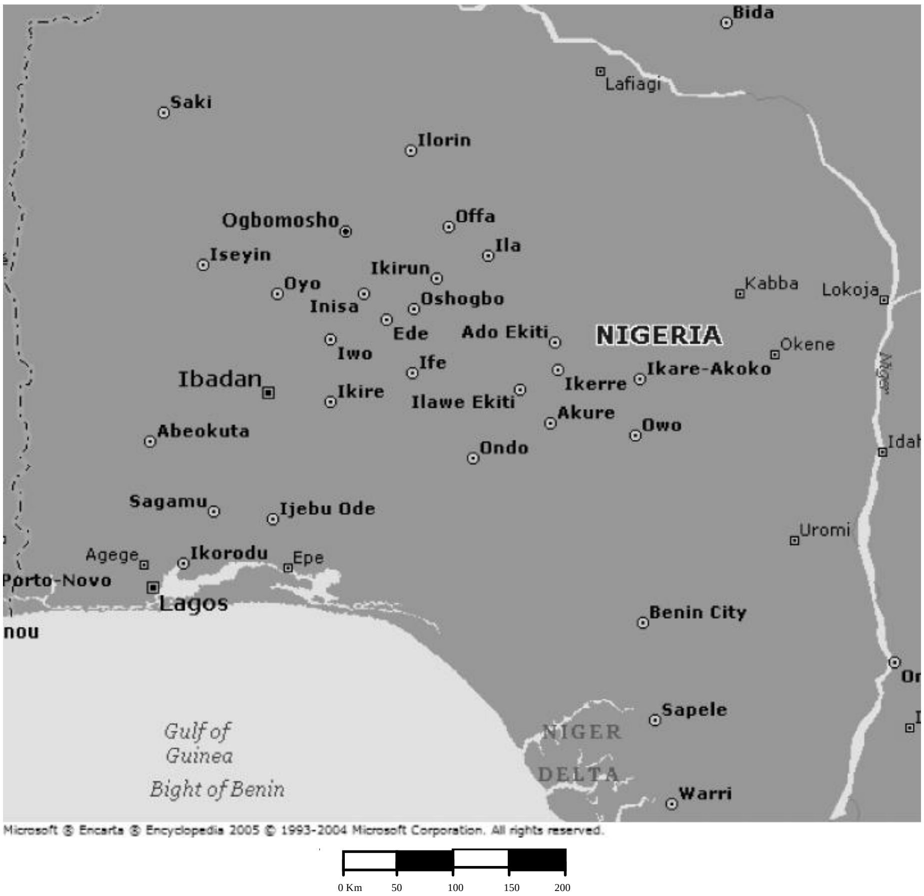
Location and Geography of Study Area

Ado-Ekiti – Ogbagi road is located within Ekiti and Ondo States, south-western Nigeria. This road is one of the major links between the south-western Nigeria and the northern part of Nigeria. The study area lies within longitudes $5^0 07''$ E and $5^0 27''$ E and latitudes $7^0 03''$ N and $7^0 49''$ N (Figure 1). The relief of Ado-Ekiti and Ogbagi is relatively high with isolated hills and inselbergs that are dome-shaped. At the base of these rocks are boulders littering all over the place. The major river draining the area is Ireje River which flows to the south-east; it is associated with simple form of minor tributaries (Ebisemiju, 1989).

Geology of the Study Area

The study area is located on the Proterozoic basement complex of south-western Nigeria. The rock units are coarse-grained charnockite, fine- to medium-grained granite, porphyritic biotite-hornblende granite and quartzite. The superficial

Figure 1: Map of S.W. Nigeria Showing Location of Study Area Indicated by the White Arrow



Source: Microsoft Encarta (2016)

deposits are made up of cobbles of quartzite, fine- to coarse-grained sand and clay (Omotoyinbo, 1994). The most abundant rock in the study area is charnockite. The charnockite has different varieties predicated by its occurrence in dark-green and greenish-grey colours with milky quartz, greenish feldspar and biotite phenocysts. The charnockite outcrops in the study area are similar to those described as "bauchite" around Bauchi township, Bauchi State of Nigeria by Oyawoye (1959 and 1962). The structures on the rocky outcrops are dykes, veins, joints, fractures, etc. (Omotoyinbo, 1994).

MATERIALS AND METHODS

Materials

The materials used for this study are geological hammer, hand auger, scooper, shovel, sample bags, GPS, masking tape, metric tape, pencils, field note books, digital camera and ten soil samples.

Methods

Ten samples were collected from selected cuttings and pot-holes sections of the Ado-Ekiti – Ogbagi road for particle size analysis, Atterberg limits and compaction test to assess optimum moisture and Maximum Dry Densities (M.D.D.) and California Bearing Ratio (C.B.R.). The tests were carried out using the methods outlined in Turnbull (1950), AASHTO (1978), Holtz and Kovacs (1981) and Bowles (1984).

RESULTS

The results are summarily presented in Tables 1-6. Compaction tests on the samples yielded optimum moisture content (O.M.C.) range of values from 10.00% to 24.00% and an average value of 15.72%. The corresponding M.D.D. values ranged between 15.49 g/cm^3 to 22.45 g/cm^3 with an average value of 19.68 g/cm^3. The C.B.R. tests yielded 9.00% to 12.00% range of values with an average of 10.10%. The Atterberg limits tests of the samples yielded liquid limit range of values from 15.00% to 28.50%, with an average of 25.07%. The plastic limit tests gave a range of values from 2.85% to 16.10% and an average of 12.44%. The plasticity indices ranged from 10.75 to 14.63 with an average of 12.63 for all the samples.

DISCUSSION OF RESULTS

The cumulative frequency curves from the percentage mass fractions were plotted against the particle sizes in millimetres. In Figure 2, the 50th, 70th, 90th percentiles indicate that the dominant particle fractions range from medium- to coarse-grained sand on AASHTO material designation scale. Furthermore, the plot of plasticity index versus liquid limit using the Casagrande's (1948) plasticity chart indicates that the samples do not fall within the clay minerals sections of the chart. The samples have low water retention capacity and that qualifies them as competent and good construction materials (Figure 3). Also, in Figure 4, the plot of plasticity index versus liquid limit on Casagrande's (1948) chart indicates that the samples are neither clayey nor organic soils. The result of the Atterberg limits tests and the plasticity indices for the samples are within the standards of the Federal Ministry of Works and Housing (1972) for construction materials. Holtz and Kovacs (1981) argued that heavy rainfall could bring about increase in plasticity of the base-material. Correspondingly, if the hydrogeochemical characteristics of the study area were taken into consideration, the susceptibility of the constructed road to failure would be highly minimized.

Table 1: Particle Size Analysis of Samples 1 and 2

Sieve Size (mm)	Sample No. 1			Sample No. 2		
	Wt. (g)	Wt. %	Cumulative Wt %	Wt. (g)	Wt. %	Cumulative Wt %
4.75	87.4	24.76	24.76	72.1	28.2	28.2
3.35	0	0	24.76	60.8	23.78	51.98
2.36	73	20.68	45.44	51.9	20.3	72.28
1.18	61.5	17.42	62.86	35.5	13.88	86.16
0.425	49.8	14.11	76.97	18	7.04	93.2
0.3	38.7	10.96	87.93	9.5	3.71	96.91
0.15	28.5	8.07	96	5.5	2.15	99.06
0.075	10.8	3.06	99.06	1.9	0.74	99.8
0.063	3.3	0.94	100	0.5	0.2	100
	353	100		255.7	100	

Table 2: Particle Size Analysis of Samples 3 and 4

Sieve Size (mm)	Sample No. 3			Sample No. 4		
	Wt. (g)	Wt. %	Cumulative Wt %	Wt. (g)	Wt. %	Cumulative Wt %
4.75	0	0	0	0	0	0
3.35	66.7	27.44	27.44	72.1	24.65	24.65
2.36	54.9	22.58	50.02	62.4	21.33	45.98
1.18	43.7	17.98	68	51.1	17.47	63.45
0.425	32.7	13.45	81.45	39.1	13.37	76.82
0.3	25.6	10.53	91.98	35.5	12.14	88.96
0.15	12.4	5.1	97.08	21.2	7.25	96.21
0.075	5.1	2.1	99.18	7.3	2.49	98.7
0.063	2	0.82	100	3.8	1.3	100
	243.1	100		292.5	100	

The interpretation of the results of the various tests indicated that the values for the sub-grade materials are within the approved standards for road construction materials. Holtz (1959), Holtz and Broms (1972) and Legget (1979) considering the influence of groundwater on the stability of rock-masses and the properties and problems associated with expansive clays, stressed emphatically on the need to use geological and hydrogeochemical characteristics of the environment of construction site into design of roads.

Table 3: Particle Size Analysis of Samples 5 and 6

Sieve Size (mm)	Sample No. 5			Sample No. 6		
	Wt. (g)	Wt. %	Cumulative Wt %	Wt. (g)	Wt. %	Cumulative Wt %
4.75	89.2	27.45	27.45	0	0	0
3.35	0	0	27.45	9.81	4.72	4.72
2.36	82.2	25.3	52.75	93	44.75	49.47
1.18	75.8	23.33	76.08	68.6	33.01	82.48
0.425	37.3	11.48	87.56	15.9	7.65	90.13
0.3	21.2	6.52	94.08	6.9	3.32	93.45
0.15	13.8	4.25	98.33	3.5	1.68	95.13
0.075	4.7	1.45	99.78	1.3	0.63	95.76
0.063	0.7	0.22	100	8.8	4.24	100
	324.9	100		207.81	100	

Table 4: Particle Size Analysis of Samples 7 and 8

Sieve Size (mm)	Sample No. 7			Sample No. 8		
	Wt. (g)	Wt. %	Cumulative Wt %	Wt. (g)	Wt. %	Cumulative Wt %
4.75	56.8	22.43	22.43	71.6	20.94	20.94
3.35	49.4	19.51	41.94	65.8	19.24	40.18
2.36	43.4	17.14	59.08	60.6	17.72	57.9
1.18	32.8	12.95	72.03	49.9	14.6	72.5
0.425	30.7	12.13	84.16	38.3	11.2	83.7
0.3	18.4	7.27	91.43	28.6	8.37	92.07
0.15	13.2	5.21	96.64	18.5	5.41	97.48
0.075	5.9	2.33	98.97	6.7	1.96	99.44
0.063	2.6	1.03	100	1.9	0.56	100
	253.2	100		341.9	100	

Table 5: Particle Size Analysis of Samples 9 and 10

Sieve Size (mm)	Sample No. 9			Sample No. 10		
	Wt. (g)	Wt. %	Cumulative Wt %	Wt. (g)	Wt. %	Cumulative Wt %
4.75	83.6	21.1	21.1	78.7	24.82	24.82
3.35	76.4	19.28	40.38	70.5	22.23	47.05
2.36	68.8	17.36	57.74	60.8	19.17	66.22

Table 5 (Cont.)

1.18	56.6	14.29	72.03	44.4	14	80.22
0.425	38.3	9.67	81.7	31.5	9.93	90.15
0.3	34.1	8.61	90.31	17.1	5.4	95.55
0.15	25	6.31	96.62	9.8	3.1	98.65
0.075	10.3	2.6	99.22	3.4	1.07	99.72
0.063	3.1	0.78	100	0.9	0.28	100
	396.2	100		317.1	100	

Table 6: Result of Atterberg Limits and Compaction Tests

Sample No.	1	2	3	4	5	6	7	8	9	10	Average
Liquid Limit	25.3	28.4	15	28	28.5	28	28.5	23	17.5	28.5	25.07
Plastic Limit	12.9	15.2	2.85	16.06	15	16	15.2	12.25	2.87	16.1	12.44
Plasticity Index	12.4	13.2	12.15	11.94	13.5	12	13.3	10.75	14.63	12.4	12.63
C.B.R. %	9.5	9.5	9.5	9	9	9.5	10	12	11	12	10.1
O.M.C. %	13.75	10	23.75	10.5	10.5	24	23	12.7	19	10	15.72
M.D.D. g/cm^3	22.45	22	15.49	18.7	21	17.67	20	21	18.7	19.82	19.68

Figure 2: Frequency Distribution Curves of Samples

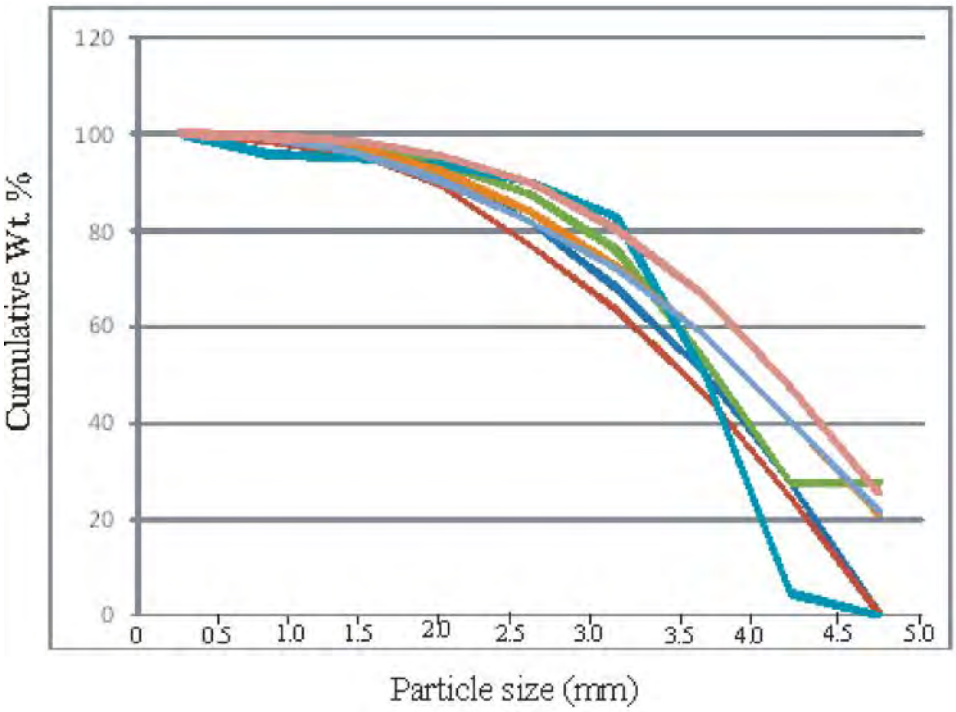


Figure 3: Clay Minerals Identification Using Casagrande's Plasticity Index Chart (After Casagrande, 1948)

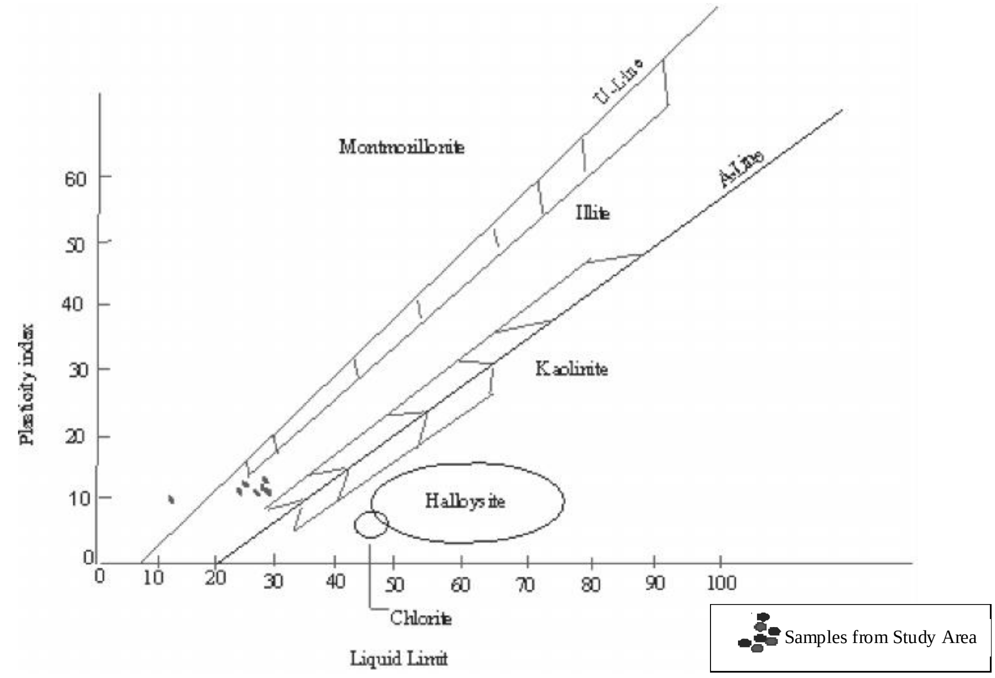
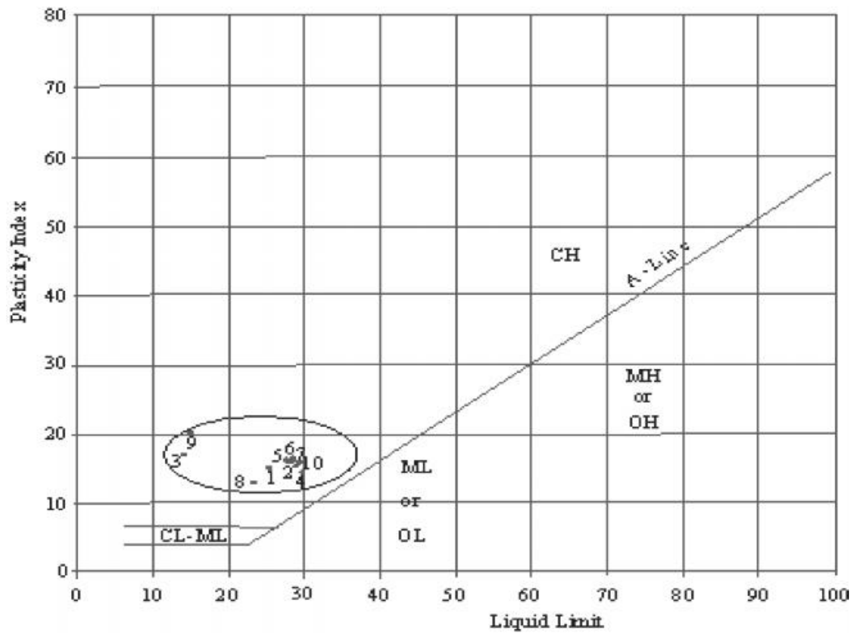


Figure 4: Samples Classification Using Casagrande's Plasticity Index Chart (After Casagrande, 1948)



Note: CL = Predominantly clayey with low plasticity; CH = Predominantly clayey with high plasticity; ML = Predominantly silty soil with low plasticity; MH = Predominantly silty soil with high plasticity; OH = Organic soil with high plasticity; OL = Organic soil with low plasticity; –1, 2, 3, 4, etc. = Sample nos.

CONCLUSION

Several geotechnical studies have established the relationship between C.B.R. and M.D.D. values of soils (Lambe and Whitman, 1958; Lee and Singh, 1971 and Bowles, 1984, pp. 204-240). The groundwater table and the geology of the base-materials are important in the design of failure-proof roads. The interpretation of the results of the various tests carried out on the Ado-Ekiti – Ikare road indicated that the road surfacing materials used are appropriate for pavement construction. However, poor road design and outright refusal by contractors to keep to the agreed industrial specifications or standard may have contributed to the observed pavement failure, which may also be accountable for some of the accidents on the road.

RECOMMENDATIONS

The following are suggested measures for prevention of road failure in Nigeria and especially in the tropical rain forest in which this study area is located in:

- Effective surface dressing and treatment,
- Enforcement of compliance with the design specifications during construction of roads,
- Construction of drainage channels on both sides of a road,
- Timely repairs of the roads,
- Routine maintenance of roads as part of the contractual agreement,
- Effective and appropriate project monitoring,
- Stabilisation of the sub-grade, and
- The study and utilization of the geological and hydrogeochemical characteristics of the environment of construction site into the design of roads.

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