ASSESSMENT OF POLYVINYL ACETATE AS STABILIZING AGENTS FOR SOME NIGERIAN PROBLEM SOILS

B.D OLUYEMI-AYIBIOWU [1], OLA S.A [2] AND OWOLABI, A.O [3]

[1,2,3] Civil and Environmental Engineering Department
The Federal University of Technology, Akure
Ondo State, Nigeria

ABSTRACT
Provision of good roads is an important key to the development of a nation and her economy. A good road network provides easy access to goods and services, and thus making lives of the inhabitants comfortable. The present hikes in prices of road materials in Nigeria have caused many of the roads in the country to be left uncatered for, and thus in states of disrepair. Therefore, the use of alternative suitable materials for road construction is paramount. This work is concerned with the use of polyvinyl acetate, to strengthen some Nigerian problem soils. Soil samples were collected from six locations within the country and their geotechnical properties at the natural and stabilized states evaluated. On mixing the soil samples with polyvinyl acetate, general improvement on the strength characteristics resulted. The CBR results showed that all the samples were improved from unsuitable subgrade or subbase materials to suitable base materials. With this, some of the unsuitable widely available soil materials in the country could be used for road works by stabilizing with this material and thus helping in the provision of good road networks in the areas where they exist.

Key Words: Polyvinyl acetate, Soil samples, Stabilizers, Road, Laterites, Black Cotton Soils, Optimum Moisture content, Maximum Dry Density, California Bearing Ratio,

1.0 INTRODUCTION

Road construction in most developing countries involves the use of soil materials for the subbase and base of the roads, but some of these soil materials may not be directly suitable for use due to their poor strength characteristics, and when such occurs, the engineer is left with the choice of borrowing suitable materials from other sites or improving the strength of the available ones. Importing soils to site normally increase the cost of construction due to delay in construction, increased haulage cost and time wastage and this may lead to the other alternative of the adding stabilizing agents to improve the properties of the available soil (Megan *et al.*, 1999).

Soil-cement, lime stabilization and others have been in use for a long time and can be very effective but have some disadvantages in that they are more expensive, and at times difficult to apply, time consuming and environmentally hazardous. Also the technique of application has made them to be expensive (Owolabi *et al.*, 2004). Cement has been used with great success to stabilize natural soils because almost all soils respond to treatment with cement. However, the chemical conditions of some soils which can inhibit the normal hardening of cement or lead ultimately to loss of durability or high construction cost for the highly plastic soils have limited their use. Bitumen is also a suitable stabilizer for improving the properties of sand all over the world, but it's disadvantageous in terms of energy loss during heating and it's dependent on machines to ensure maximum production and quality of the end product. It has also been considered to be both detrimental to the environment as well as to the human element exposed to the hazardous emissions produced in the industry (TRRL, 1986).

In Nigeria, there had been massive investment by the governments to provide good roads for rapid economic development, which depends to a large extent on the efficiency of the road transport system. But despite these enormous investments, the nation is still faced with the costly challenges of providing a network of good roads, which have adversely affected the economic activities in terms of access to food and raw material producing areas, and have also led to the high distribution cost of goods at the purchase and consumption points. The increasing need for sustainable development throughout the world has led to researches into the assessment of alternative road materials to complement the conventional ones (READOP, 2005).

There are some nontraditional chemicals which may offer viable alternatives for stabilizing weak soils at reduced construction cost. (Eyo, 2006). It is against this background that this research work is brought up to use polyvinyl acetate and assess its effectiveness in improving soil materials for road works.

2.0 AIM OF THE RESEARCH.

The aim of this research work is to stabilize some Nigerian problem soils with the chemical stabilizer and assess performance for onward use for road construction and maintenance purposes. The work included the determination of the physical and chemical properties of the chemical stabilizer in the laboratory to ascertain the constituent materials and use it for stabilizing some weak soil materials collected from selected locations within the country to determine their strength characteristics and effectiveness.

3.0 MATERIALS AND METHOD

The research work involved the characterization of the selected product by analyzing it in the laboratory to identify the primary active ingredients. This was done by carrying out physical and chemical analysis of the material to determine the chemical composition of each using a variety of chemical test methods. Some of the physical and chemical tests carried out are pH, conductivity, ion chromatography, spectroscopy, electron microscopy and total organic carbon analysis. ASTM specifications and test procedures D2190-2193 were used for the tests.

Representative soil samples were collected from different locations within the country as marked on Figure 1 and their natural geotechnical properties determined in the laboratory by performing relevant tests on them. The soil samples were collected from the following areas:

(a) Residual Black Cotton Soils collected from three locations namely; Numan
Jalingo road; Numan – Yola road and Numan - Gombe road, all in the North – Eastern Nigeria

Black cotton soils are tropical expansive clay deposits, which are particularly troublesome due to their high swelling and shrinkage potentials. They occur principally in semi arid tropics with alternating wet and dry seasons. They are found in Australia, India, South Africa, Ethiopia, Tanzania, Asia and some other Africa countries (Madedor and Lal, 1985). The soil materials are vastly available in the North Eastern Nigeria. Ola (1983) in his work described black cotton soils as being highly plastic silty clays formed by the weathering of basalt rock, shale and clay sediments. The soil contained a high proportion of montmorillonite, kaolinite and quartz making up the remainder. The high shrinkage and swelling of these soils has caused a lot of problems with the use of the soils for road construction works due to excessive cracking.

(b) Coastal soils from Igbokoda- Ayetoro road in the riverine area of Ondo State.

Igbokoda is the headquarters of the Ilaje's in the riverine area of Ondo State. The climatic condition in the area is tropical with rain and dry seasons. The area is heavily forested and the mean annual rainfall ranges between 500mm and 1000mm. This along with poor drainage in the area resulted in marshy land and swamps.

The soil material consists of silty sandy and weak lateritic deposits from the weathered upland material. As the groundwater drains downward, there resulted a greater concentration of silt and clay deposits. In addition, irregular distributions of weakly cemented red brown nodules in the upper horizons are formed. The soil is thus susceptible to disturbance and softening when saturated due to resulting chemical breakdown of bonding agents and leaching of fines (Ajayi, 1985). The coastal sands therefore are yellowish to grayish, fined grained, uniformly graded and silty in nature. Road construction in this area is faced with serious problem in terms of finding suitable road materials. This has subsequently led to high cost of road construction due to long distance of hauling borrowed materials.

(c) Lateritic soil samples from Ayede-Ogbese-Ago Dada and Oda road, the suburbs of Akure town in Ondo State.

The laterites and lateritic soils of Nigeria originate from intense weathering of the crystalline rocks of the basement complex, which underlines about 60% of the country (Ajayi, 1985). They are formed in tropical regions usually in areas with significant dry season and weathering of rocks with high iron content. Ondo state is located in the deciduous tropical region rainforest belt of southwestern Nigeria with both the rainy and dry seasons in a year. Different degrees of laterization are common features within the zone.

The properties of lateritic soils depend on those inherited from the parent rock material, environmental factors and characteristics of the locality in which the soil has been in the course of its geologic history (Gidigasu, 1976). The behaviour of laterites in pavement construction depends on the particle size characteristics, nature and strength of gravel particles and the degree to which the soil has been compacted. When the laterite is well graded, the material performs satisfactorily both as subbase and base material. Weak laterites have tendency to break down during compaction and under repeated loading resulting in strength reduction especially in the presence of water due to softening effect on the soil, which leads to pavement distress and eventual failure. In the selected area, there exists vast abundance of weak lateritic soil, which is not suitable directly for road construction works (Ola, 1988). Figure 1 shows the sample locations of the three representative soil types.

The mechanisms of soil modification were studied by mixing polyvinyl acetate with the collected soil samples at varied percentages and application rates in order to investigate the effectiveness of the products on soil strength improvement. The laboratory tests carried out include specific gravity and moisture content determinations, measurement of the Atterberg limits (liquid limit, plastic limit, and plasticity index), particle size characteristics, compaction characteristics (evaluated by comparing the compacted density of untreated and treated specimens) using the West African Compaction Method at three layers using 4.5kg rammer and California Bearing Ratio (CBR).

4.0 RESULTS AND DISCUSSIONS

4.1 Chemical Analysis of Polyvinyl acetate

Table 1: Summary Result of Physical and Chemical Analysis of the Material

Parameter	Polyvinyl acetate
Physical form	Liquid
Appearance	Whitish
Odour	Offensive
pH	5.2
Specific gravity	0.92
Volatility	0.014
Density	1.136g/cm^3
Copolymer	1.93%
Vinyl acetate (Total solids) Other Ingredients:	28.2% Fe = 36ppm, Mg = 4ppm Ca = 1ppm, Al = 32ppm Zn = 0.7ppm, Cu = 0.5ppm
Water	69.87%

From Table 1, the material is a liquid which contains 28.2% of vinyl acetate copolymers, 69.87% water and 1.93% of some metals, which are iron 36ppm, 4ppm magnesium, 1ppm of calcium, 32ppm of aluminum, 0.7ppm of zinc and 0.5ppm of copper. The pH of the material and specific gravity are 5.2 and 0.92 with density of 1.136g/cm^3. The material was analyzed locally in the laboratory to be a polymerized vinyl acetate solution.

4.2 Characteristics of Natural Soil Samples

To evaluate the engineering characteristics of the natural soil samples collected, classification tests which include particle size analysis, Atterberg limits determination and strength tests which are compaction and determination of California Bearing ratio for the samples were carried out on them. These were carried out using the West Africa Compaction method as stated above. Tables 2, 3 and 4 show the summary results of the Atterberg limits, particle size distribution, compaction characteristics and strength characteristics of the natural samples respectively with the particle size curves shown in Figure 2.

Table 2: Summary Results of the Atterberg's Limits of Natural Soil Samples

SAMPLES	LIQUID LIMIT, %	PLASTIC LIMIT,%	PLASTICITY INDEX, %	LINEAR SHRINKAGE,%
Igbokoda – Ayetoro	Not Applicable	Not Applicable	Not Applicable	Not Applicable
Oda Natural soil sample	38.0	20.1	17.9	6.5
Ayede – Ogbese Natural soil sample	36.5	19.7	16.8	5.8
Yola - Gombe Natural soil sample	58.4	32.5	25.9	9.8
Numan - Jalingo Natural soil sample	53.3	31.7	21.6	9.2
Numan –Yola Natural Soil Sample	51.5	32.5	19.0	8.9

Table 3: Summary of Particle Size Distribution of Soil Samples

Sample location	Gravel Fractions, %	Sand Fractions, %	Silt fractions, %	Clay Fractions, %	Soil Classification
Igbokoda – Ayetoro	0.0	95.8	4.2	-	A-3
Oda road	2.5	57.5	17.0	23.0	A-2-6
Ayede–Ogbese road	1.5	52.5	15.0	31.0	A-2-6
Yola – Gombe road	0.1	10.2	32.0	57.7	A-7-6
Numan–Jalingo road	0.2	13.0	30.0	56.8	A-7-6
Numan – Yola road	0.2	16.0	27.0	56.8	A-7-6

Table 4: Summary of Compaction Characteristics and California Bearing Ratio of Natural Soil Samples

Samples/ Location	Optimum Moisture Content, OMC %	Maximum Dry Density, MDD, KN/m^3	California Bearing Ratio, % (unsoaked)
A. Igbokoda/Ayetoro	9.0	15.6	7.7
B. Oda Road	13.5	19.7	20.0
C. Ayede-Ogbese	13.9	16.4	23.
D. Yola – Gombe Road	15.1	18.9	22.5
E.Numan-Jahingo Road	15.5	21.4	28.7
F. Nurman – Yola road	14.9	18.2	32.5

(i) Igbokoda-Ayetoro Samples

The summary results of the laboratory tests on the natural soil samples are as shown on Tables 2, 3 and 4 with the particle size curves of tested soil samples shown in Figure 2. The results in Table 3 show that Igbokoda-Ayetoro samples are generally fine grained with little or partially no gravel fractions. It ranges from fine silt to coarse sandy soils. It has 0.02% gravel, 95.8% sand sizes and 4.2% silt with no clay fraction. It is thus classified as A-3 according to American Association of Highway and Transport Officials (AASHTO) soil classification system. As shown in Table 4, the soil has a maximum dry density, MDD of $15.6kN/m^3$ and Optimum Moisture Content, OMC of 9% with California Bearing ratio, CBR value of 7.7%, which indicates a very poor subgrade soil.

(ii) Akure-Oda Road Samples

The Atterberg limits for Akure-Oda road natural samples as shown in Table 2 are 38% liquid limit (LL), 20.1% plastic limit (PL) and 17.9% plasticity index (PI) with linear shrinkage of 6.5%. The material is classified as A-2-6. The MDD, OMC and CBR values from Table 4 are $19.7kN/m^3$, 13.5% and 20% respectively. The Federal ministry of Works and Housing general specifications for roads and bridges Vol. 11, 1994 states that for plasticity, base materials must not have LL and PI not greater than 35% and 12% respectively. For the subbase, LL and PI should not be greater than 35% and 30% while for the subgrade, LL and PI should not be greater than 50% and 30%.

For the strength characteristics in Table 4, it gave a minimum unsoaked CBR value of 7% for the subgrade, 30% for subbase and 80% for the base. Comparing the test result above, it could be seen that the material in its natural state is unsuitable for either a subbase or base material unless otherwise improved.

(iii) Ayede-Ogbese Samples

As shown on Table 3, the sample has 1.5% gravel size, 52.5% sand, 15% silt and 31% clay fraction with LL of 36.5%, PL of 19.7%, PI of 16.8% and linear shrinkage (LS) of 5.8% as shown on Table 2. The soil is classified as A-2-6 according to AASHTO. It has average unsoaked CBR value of 23.4% also indicating a poor subbase and unsuitable base material which should have minimum standard values of 30% and 80% unsoaked CBR.

(iv) Black cotton soil from Yola-Gombe Road

This gave 0.1% gravel sizes, 10.2% sand fractions and 32% of silt and 57.7% clay fractions with a LL of 58.4%, PL of 32.5% and PI of 25.9% with LS of 9.8% indicating a soil with high shrinkage characteristics. The soil is classified as A-7-6. The MDD and OMC are 18.9kN/m^3 and 15.5% respectively with a CBR value of 28.7%. The soil is not recommended for either the subbase or base layers due to the high clay content, which will result in high swelling and eventual failure of the pavement if used.

(v) Numan-Jalingo Road Samples

This contains 0.2% gravel, 13.0% of sand fraction 30% of silt and 56.8% clay fractions. The Atterberg limits are 53.3% liquid limit, 31.7% plastic limit and 21.6% plasticity index and linear shrinkage of 9.2%. The soil is also classified as A-7-6. The strength characteristics gave a CBR of 28.7%, which also confirms an unsuitable subbase and base materials with high shrinkage and swelling characteristics.

(vi) Numan-Yola Road

The particle size analysis on this sample indicates a silty clay sand with 0.2% gravel fraction, 16.0% sand, 27% silt and 56.8% of clay fractions having PI of 19% and LS of 8.9%. The sample is also classified as A-7-6. The MDD and OMC are 18.2 kN/m^3 and 14.9 % respectively while the CBR value is also 32.5%. It is a fair subgrade material but naturally unsuitable for the subbase or base layers of roads.

4.2. CHARACTERISTICS OF SOIL SAMPLES STABILIZED WITH POLYVINYL ACETATE

Polyvinyl acetate was mixed with the soil samples in varied proportions of 2, 4, 6, 8 and 10% to ascertain the best mix and the soil’s responses were evaluated in the laboratory. Graphs were plotted using the results from on all considered soil locations (Igbokoda-Ayetoro, Oda, Ayede-Ogbese, Yola-Gombe, Numan-Jalingo and Numan-Yola roads). It was carried out on the different soil types to evaluate the plasticity and strength characteristics.

Tables 5 and 6 show the effects of polyvinyl acetate on the soil’s properties at both the natural and stabilized states.

TABLE 5: EFFECT OF POLYVINYL ACETATE ON PLASTICITY OF SOILS

SAMPLE LOCATION	LL%	MEAN LL %	PL%	MEAN PL	PI%	MEAN PI %	LS%	MEAN LS %
Oda road, 0%	36		22.0		14		5.8	
	36	38	18.0	20.1	18	17.9	6.1	6.5
	42		20.3		21.7		7.6	
2% additive	35.0		26.1		8.9		6.3	
	26.8	30.1	12.7	18.0	14.1	12.1	5.8	6.2
	28.5		15.2		13.3		6.5	
4% additive	31.1		22.5		8.6		6.1	
	28.4	28.5	18.3	19.9	10.1	8.6	6.3	5.8
	26.0		18.9		7.1		5.0	
6% additive	28.5		19.8		8.7		4.6	
	28.6	28.1	20.1	20.1	8.5	8.0	4.0	4.1
	27.2		20.4		6.8		3.7	
8% additive	28.1		18.5		9.6		4.3	
	29.1	26.5	21.1	19.0	8.0	7.5	3.8	4.0
	22.3		17.4		4.9		3.9	
10% additive	26.4		19.0		7.4		4.1	
	27.8	25.1	17.7	18.0	10.1	7.1	3.7	3.6
	21.1		17.3		3.8		3.0	
Ayede-Ogbese,	35		20		15		4.9	
0%	40.5	36.5	20.5	19.7	20	16.8	7.5	5.8
	34		18.6		15.4		5.0	
2% additive	35.2		20.9		14.3		5.0	
	37.3	34.2	20.4	21.1	16.9	13.1	5.2	5.0
	30.1		22.0		8.1		4.8	
4% additive	30.9		21.8		9.1		4.0	
	30.8	30.1	19.8	20.9	11.0	9.2	5.4	4.3
	28.6		21.1		7.5		3.5	
6% additive	31.8		23.4		8.4		5.1	
	29.0	29.1	19.8	20.6	9.2	8.5	3.9	4.0
	26.5		18.6		7.9		3.0	
8% additive	28.3		22.6		5.7		4.5	
	28.2	27.1	16.9	19.1	11.3	8.0	3.8	3.8
	24.8		17.8		7.0		3.1	
10% additive	27.5		20.1		7.4		3.5	
	25.6	26.0	19.2	18.7	6.4	7.3	3.1	3.2
	24.9		16.8		8.1		3.0	
Yola-Gombe, 0%	51.6		37		28.0		10.5	
	60.5	58.4	33	32.5	27.1	25.9	11.1	9.8
	63.1		27.5		22.6		7.8	
2% additive	61.5		33.1		28.4		7.9	
	48.6	53.1	30.8	30.8	17.8	22.3	5.7	6.6
	49.2		28.5		20.7		6.2	
4% additive	43.2		20.1		23.1		6.0	
	38.1	37.1	19.2	18.6	18.9	18.5	5.6	5.5
	30.0		16.5		13.5		4.9	

SAMPLE LOCATION	LL%	MEAN LL %	PL%	MEAN PL	PI%	MEAN PI %	LS%	MEAN LS %
6% additive	33.8		18.2		15.6		6.5	
	36.6	33.5	17.4	17.5	19.2	16.0	4.3	5.2
	30.1		16.9		13.2		4.8	
8% additive	30.9		13.5		17.4		5.7	
	30.6	30.1	11.7	12.6	18.9	17.5	4.6	5.0
	28.8		12.6		16.2		4.7	
10% additive	38.0		15.2		22.8		4.8	
	24.9	30.0	15.4	13.9	9.5	16.1	3.5	4.3
	27.1		11.1		16.0		4.6	
Numan-Jalingo,	48.5		35.7		21.4		12.5	
0%	51.3	53.3	26.2	31.7	22.5	21.6	7.6	9.2
	60.1		33.2		20.9		7.5	
2% additive	48.0		28.9		19.1		8.5	
	36.5	40.1	24.2	24.4	12.3	15.7	5.9	6.5
	35.8		20.1		15.7		5.1	
4% additive	32.0		18.5		13.5		6.0	
	30.9	30.5	18.2	18.0	12.7	12.5	4.5	5.0
	28.6		17.3		11.3		4.5	
6% additive	29.5		16.5		12.4		4.9	
	27.0	28.1	15.8	16.0	12.1	12.1	4.9	4.8
	27.8		15.7		11.8		4.6	
8% additive	26.0		15.1		10.9		4.2	
	25.1	25.6	14.0	14.1	11.1	11.5	3.8	4.0
	25.7		13.2		12.5		4.0	
10% additive	24.5		13.5		11.0		4.1	
	24.6	24.2	13.3	13.1	11.3	11.1	3.7	3.8
	23.5		12.5		11.0		3.6	
Numan-Yola,	52.9		28.8		20.1		9.0	
0%	48.8	51.5	35.6	32.5	16.6	19.0	9.0	8.9
	52.8		33.1		20.3		8.7	
2% additive	51.0		35.0		16.0		6.8	
	36.5	40.0	18.2	24.4	18.3	15.6	6.0	6.5
	32.5		20.0		12.5		6.7	
4% additive	33.0		21.5		10.4		4.2	
	30.0	30.8	16.8	18.3	14.2	12.5	3.8	4.0
	29.4		16.6		13.8		4.0	
6% additive	27.5		17.1		10.4		4.3	
	27.4	27.3	16.8	17.2	10.6	10.1	3.9	4.0
	27.0		17.7		9.3		3.8	
8% additive	25.1		14.6		10.5		4.0	
	26.4	24.5	13.8	14.3	12.6	10.2	3.8	3.8
	22.0		14.5		7.5		3.6	
10% additive	21.5		10.3		11.2		3.7	
	20.4	20.9	11.1	10.9	9.3	10.0	3.6	3.5
	20.8		11.3		9.5		3.2	

TABLE 6: STRENGTH CHARACTERISTICS OF STABILIZED SOIL SAMPLES WITH POLYVINYL ACETATE

SAMPLE LOCATION	OMC %	MEAN OMC %	MDD kN/m^3	MEAN MDD kN/m^3	CBR %	MEAN CBR %
IGBOKODA-	8.9		15.9		8.2	
AYETORO, 0%	9.2	9.0	15.7	15.6	7.7	7.7
	8.9		15.2		7.2	
2% additive	9.2		17.6		30.1	
	9.4	9.3	17.2	17.3	30.6	30.5
	9.3		17.1		30.8	
4% additive	8.9		17.0		58.7	
	9.3	9.2	17.7	17.5	58.8	58.9
	9.4		17.8		59.2	
6% additive	9.4		16.5		50.8	
	9.8	9.5	16.4	16.3	50.0	50.3
	9.3		16.0		50.1	
8% additive	9.5		15.6		49.9	
	9.7	9.5	16.0	15.8	50.3	50.1
	9.3		15.8		50.1	
10% additive	9.2		15.9		40.7	
	9.4	9.2	15.2	15.5	40.6	40.5
	9.0		15.4		40.2	
Akure-Oda road, 0%	13.7		18.9		19.8	
	14.7	13.5	19.0	19.7	19.0	20.0
	12.1		21.2		21.2	
2% additive	14.0		19.4		70.9	
	13.0	13.4	20.5	20.2	70.2	70.5
	13.2		20.1		70.4	
4% additive	12.8		22.0		90.1	
	13.8	13.2	21.9	21.8	89.6	89.8
	13.0		21.5		89.7	
6% additive	13.3		21.0		84.3	
	12.8	12.9	20.9	20.8	84.4	84.2
	12.6		20.5		83.9	
8% additive	12.1		19.7		76.6	
	12.5	12.5	19.8	19.9	76.1	76.5
	12.9		20.2		76.8	
10% additive	11.9		19.9		89.9	
	12.3	12.0	19.4	19.6	70.2	70.2
	11.8		19.5		70.5	
Ayede-Ogbese, 0%	14.5		17.5		22.5	
	14.0	13.9	15.7	16.4	23.1	23.4
	13.2		16.0		24.6	
2% additive	14.4		19.8		56.2	
	13.6	13.9	19.0	19.2	55.8	56.1
	13.7		18.8		56.3	
4% additive	13.0		20.5		88.4	
	14.1	13.5	20.6	20.3	89.0	88.7
	13.4		19.8		88.7	

SAMPLE LOCATION	OMC %	MEAN OMC %	MDD kN/m3	MEAN MDD kN/m3	CBR %	MEAN CBR %
6% additive	12.6		19.1		60	
	13.6	13.2	17.8	18.2	62	63
	13.0		17.7		67	
8% additive	12.8		17.4		58.4	
	13.2	13.3	16.8	17.1	58.0	58.1
	13.9		17.0		57.9	
10% additive	12.5		16.6		56.1	
	13.6	13.0	16.9	16.4	56.8	56.5
	12.9		15.7		56.6	
Yola-Gombe, 0%	16.0		19.5		30.9	
	15.6	15.5	19.1	18.9	27.7	28.7
	14.9		18.1		27.5	
2% additive	14.6		20.0		68.8	
	16.2	15.6	19.8	19.2	70.4	69.2
	16.0		17.8		68.4	
4% additive	13.5		20.5		87.3	
	15.6	15.1	18.9	19.8	85.8	85.1
	16.2		20.0		82.2	
6% additive	14.5		18.1		73.8	
	13.6	13.9	18.7	18.1	71.4	72.5
	13.6		17.5		72.3	
8% additive	13.5		17.3		63.2	
	13.0	13.2	16.2	17.1	62.8	63
	13.1		17.8		63.0	
10% additive	12.6		15.4		51.5	
	12.9	13.0	17.5	16.0	50.3	50.8
	13.7		15.1		50.6	
Numan-Jalingo, 0%	16.1		21.8		30.5	
	15.6	15.5	21.6	21.4	30.4	28.7
	14.8		20.8		25.2	
2% additive	14.6		19.8		49.9	
	14.4	14.1	20.3	21.2	50.4	50.1
	13.3		23.5		50.0	
4% additive	14.4		22.0		80.6	
	13.4	13.6	21.3	21.8	81.8	82.0
	13.0		22.1		83.6	
6% additive	13.0		17.6		67.6	
	12.8	13.1	19.0	18.4	70.2	69.0
	13.5		18.6		69.2	
8% additive	11.7		17.1		58.6	
	13.0	12.1	18.6	17.9	60.6	60.1
	11.6		18.0		61.1	
10% additive	11.5		16.1		44.0	
	11.8	11.8	16.3	16.1	46.8	45.2
	12.1		15.9		44.8	

SAMPLE LOCATION	OMC %	MEAN OMC %	MDD kN/m3	MEAN kN/m3	MDD	CBR %	MEAN CBR %
Numan-Yola,0%	15.3		18.0			30.1	
	14.9	14.9	18.1	18.2		32.9	32.5
	14.5		18.5			34.5	
2% additive	15.5		20.6			60.9	
	13.7	14.5	19.0	20.2		61.4	60.7
	14.3		21.0			59.8	
4% additive	14.0		22.0			87.5	
	13.6	13.7	21.4	21.5		90.3	90.0
	13.5		21.1			92.2	
6% additive	13.1		17.8			72.0	
	11.7	12.5	18.6	18.1		69.0	70.5
	12.7		17.9			70.5	
8% additive	12.5		18.2			69.0	
	12.0	12.2	16.5	17.5		67.6	68.1
	12.1		17.8			67.7	
10% additive	11.6		16.7			52.6	
	12.2	12.0	15.9	16.1		50.1	51.5
	12.2		15.7			51.8	

4.2.1. Igbokoda-Ayetoro Samples

In Table 6, with addition of the polyvinyl acetate, the MDD increased from the natural value of 15.6kN/m^3 to a maximum value of 17.5kN/m^3 at 4% mix and thereafter reduced upon further increase of the mix to a value of 15.5kN/m^3 at 10% mix ratio.

Also in Table 6, the strength test shows improvement in the CBR values from a natural value of 7.7% to 58.9% at 4% mix of the polyvinyl acetate. This gave a percentage increase in strength of 665% over that of the soil. Application of the stabilizer had improvement on compaction and strength characteristics of tested soil samples.

4.2.2. Akure-Oda Road Samples

The natural soil has 38% LL, 20.1% PL, 17.9% PI and 6.5% LS. The plasticity reduced gradually with increase in the mix proportion with polyvinyl acetate to a minimum value of 7.1% PI and LS of 3.6 at 10% mix as shown in Table 5. The sample increased from the natural MDD of 19.7kN/m^3 to MDD of 21.8kN/m^3 with polyvinyl acetate.

The CBR increased from 20% natural value to 89.8% with the stabilizer. The percentage increase from the resulting strength of polyvinyl acetate stabilized sample is 349% over the natural soil.

4.2.3. Ayede-Ogbese Road Samples

In Table 5, the natural soil gave LL of 36.5%, PL of 19.7%, PI of 16.8% and LS of 5.8. Addition of polyvinyl acetate to the soil resulted to PI of 13.1% and LS of 5.0% at 2% mix. The plasticity further reduced with increase in the stabilizer content to a PI of 3.2% at 10% mix. The MDD of the natural sample increased from 16.4kN/m^3 to a maximum of 20.3kN/m^3 at 4% mix with polyvinyl acetate. The CBR increased from a natural CBR value of 23.4% to 88.7% at 4% mix for the polyvinyl acetate. The stabilized CBR value gave a percentage increase in strength of 279% over that of the natural soil.

4.2.2.4. Black Cotton Soil from Yola-Gombe Road

The plastic properties of the soil also reduced with the addition of the stabilizer. Using 4% mix gave the optimum values of 18.5% PI and LS of 5.5% as shown in Table 5. From Table 6, the natural MDD of 18.9kN/m^3 increased to 19.8kN/m^3 with the CBR increasing from a natural value of 28.7% to 85.1% using 4% mix.

4.2.2.5. Numan-Jalingo Road Samples

With the stabilizer, PI also reduced from 21.6% natural value to 12.5% with the LS reducing to 5.0% from the natural value of 9.2%. The compaction characteristics gave average MDD of 21.4kN/m^3 and OMC of 15.5% at the natural state with a CBR of 28.7%. By adding polyvinyl acetate, a MDD of 21.8kN/m^3 was achieved while the CBR value increased from 28.7% natural value to 82.0 % at 4% mix.

The percentage increase in strength using polyvinyl acetate over the natural soil is 186%. This shows the efficacy of polyvinyl acetate to improve the soil strength.

4.2.2.6. Numan-Yola Road Samples

Application of polyvinyl acetate also reduced the plasticity and shrinkage characteristics of the black cotton soil from this location. At the 4% mix, the PI reduced from natural value of 19% to 12.5% with reduced LS from 8.9% to 4%. The compaction gave a natural MDD and OMC of 18.2kN/m^3 and 14.9 % respectively. Mixing with the stabilizer gave MDD of 21.5kN/m^3 and OMC of 13.7 % while the CBR increased from 32.5 % to 90% at the best mix of 4%. This gave a percentage increase in strength of 177% over the natural soil.

Figure 3 to Figure 13 show the variation in plasticity and strength characteristics of soils stabilized with polyvinyl acetate.

5.0 CONCLUSSION

Laboratory test results on the tested soil samples confirm that soil materials from Igbokoda – Ayetoro road are unsuitable for road construction in the natural state. The soil sample is classified as A-3 according to American Association of Highway and Transport Officials (AASHTO) soil classification system.

Soil samples from Oda road and Ayede – Ogbese road are classified as A-2-6. They are very unsuitable for the base course.

The black cotton soils tested are classified as A-7-6 materials. They are also unsuitable for road construction in their natural state without improvement due to their high shrinkage and swelling characteristics.

Test results show all the tested soil samples except Igbokoda – Ayetoro samples are highly plastic with wide linear shrinkage properties.

On mixing the soil samples with polyvinyl acetate, great reduction in the plasticity and shrinkage characteristics of the treated soil samples were achieved. Also general improvement on the strength characteristics resulted. The CBR results showed that all the samples were improved from unsuitable subgrade to suitable subbase materials while some were improved to good base materials.

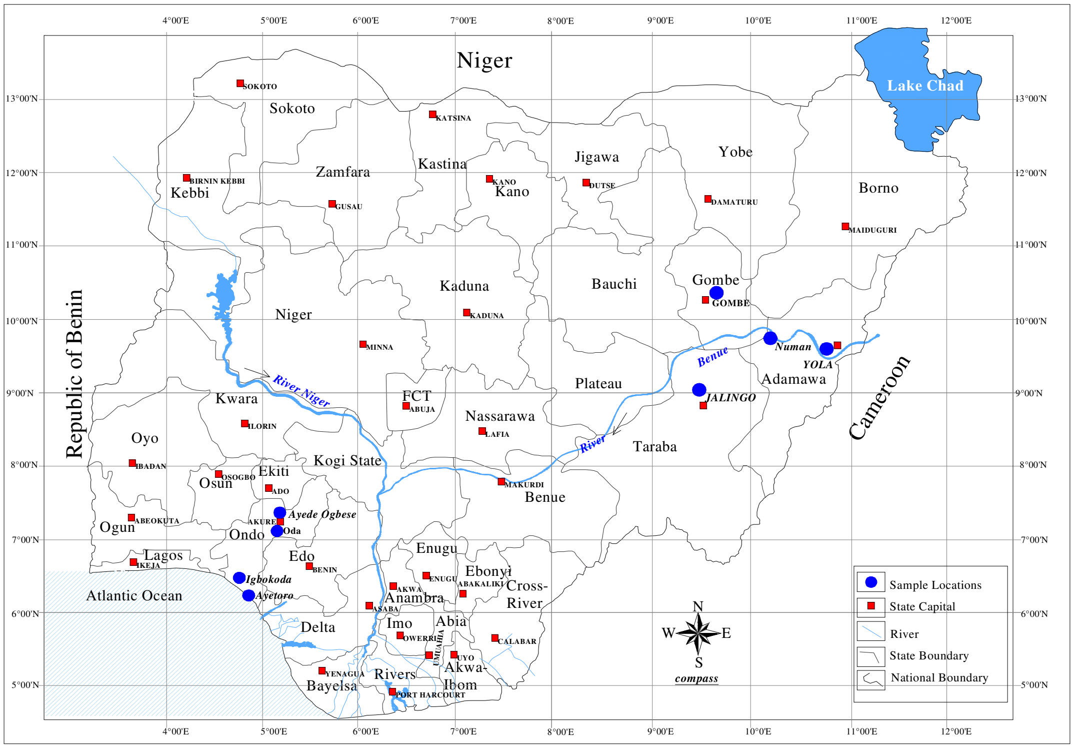
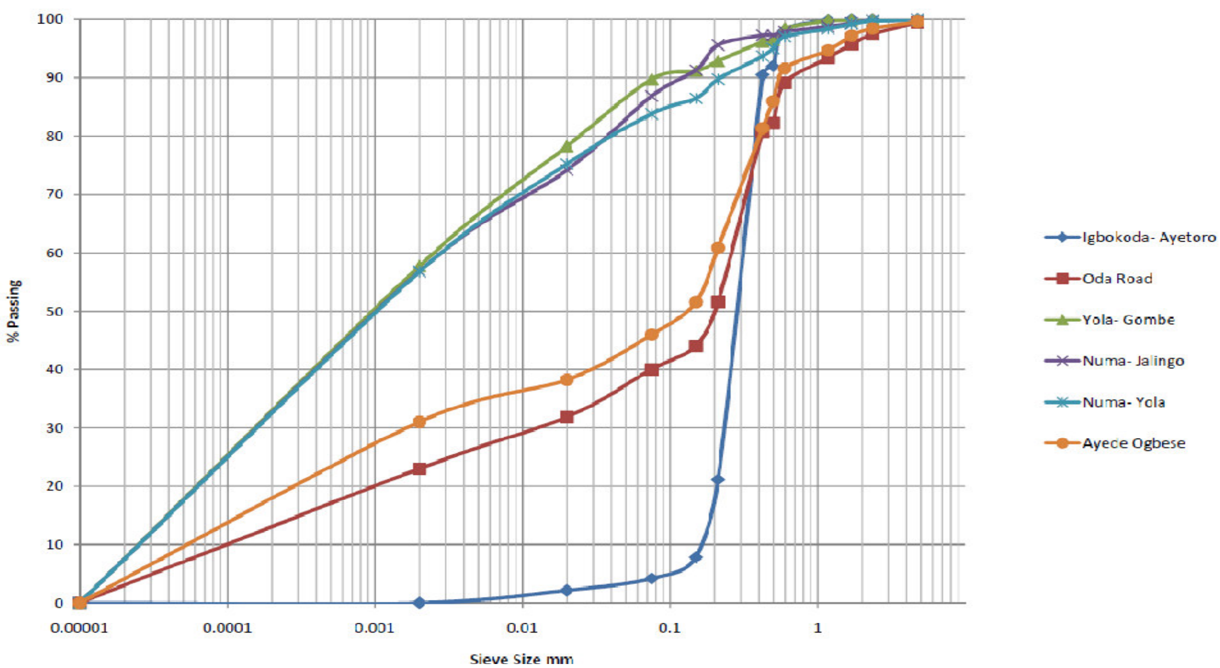


Fig. 1: Map of Nigeria Showing the Soil Sample Locations



Clay	Silt			Sand			Gravel		
	Fine	Medium	coarse	Fine	Medium	Coarse	fine	medium	coarse

0.002 0.006 0.02 0.06 0.2 0.6 2 6 20 60

Fig. 2: Particle Distribution Curves of the Collected Soil Samples

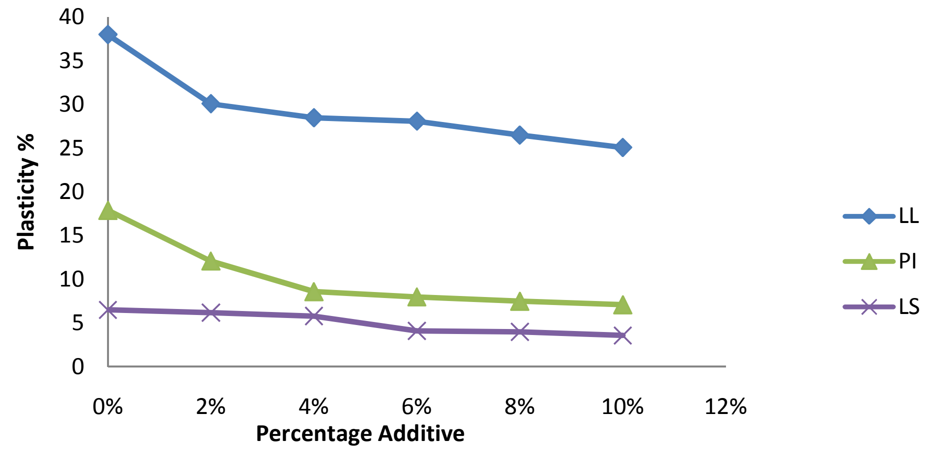


FIG. 3: A graph of plasticity against % Additive using Polyvinyl Acetate for Oda road soil samples

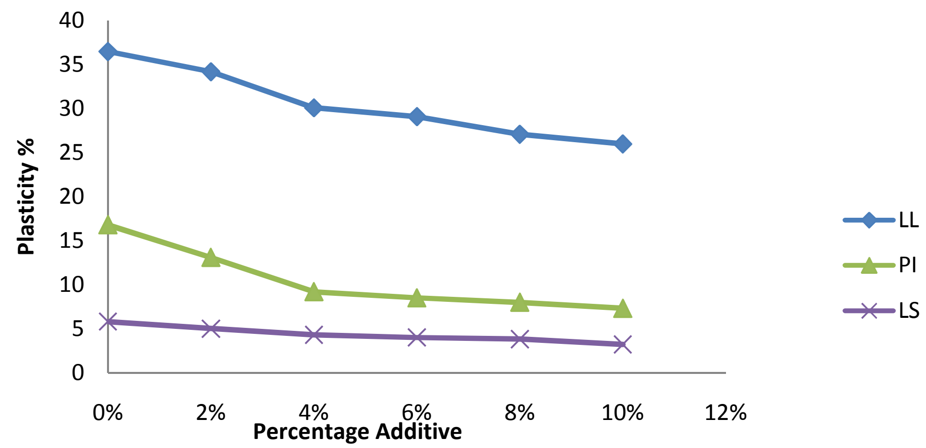


FIG. 4: A graph of plasticity against % Additive using Polyvinyl Acetate for Ayede-Ogbese soil samples

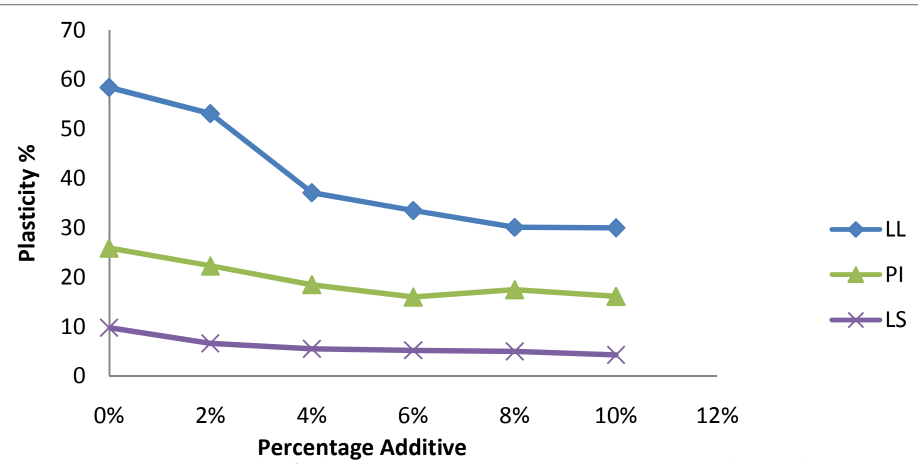


FIG. 5: A graph of plasticity against % Additive using Polyvinyl Acetate for Yola-Gombe soil samples

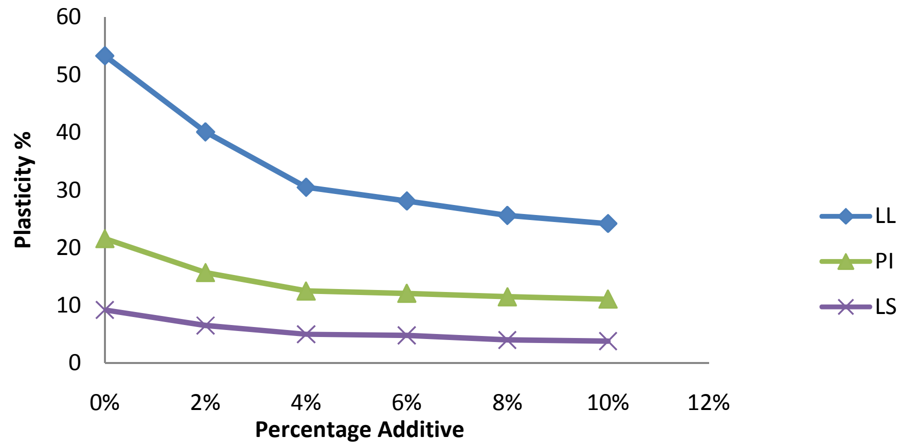


FIG. 6: A graph of plasticity against % Additive using Polyvinyl Acetate for Numan-Jalingo soil samples

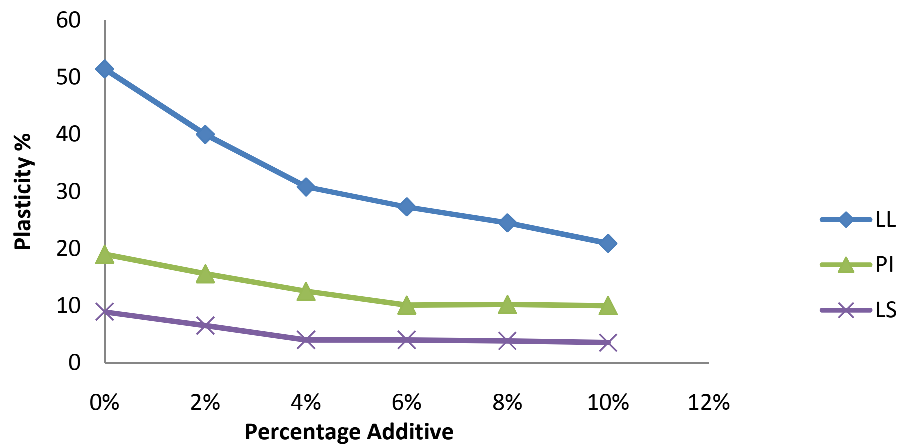


FIG. 7: A graph of plasticity against % Additive using Polyvinyl Acetate for Numan-Yola soil samples

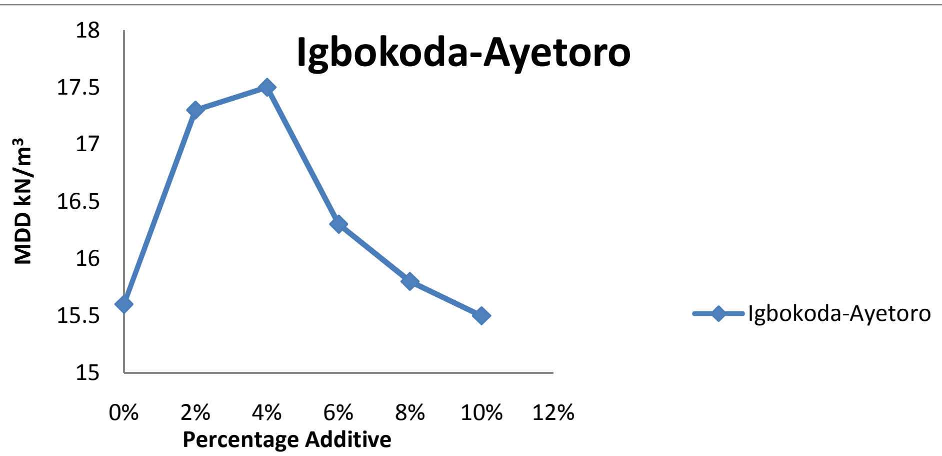


FIG. 8: Variation of MDD with % Additive using Polyvinyl Acetate for Igbokoda soil samples

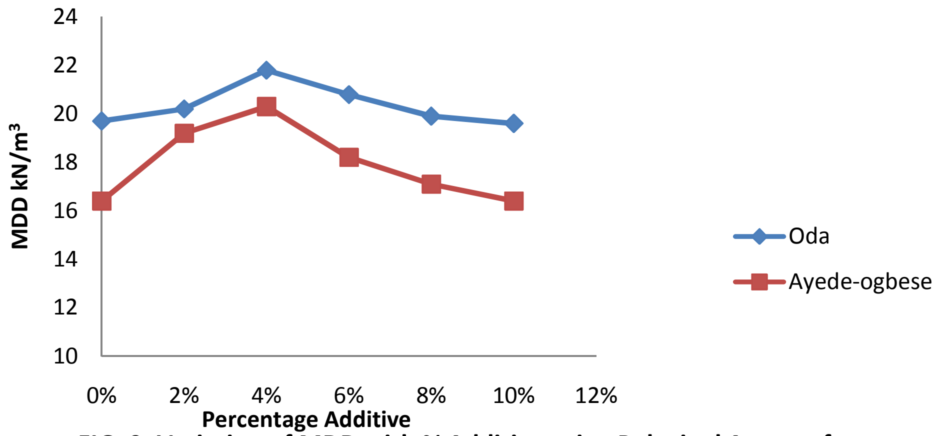


FIG. 9: Variation of MDD with % Additive using Polyvinyl Acetate for Oda and Ayede -Ogbesesoil samples

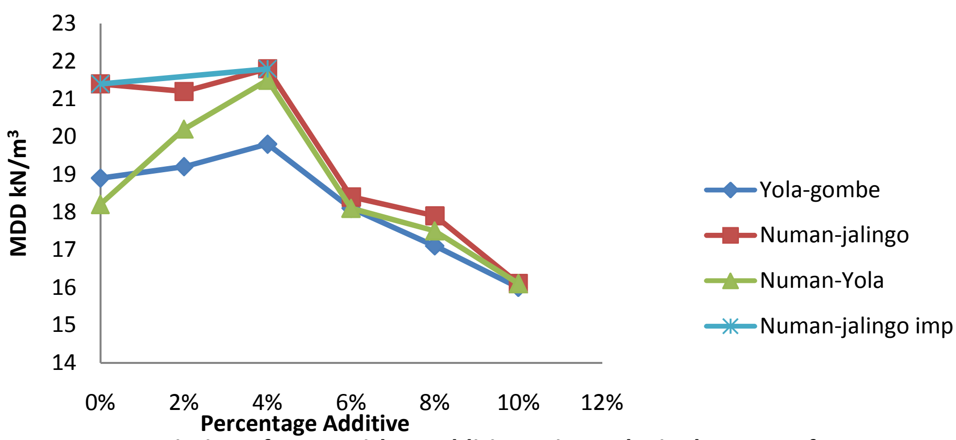


FIG. 10: Variation of MDD with % Additive using Polyvinyl Acetate for Yola-Gombe, Numan-Jalingo and Numan-Yola soil samples

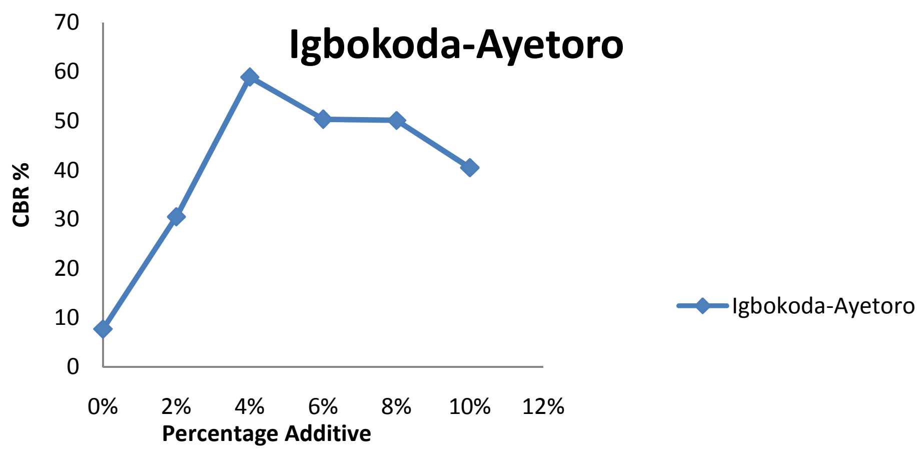


FIG. 11: Variation of CBR with % Additive for Igbokoda soil samples using Polyvinyl Acetate

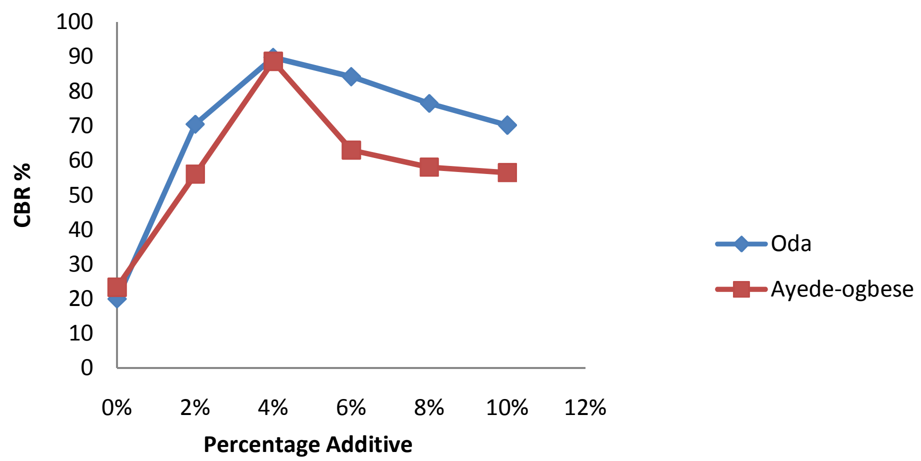


FIG. 12: Variation of CBR with % Additive for Oda and Ayede-Ogbese soil samples using Polyvinyl Acetate

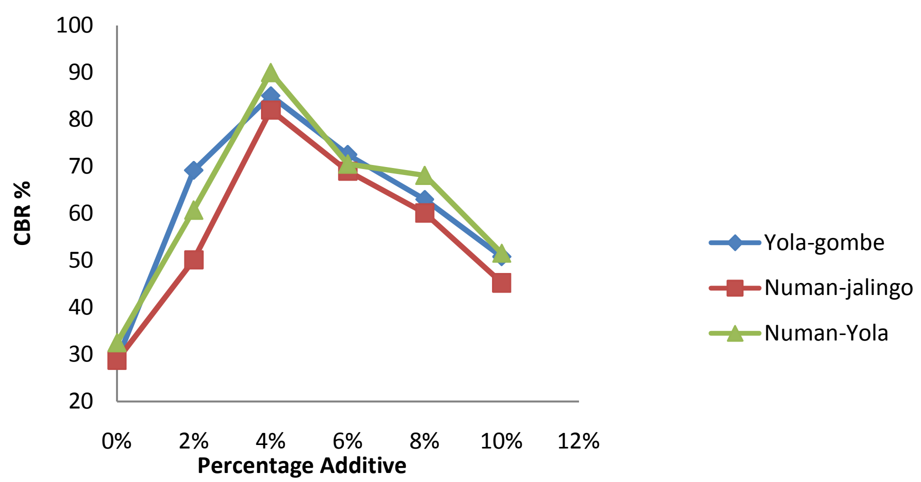


FIG. 13: Variation of CBR with % Additive for Yola-Gombe, Numan-Jalingo and Numan-Yola soil samples using Polyvinyl Acetate

REFERENCES

Ajayi, L.A (1985): The Laterites and Lateritic soils of Nigeria, Geotechnical Practice in Nigeria, International Society of Soil Mechanics and Foundation Engineering, Nigerian Geotechnical Association, Nigerian Commemorative Publication, Pp 7 - 15

Base Seal International, Inc. (2007): Base Seal BS-100 Concentrate is Very Easy To Use, Base Seal Liquid Soil Stabilizer and Top Shield Fog Sealant & Dust and Erosion Control,Base Seal International, Inc., Houston.

Eyo T.B (2006): A Crying Pavement, Research and Development Opinion (READOP) Series 10, Research and Development Unit, FERMA

Gidigasu, M.D (1976): Laterite Soil Engineering, Pedogenesis and Engineering Principles, Elsevier Scientific Publishing Company, Amsterdam

Madebor, A.O and Lal, N.B (1985): Engineering Classification of Nigerian Black Cotton Soils for Pavement Design and Construction, Geotechnical Practice in Nigeria, International Society of Soil Mechanics and Foundation Engineering, Nigerian Geotechnical Association, Nigerian Commemorative Pp 49-67

Megan, M.A, Ellis, S.J, Mercer, J. (1999): Use of Alternative Aggregates and Binders in Highway Construction in the UK, Highways Agency, Department of Environment, Transportation Research Laboratory, Crowthorne, UK

Ola, S.A (1983): The Geotechnical Properties of the Black cotton Soils of North – Eastern Nigeria, Tropical Soils of Nigeria in Engineering Practice, A.A Balkema, BR. Rotterdam, Netherlands, Pp 85 - 101

Ola, S.A (1988): Geotechnical Properties of Nigerian Soils and Ten years of collaborative research with Nigerian Building and Road Research Institute (NBRRI), Ten Year Commemorative Publication, Lagos, Nigeria, Pp 189 - 218

Owolabi, A.O, Oluyemi- A, B.D and Aderinola O.S (2004): Effect of Moisture on the Strength of Lime Stabilized Lateritic Soils (A Case Study of Ojota, Lagos) – Journal of Civil Engineering, pp 10-14

Research and Development Opinion (READOP) (2005): Multi-Innovative Road Maintenance Products, READOP Series 6, Research and Development, FERMA

Technical Recommendations for Highways, TRRL (1986): Cementitious Stabilizers in Road Construction, Draft TRH 13, Pretoria, South Africa