

# Effect of Engineering Properties of Soil on Pavement Failures in Ogbagi - Akoko Area, Southwestern, Nigeria

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## Abstract

Geotechnical properties of lateritic soil from 8 failed and 2 un –failed sections of road along Ogbagi and Arigidi Akoko, Southwestern Nigeria were investigated to determine the causes of the road failure. Tests carried out were natural moisture content, specific gravity, grain size distribution, atterberg limits, linear shrinkage, compaction and California bearing ratio. From the test results, natural moisture content ranged between 6.75 and 25.5 %, specific gravity (2.68 and 2.76), linear shrinkage (5.7 and 11.4 %) , maximum dry density (1483 and 1780 kg/m<sup>3</sup>), optimum moisture content (13.5 and 26.0 %), CBR (14 and 31%), liquid limits (31.1 and 53.5 %), plastic limits (0 and 28.2 %) and plasticity index (0 and 29.5 %). Factors responsible for the failure of the pavement are stress induced associated with high swelling of the soil due to ingress of water through joints or cracks, poor engineering properties of the soil due to high percentage of fine materials or clayey nature of topsoil/sub-grade soil below the pavement, poor compaction and drainage systems of the road.

**Keywords:** Atterberg limits, Engineering properties, lateritic soil, pavement failures, grain size

## 1. Introduction

Good road networks are very vital to the socio-economic growth of any nation, especially the developing country like Nigeria. Government at all levels in Nigeria is presently embarking on road construction to provide networks of good roads to facilitate the transport of goods and services. This gesture is not only ensuring a safe traffic or ease transportation problems but also facilitating the marketing of goods particularly agricultural products by the teeming populace of rural dwellers around the country. However, many highways and roads in Nigeria including the present study area are considered unsafe for vehicular movement because of their attendant pavement failures arising from the development of potholes and all sorts of failing characteristics in the early life of the road between two to three years. Some of the major factors generally responsible for pavement failure in southwestern Nigeria include; the use of sub standard materials for construction, applications of temperate region specifications on tropical regional roads (Gidigas, 1980). Other factors include nature of subsurface, poor drainage system and poor quality construction work. Earlier researchers on road pavement designs or failures in Nigeria include Adeyemi and Oyeyemi (2000); Jegede (2000); Ofonime and Aniekan (2005); Aghamelu and Okogbue (2011). This paper presents the result of the effect of engineering properties of soil on pavement failures along Ogbagi and Arigidi – Akoko road, southwestern Nigeria. The area lies between latitudes 07<sup>o</sup> 33<sup>1</sup> and 07<sup>o</sup> 37<sup>1</sup> North of Equator and longitudes 05<sup>o</sup> 45<sup>1</sup>E and 05<sup>o</sup> 49<sup>1</sup> East of the Greenwich median (Figure 1). The study area belongs to the Pre-Cambrian Basement Complex of southwestern Nigeria. The major rock types include Migmatites, quartzite, charnockites and older granites (Rahaman, 1976).

## 2. Materials and Methods

A total of ten soil samples were collected at ten different locations between the depth of 0.62 and 1.2 m. Soil samples were collected both from the failed and un-failed sections of the road. Samples collected were air dried for two weeks before being subjected to tests at the Engineering Geology Laboratory, Department of Geology, Federal University of Technology Akure. The tests carried out include the following: natural moisture content, specific gravity, grain size analysis, atterberg limits, linear shrinkage, compaction and California bearing ratio.

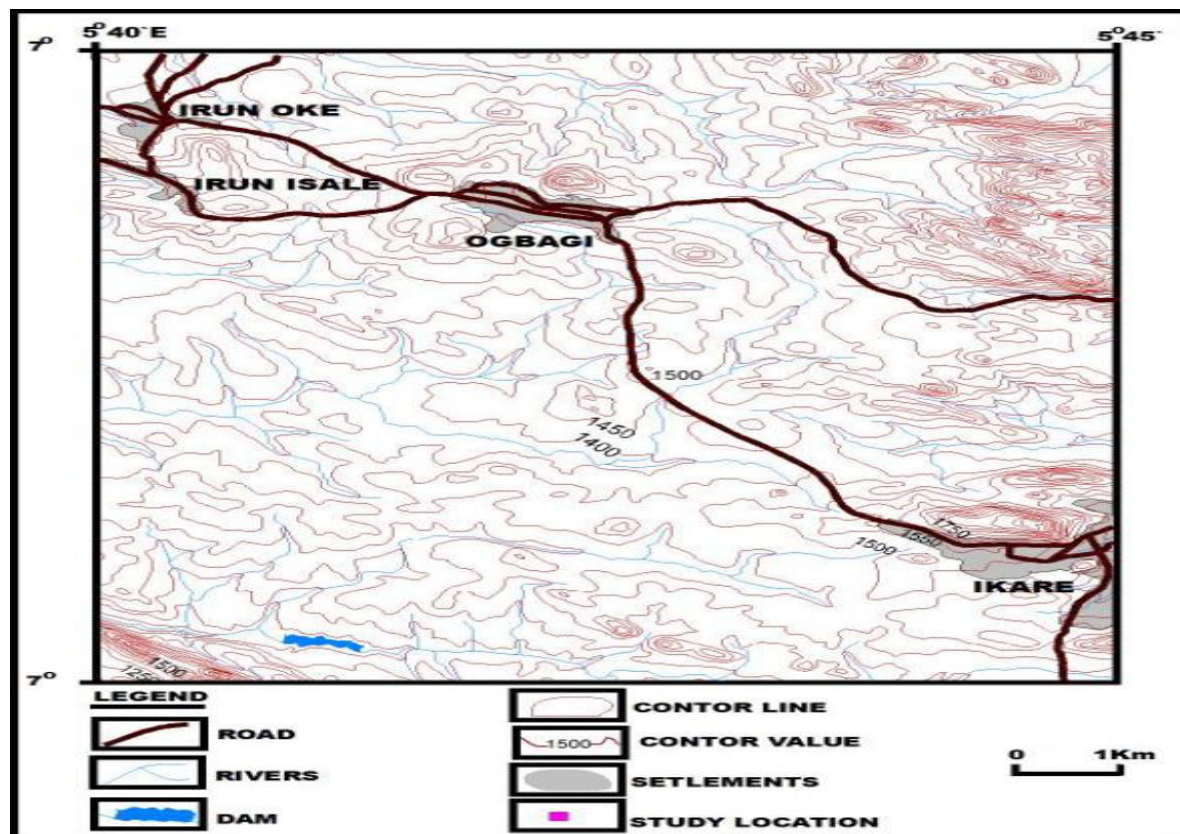


Figure 1. Topographical Map of the Study Area showing Locations

### 3. Results and Discussions

The engineering indices of the soil are presented in Table 1, the compaction and California Bearing Ratio (CBR) results are presented in Table 2 while the rating used for evaluation (after Offonime and Aniekan, 2005) are presented in Table 3

Table 1: Engineering indices of the soils

Location	L <sub>1</sub>	L <sub>2</sub>	L <sub>3</sub>	L <sub>4</sub>	L <sub>5</sub>	L <sub>6</sub>	L <sub>7</sub>	L <sub>8</sub>	L <sub>9</sub>	L <sub>10</sub>
Natural content %	15.9	23.5	23.7	13.1	6.8	23.8	16.8	25.5	20.0	18.8
Liquid Limit %	50.0	48.1	43.9	42.0	31.1	38.3	46.1	42.0	44.1	53.6
Plastic Limit %	24.1	22.1	20.1	20.1	0	28.2	20.0	0	24.2	24.1
Plastic Indices %	27.9	26.0	21.7	21.9	31.1	10.1	26.1	42.0	19.9	29.9
Linear Shrinkage %	11.4	10.7	9.3	8.6	5.7	6.4	10.0	8.6	9.3	11.4
Specific Gravity	2.74	2.73	2.72	2.68	2.72	2.75	2.71	2.76	2.72	2.73
% Clay	55.3	49.3	48.1	44.4	28.2	32.1	45.2	52.2	54.1	62.0
% Sand	36.6	46.2	49.7	46.4	70.6	64.8	50.8	46.7	44.9	34.7
% Gravel	8.1	4.4	2.2	9.2	1.2	3.1	4.0	1.1	1.0	3.3
Activity	6.6	7.6	6.6	6.8	-	2.8	6.4	-	4.4	6.4

Table 2: Compaction and CBR Results

Location	L <sub>1</sub>	L <sub>2</sub>	L <sub>3</sub>	L <sub>4</sub>	L <sub>5</sub>	L <sub>6</sub>	L <sub>7</sub>	L <sub>8</sub>	L <sub>9</sub>	L <sub>10</sub>
MDD (Kg/m <sup>3</sup> )	1630	1615	1617	1630	1780	1723	1575	1546	15.40	1483
OMC %	16.4	17.5	19.3	16.9	13.1	13.5	19.8	22.8	23.8	26.0
CBR %	24	23	20	24	35	31	21	20	19	14

Table 3: Rating used for evaluation (After Offonime and Aniekan, 2005)

Parameters	Low	Medium	High	Very High
	L	M	H	VH
	1	2	3	4
CBR %	<10.0	10-15	15-30	>30
LL %	>70	50-70	30-50	<30
PI %	>17	15-17	12-15	<12
MDD (Kg/m <sup>3</sup> )	<1800	1800-1850	1850-1900	>1900

### 3.1 Natural Moisture Content

The natural moisture content varies between a minimum of 13.1 % at location 4 and a maximum of 25.5 % at location 8. The relatively high moisture contents of location 8 may be due to clayey nature of the weathered basement sub grade since affinities of the soil for water depend on the presence of clay minerals (Adeyemi, 2003).

### 3.2 Grain size Distribution

The summary of grain size distribution is presented Table 1. The percentage of fines in locations 2, 3, 4, 5, 6 and 7 is lower than 50 % except in locations 1, 8, 9 and 10 with percentage of fines higher than 50 %. This is an indication that the soils in locations with percentage of fines greater than 50 % have poor engineering properties. Therefore, soils in locations 1, 8, 9 and 10 serves to be a very good potential as liner for landfill site. Finer soils have high specific surface with low leachate migration (Oyediran and Durojaiye, 2011).

### 3.3 Linear Shrinkage

Madedor (1983) recommended that linear shrinkage should not be more than 8 % for sub-base and less or equal to 10 for sub-grade. Samples L1, L2 and L10 from failed sections have high value of linear shrinkage greater than 10 thereby making them unsuitable as sub-grade and consequent failure of the road segment. The materials constituting these portions of the road lack engineering capability to sustain as good sub grade materials. Continuing use of the materials as sub grade is liable to pose field compaction problem. The linear shrinkage from the remaining locations ranges from 5.7 to 10.0 indicating good sub-grade and hence stable. However, portions of the road segments where similar range of values are recorded at the failed section(s) in the locations/areas where linear shrinkage ranges from 5.7 to 10.0 may be due to poor drainage system.

### 3.4 Consistency Limits

The minimum liquid limits, plastic limits and plasticity index are 31.1 %, 0 % and 0 % and maximum liquid limits, plastic limits and plasticity index are 53.6 %, 28.2 % and 42.0 % respectively. Casagrande chart classification of all the soils show that the soils are of medium to high plasticity and hence compressibility (Figure 2). Casagrande chart classification indicates that majority of the soil samples from the study area are predominantly inorganic soil while very few of them are organic.

### 3.5 California Bearing Ratio (CBR)

The CBR values range between 14 and 35 %. Based on Asphalt institute (1962) CBR of 0 - 3 is very poor, 3 - 7 is poor to fair, 7 - 20 is fair and 20 - 50 is good. Locations 3, 8, 9 and 10 indicate a fair rating based on their CBR values and therefore can be used as base materials in road construction. However, locations 1, 2, 4, 5, 6, and 7 indicate a good rating based on their CBR values and can be used as asphalt

### 3.6 Specific gravity

The specific gravity range between 2.68 and 2.76. The higher the specific gravity the higher is the degree of laterization (Badmus, 2010). This indicates that soils at location 8 has the highest degree of laterization and soils at location 4 has the least degree of laterization in the study area.

### 3.7 Compaction Characteristics

The maximum dry density varies between 1483 and 1780 kg/m<sup>3</sup> while the optimum moisture content is between 13.4 and 26.0 %. The relatively high maximum dry density of location 5 (1780 kg/m<sup>3</sup>) can be attributed to high content of clay soil.

## 4.0 Conclusions

Investigation on the effect of engineering properties of soil on pavement failure can be attributed to the following factors:

- High swelling potential of the soil due to ingress of water through joints or cracks developed as a result of

stresses.

- Poor compaction during the construction of the roads
- Poor engineering properties of the soil, since the soil in the study area has high percentage amount of fine materials and they are poorly sorted.
- Poor drainage systems, since most of the failed sections are water logged.

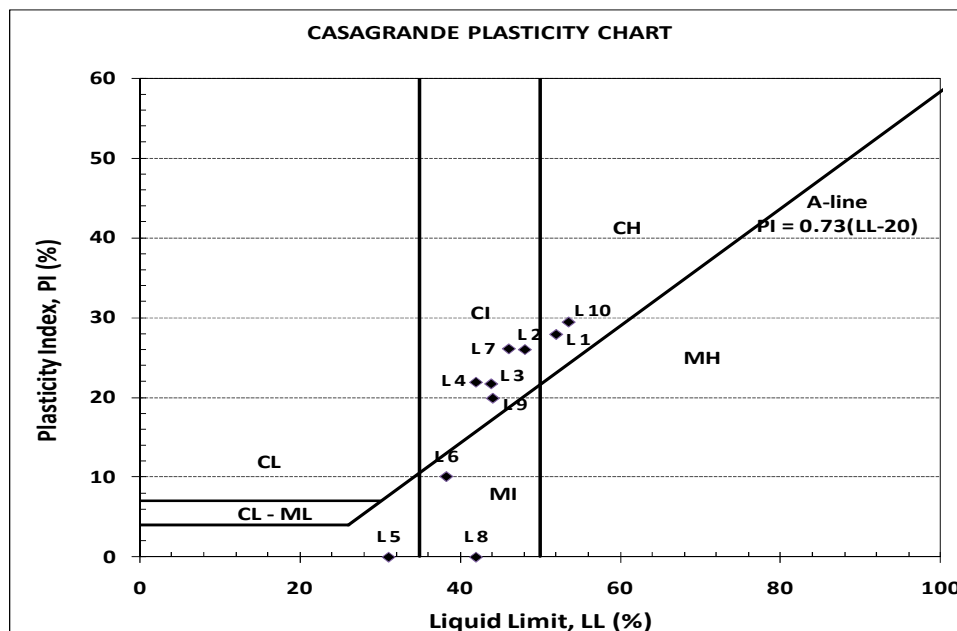


Figure .2: Plasticity chart of the study area

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