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GEOTECHNICAL PROPERTIES OF LATERITIC SOIL STABILIZED WITH YAM PEEL ASH FOR SUBGRADE CONSTRUCTION

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ABSTRACT

Consequent upon problems encountered vis -a -vis the engineering properties of lateritic soil for the purpose of construction of road pavements in Africa, especially in the South – South, South - East and some part of South – West regions of Nigeria, the bearing capacity of some sub-grade soils have been found to be low considering the loads imposed on the surface which are transferred down to the sub-grade. The methods employed previously in the stabilization of soils is have been the use of cement, lime, bitumen and lean concrete which are very expensive and also cause environmental hazards and health problems especially to construction workers. In view of these setbacks, this research investigated the effect of stabilization with more economical and hazard free stabilizer such as yam peel ash on the geotechnical properties of lateritic soils. Soil sample was collected from a lateritic soil subgrade of chainage 1 + 500 to 2 + 000 along Ikirun to Osogbo Road, Osun State, Nigeria. It was collected at a depth of not less than 150mm below the ground surface using the disturbed sampling technique. The natural moisture content was determined and the other soil was air-dried to carry the other laboratory tests such as (atterberg limits, compaction, sieve analysis, California Bearing Ratio (CBR.), and specific gravity. The

Yam Peel Ash, YPA [dioscorea] was used as replacement by weight of dry soil at different percentages (0%, 3%, 6%, 9%, and 12%). The CBR values obtained from the results of untreated lateritic soil was 29% while the optimum CBR values obtained for the stabilized lateritic soil 40% at 6% YPA content. The effect of YPA stabilization on thegeotechnical properties of lateritic soil brings considerable improvement on the physical Engineering characteristics of the lateritic soils as evidence by the results of the test carried out. The aim of this research work is to determine the effect of yam peel ash on geotechnic properties of lateritic soil as an alternative stabilizing agent for subgrade in road construction

Keywords: Yam Peel Ash YPA [Dioscorea], Stabilization, Lateritic Soil, California Bearing Ratio (CBR.) and Compaction.

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1. INTRODUCTION

Soil Stabilization is being used for a variety of engineering works, the most common application is in the construction of roads and highway pavements, where the main objective is to increase the strength or stability of the underlying soil and to reduce construction cost by making the best use of locally available materials [1].Civil engineering projects located in areas with soft or weak soils have traditionally incorporated improvement of soil properties by using various methods. Over the years, cement and lime have been two main materials used for stabilizing soils and pozzolans which are broad class of siliceous or siliceous and aluminous materials which possess little or no cementitious capabilities, but in finely divided form and in the presence of water, react chemically with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties [1, 6]. These materials have rapidly increased in price due to the sharp increase in the cost of energy. Thus, the use of agricultural waste (such as yam peel ash) which is the focus of this research, is expected to considerably reduce the cost of construction and as well reduce the environmental and health hazards associated with the aforementioned stabilizers. Yam peel is an agricultural waste obtained from milling of Yam Tuber (Dioscorea). Availability of yam peel will not be a challenge since Nigeria is one of the highest producers of yam in the world, hence, the use of YPA for upgrading of soil strength should be encouraged [3, 4].Soil stabilization is the process of improving the shear strength parameters of soil and thus increasing the bearing capacity of soil. It is required when the soil available for construction is not suitable to carry structural load. Soils exhibit generally undesirable engineering properties. Soil Stabilization is the alteration of soils to enhance their physical properties. Stabilization can increase the shear strength of a soil and/or control the shrink-swell properties of a soil, thus improving the load bearing capacity of a sub-grade to support pavements and foundations. Soil stabilization is used to reduce permeability and compressibility of the soil mass in earth structures and to increase its shear strength [4].

2. MATERIALS AND METHOD

The soil used in this study is reddish brown in colour and is known as lateritic soil, it was obtained from a highway construction work at oshogbo federal road. The soil samples where taken with a shovel and sealed in a sack. The soil sample was air dried to obtain paticles passing through the 275mm sieve. Yam peel Ash (YPA), that was used as a treatment agent for this research was obtained from kisi, Irepo Local Government Area located at the northern part of Oyo state, in South West Nigeria. A partially dried sample of Yam peel was obtained from the source. It was gathered together and sun-dried before burning into ash using an open incinerator. The ash was allowed to cool, gathered and well grounded. After grinding, it was passed through a 0.75 micron sieve and useful ash was taken as that finer than. [5, 7, 9]

3. SAMPLING

The soil samples were collected from a lateritic soil subgrade between chainage 1 + 500 to 2 +000 along Ikirun to Osogbo Road, Osun State in Nigeria. It was collected at a depth of not less than 150mmbelow the ground surface using the disturbed sampling technique. Thenatural moisture content was determined and the other soil was air-dried to carry the other laboratory tests. The YPA was used as replacement by the weight of dry soil at different percentage (0%, 3%, 6%, 9%, and 12% by dry weight of the soil).

3.2. Materials used

The materials used for this research are lateritic soil, yam peel ash and water.

3.2.1. Lateritic soil

Laboratory tests were carried out on the laterite samples collected at the back of lateritic soil subgrade chainage 1 + 510 along Ikirun to Osogbo Road, Osun State.

3.2.2. Yam Peel Ash (YPA)

The yam peels collected from domestic waste were burnt using incinerator after which they were grounded to fineness form and sieved using sieve 90 micron mesh according to [9].

3.2.3. Water

Portable water free from contamination was used throughout this study.

3.3. Laboratory Test

The following tests were carried out in this research;

i. SRF Chemical Test on YPA
ii. Natural Moisture Content
iii. Sieve Analysis
iv. Specific Gravity
v. Atterberg Limit
vi. Compaction Test
vii. California Bearing Ratio (CBR)

3.3.1. Chemical Compositions ofYPA

The chemical compositions below were determined at SMO Laboratory, Joyce 'B' Road, off Mobil-Ring Road, Ibadan, Nigeria [4, 5]

i. Silicon Dioxide (SiO_2)
ii. Aluminium Oxide (Al_2O_3)
iii. Ferric Oxide (Fe_2O_3)
iv. Magnesium Oxide (MgO)

v. Calcium Oxide (CaO)
vi. Sulphur Trioxide (SO_3)
vii. Sodium Oxide (Na_2O)
viii. Potassium Oxide (K_2O)
ix. Loss of Ignition

3.3.2. Determination of Natural Moisture Content

This is the determination of the natural moisture content present within the lateritic soil samples. The procedure is as follows;

- Collect the sample immediately after dogging and put little of the samples (about 50g-70g) collected into two small containers (that has been weighed already) and cover them so as to retain the moisture.
- Take the samples to the laboratory for weighing.
- Put the cans containing the wet samples into the oven and leave for about 24hours to dry.
- Re weight the cans containing the soil sample and record.
- Tabulate the readings and calculate the moisture content.

3.3.3. Specific Gravity of soil sample

Procedure:

The samples were first screened on BS sieve thoroughly to remove grass particles and other deleterious materials. The weight of the empty density bottle was recorded as W_1. The sample used was filled into the density bottle and weighed; the weight was recorded as W_2 (weight of bottle + dry sample). The density bottle was gradually filled with distilled water to gauge mark, soon after the end of soaking, air entrapped and bubbles on the surface of the aggregate sample were removed by shakingthedensitybottle and the weight was recorded as W_3 (weight of bottle + dry sample + distilled water), after which the bottle was emptied and oven dry. The density bottle was then filled with distilled water to the gauge mark and weighed as W_4 (weight of bottle + distilled water). The equation used to determine the specific gravity of aggregate is given in equation 3.1. $Specific\,Gravity(Gs)\ of\ soil = \dfrac{w_2 - w_1}{(w_4 - w_1) - (w_3 - w_2)}$

.....equation 3.1

Precaution Taken:

It was ensured that the bottle was clean and dry before any content was added.

3.3.4. Particle size analysis

This procedure is carried out to determine the particle size distribution which is achieved by passing the soil sample through a set of sieves. The particle size distribution curve and the coefficient of gradation C_c and the coefficient of Uniformity C_u, are plotted on a graph to determine the class of the soil.

3.3.5. Atterberg Limit Tests

The Atterberglimit tests carried out include the liquid limit (LL), the plastic limit (PL) and the linear shrinkage limit test. The tests were carried out on each sample in their natural state, followed by the addition of cement and YPA by 0% to 12% respectively.

3.3.5.1 Liquid limit Test (LL)

Liquid limit refers to the minimum moisture content at which a particular soil type will flow under its own weight. The equipment used for the liquid limit was the use of Casagrande apparatus. The apparatus consists of a Casagrande apparatus, glass plate, spatula, palette knife, container (big and small), metler balance, sieve 425µm, mortar, pestle, grooving tool and oven. The procedure is as follows:

- The soil sample is put in the mortar and stir with the pestle
- Pour into 425µm sieve and shake for some time
- Measure 300g of the sieved soil sample
- Pour the sieved soil on the glass plate and add water to it
- Use the spatula and palette knife to stir the soil
- Put the wet soil in the Casagrande apparatus
- Divide by drawing down the grooving tools at the centre of the centre of the hinge. Operate the apparatus and engage a counter until the two parts of the soil come into contact.
- Record the number of blows
- Take a small sample at the point where it closed
- put the sample in an already weighted container and with the soil sample
- The remaining soil in the camp is mixed with the soil on the plate
- Clean the Casagrande apparatus with a damp cloth, repeat the test until four results is gotten.
- Weigh the soil samples that are taken.
- Put the sample in the oven to dry
- Re-weight the soil samples after during
- The relationship between eh moisture content and the corresponding number of blows shall be plotted on a semi-logarithm chart. The moisture content corresponding to the intersection of the flow curve with the 25 blows shall be taken as the liquid limit;

3.3.5.2 Plastic Limit

Plastic limit (PL) is the moisture content at which a soil becomes too dry to be in a plastic condition as contained by the plastic limit test. It can also be defined as the maximum moisture at which the soil can be rolled into a thread of 3mm diameter without breaking up.About 20g of the dried soil samples, all passing the 0.425mm sieve were mixed with distilled water and moulded into ball. The balls of soil were rolled by hand on a glass plate with sufficient pressure to form thread. When the diameter of the resulting thread becomes 3mm the soil is threaded together and then rolled out again. This process continues until the thread crumbles; when it is 3mm diameter and at this stage the moisture content of the soil was determined. The whole procedure was carried out twice and the average value of moisture content was taken as the plastic limit at the soil.

3.3.5.3 Plasticity index (PI)

The plasticity index of the soil was calculated from the equation:

Plasticity index (PI) = Liquid Limit (LL) – Plastic Limit (PL)

3.3.6 Compaction Test

The compaction test was performed on the soil in its natural state and with the addition of cement and Yam peel as, the Yam peel ash content was increased in steps of 3% of dry density and optimum moisture content obtained for each test was plotted for various YPA contents. The same procedure was repeated for the cement additives. The apparatus consists of a cylindrical metal mould of a capacity of 1000cm^3 with an internal diameter of 101.6mm and an effective height of 116.43mm with a detachable base plate and top plate and a collar 50mm deep that fits into the top of the mould, and a rammer having 50mm diameter circular face and weighting 4.5kg. The rammer is contained in a cylindrical sleeve designed such that the rammer falls into the soil through a height of 450mm for each below.

About 4200g of dry soil to be tested was weighed out and place in a large tray. Water was added to bring the water content of the soil to about 6% and thoroughly to nearest gram. The mould was then filled layers each layer being subjected to blows using the specific rammer for the test. The soil is then removed from the mould and sample of the soil taken from the specimen for moisture content determination and hence the dry density. The test was carried out with the same soil after pulverization of the remoulded specimen at different moisture contents of 3% of the dry weight of the soil after each test until at least two successive tests show a decrease in bulk density.

A graph of dry density against moisture content was then plotted to determine the maximum dry density and the optimum moisture content. The dry density was calculated from relation.

$$\rho = \frac{M}{V} = \frac{m_2}{1000} \quad (Mg/m^3)$$

$$\rho d = \frac{100 \times \rho}{(100 + w)} \quad (Mg/m^3)$$

Where

m1= Mass of mould (and base if included)

m2 = Mass of soil mould (and base if included)

V = Volume of the mould = 1000

W = Moisture content in %

3.3.6 California Bearing Ration (CBR) Test

Apparatus: CBR machine, support metal plate, surcharge discs

Procedure:

- After the soil has been compacted
- Remove the collar of the mould, scrape the head
- Weigh the mould with the sample
- Put the mould with the soil under the CBR machine and fix the surcharge disc
- Rotate the roller until the pointer moves
- Set the pointer to zero and operate the machine.
- Engage two counters
- Read the values of 25 intervals at first, then at 50 interval and record on the CBR record sheet.
- Remove the mould from the CBR machine and turn the mould upside down
- Put it under the machine again and read just like the first one.

4. RESULT AND DISCUSSION

The results of all the tests carried out are stated and discussed as follows.

4.1. Chemical (Oxides) Composition OF YPA

Table 4.1 shows the results of chemical composition of Yam Peel Ash

TABLE 4.1: CHEMICAL ANALYSIS TESTS RESULT

Parameters	Units	Values		
		1	2	Average
SiO_2	%	35.74	35.89	35.82
Al_2O_3	%	3.27	3.34	3.31
FeO_3	%	0.74	0.78	0.76
CaO	%	2.04	2.11	2.08
MgO	%	1.76	1.74	1.75
K_2O	%	22.51	22.46	22.49
Na_2O	%	1.83	1.80	1.82
SO_3	%	0.48	0.51	0.49
LOI	%	1.72	1.74	1.73

The test result of SRF chemical analysis test result presented in the table 4.1 above shows the percentage of Silicon Dioxide (SiO_2), Aluminium Oxide (Al_2O_3), Ferric Oxide (Fe_2O_3), Magnesium Oxide (MgO), Calcium Oxide (CaO), Sulphur Trioxide (SO_3), Sodium Oxide (Na_2O), Potassium Oxide (K_2O), Loss of Ignition (LOL). It was observed that Silicon Dioxide (SiO_2) has the highest percentage as 35.82% and the total percentage of the listed oxides is 70.25%.

ASTM C-618 (2005) specifies that the sum of SiO2, Al2O3, and Fe2O3 of a pozzolanic material should not be less than 70%. The sum of SiO2, Al2O3, and Fe2O3 of the groundnut shell ash (GSA) tested as shown in Table 4.1 is 39.89% which is low compared to that of Alabadan*et. al*. (2006) [10] and 70% specified by ASTM C-618 (2005) [11]. However, the result of the yam peel ash (YPA) tested shows that silicon dioxide (SiO2) have the highest percentage of oxide composition.

4.2. Natural moisture content

The natural moisture content determination test result was average of 22.55%.

4.3. Specific gravity test

The specific gravity test is done in accordance with BS 1377. The values of the specific gravity for the natural soil sample and also at stabilized stages are given below.

Table 4.3: Result for specific gravity test.

Test	0%	3%	6%	9%	12%
Specific Gravity	2.35	2.60	2.62	2.60	2.58

It was discovered that the specific gravity of the soil at natural state is 2.35 and later increased to 2.60 at 3% and 2.62 at 6% stabilization respectively. However, there was decrease of specific gravity value at 9% (2.60) and 12% (2.58).

4.4. Particle size analysis

The sieve analysis was done in accordance with BS 1377 by passing the soil sample through a set of sieve and a sample of 100g of soil was used. The sieve size is in the sequence of 19mm, 13.5mm, 12.5mm, 10mm, 6.3mm, 4.75mm, 2.36mm, 1.7mm, 850µm, 300µm, 150µm, 75µm and residual pan. The sieve analysis result is shown in table 4.4.

Table 4.4. Particle size analysis of the soil sample

Sieve Diameter	Mass Retaining (g)	Percentage Retaining (%)	Cum.Percentage Retaining (%)	Percentage Passing (%)
19mm	0.00	0.00	0.00	100
13.5mm	0.00	0.00	0.00	100
12.5mm	80.6	8.06	8.06	91.94
10mm	42.4	4.24	12.3	87.7
6.3mm	89.6	8.96	21.26	78.74
4.75mm	128.4	13.64	34.9	65.1
2.36mm	93.4	9.34	44.24	55.76
1.7mm	140.4	14.04	58.28	41.72
800µm	57.2	5.72	64.0	36.0
300µm	20.8	2.08	66.08	33.92
150µm	23.2	2.32	68.4	31.6
75µm	300	30	98.4	1.6
Receiver Pan	8	1.6	100	0.0

The particle size distribution of the untreated soil sample is further shown in figure 4.1.

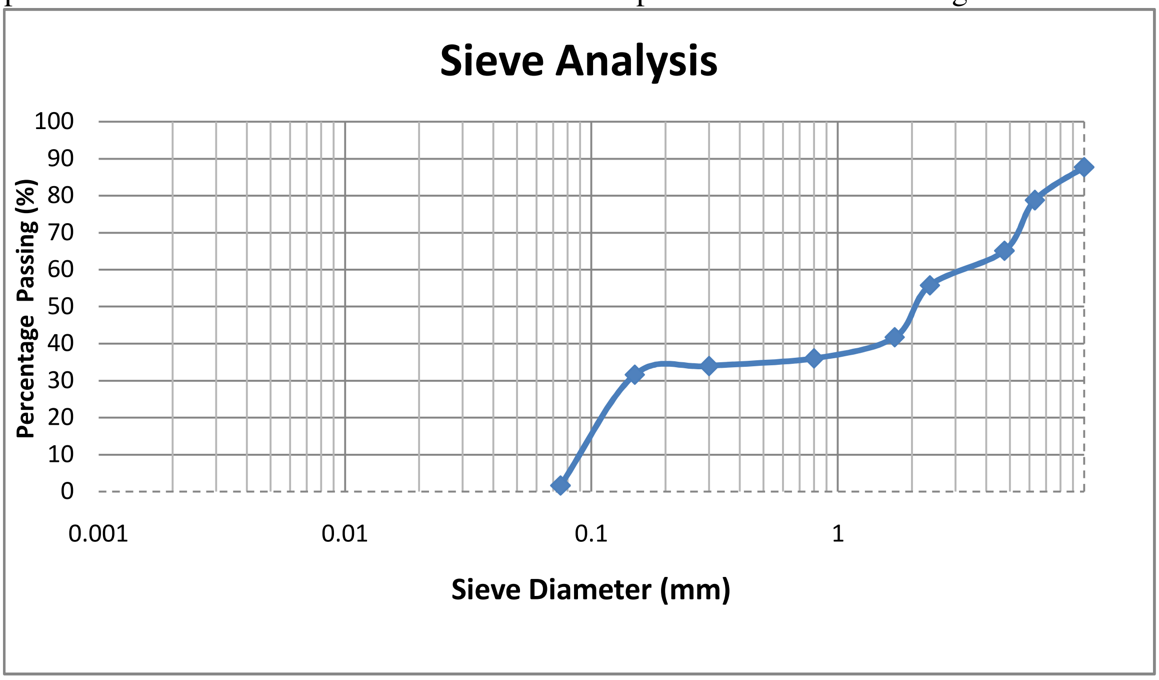

Figure 4.1: Particle Size Distribution

4.5. Atterberg Limit

The Atterberg tests which include the liquid limit tests, plastic limit tests, plasticity index tests and the shrinkage tests are carried out in accordance with BS 1377. The Atterberg tests were done for the natural soil sample and also for the stabilized (addition of Yam peel ash and cement) soil sample at an increment of 3% up to 12%.

The result is as follows:

Table 4.5: Result of Atterberg Limits Tests

AtterbergTest	0%	3%	6%	9%	12%
Liquid Limit Test	59.00	65.30	63.00	56.15	52.48
Plastic Limit Test	23.63	45.29	38.80	35.60	33.87
Plasticity Index	35.37	20.01	24.20	20.55	18.61

Initially, the liquid limit at 0% was 59.00; the plastic limit was 23.63, thereby giving a plasticity index of 35.37. Liquid limit less than 35% indicates low plasticity, between 35% and 50% intermediate plasticity, between 50% and 70% high plasticity and between 70% and 90% very high plasticity. This shows that sample has high plasticity. At the point of adding 3% of yam peel ash, the plasticity index was 20.01. The plasticity index for 6%, 9% and 12% was 24.20, 20.55 and 18.61 respectively. From the results, the plasticity index was 35.37 at 0% and it later dropped to 20.01 at 3%, at the plasticity index increased to 24.20 at 6%, while there is continuous reduction from 9% to 12%.

4.6. Index properties of soil

The index properties of the natural soil are summarized in table 4.6. The percentages passing the no. 200 sieve was 36.20%. The clay (percentage passing 2μm) fraction content was 55.05%. The plasticity index and activity were 37.27% and 0.68 respectively. The specific gravity value was 2.42. The soil sample is classified as A-7-6 according to the AASHTO classification system.

Table 4.6: Summary of the Properties of the Soil Sample

Characteristics	0%	3%	6%	9%	12%
Natural moisture content (%)	22.55				
Liquid Limit (%)	59.00	65.30	63.00	56.15	52.48
Plastic Limit (%)	23.63	45.29	38.80	35.60	33.87
Plasticity Index (%)	35.37	20.01	24.20	20.55	18.61
Specific Gravity	2.35	2.60	2.62	2.60	2.58
Percentage passing BS No 200	31.60				
AASHTO classification	A-7-6				
Colour	Reddish Brown				

4.7. Compaction test Result

The compaction test was carried out by using British Standard method of testing soil in Civil Engineering. The Maximum Dry Density (MDD) with Optimum Moisture Content (OMC) obtained are as shown in Table 4.7 below and the test results curves were shown in figure 4.2 to 4.4.

Table 4.7: Summary of Compaction Test Results of YPA-Cement as a Stabilizing Agent

Percentage of YPA (%)	Maximum Dry Density MDD (g/cm^3)	Optimum Moisture Content OMC (%)
0	1.65	12.8
3	1.77	16.8
6	1.78	15.2
9	1.68	13.4
12	1.56	12.0

The BSL shows that the addition of YPA led to increase of MDD at 3% and 6% stabilization with value of 1.77 and 1.78 g/cm^{3}receptively, after which there is continuous decrement in the MDD value.

The OMC for the natural soil at BSL are 12.8 (0%) 16.8 (3%), 15.2 (6%), 13.4 (9%) and 12.0 (12%) respectively. The addition of the YPA using BSL led to increase in the OMC at 3% with and decrease at 6% downward 12%.

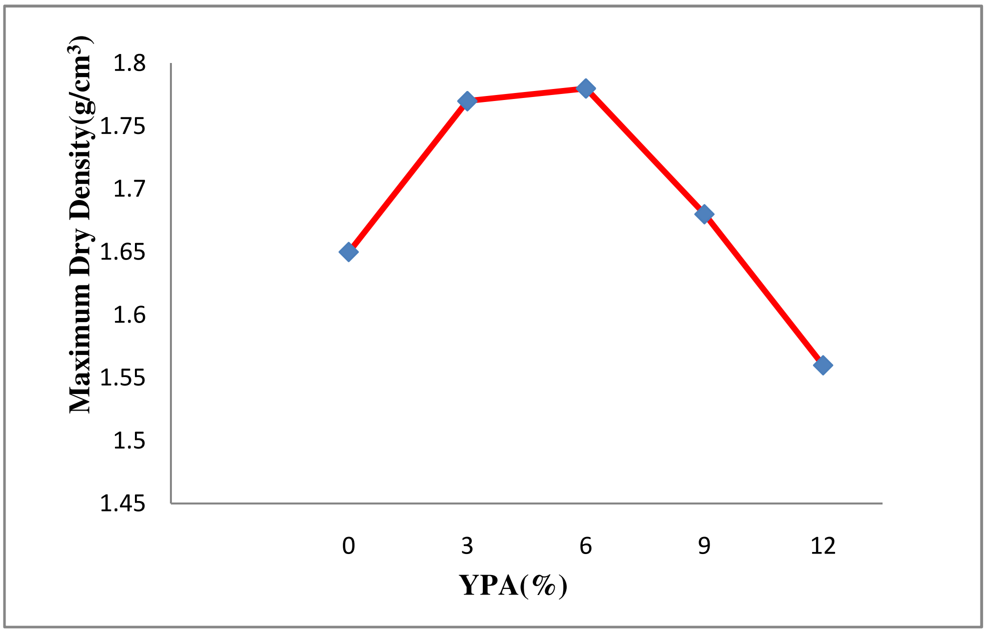

Figure 4.2 Variation of Maximum Dry Density against YPA (%)

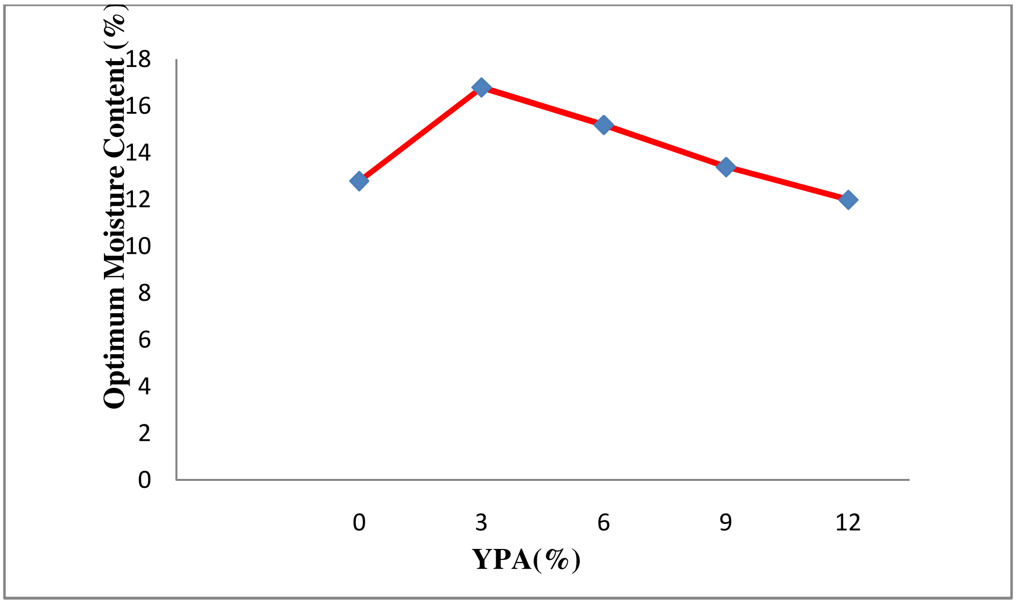

Figure 4.3: Variation of Optimum Moisture Content against YPA (%)

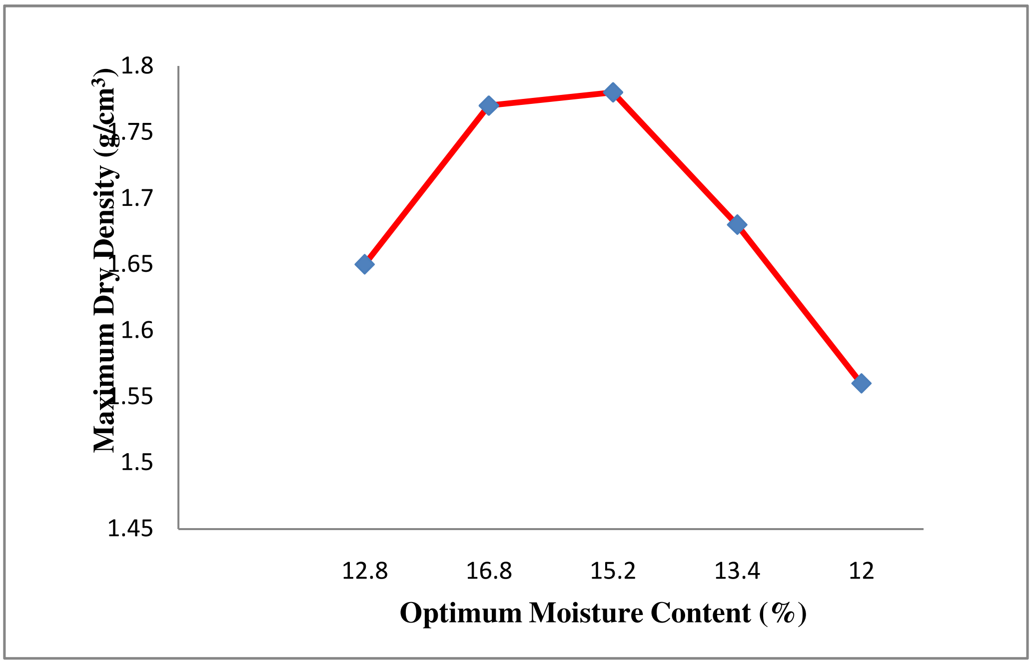

Figure 4.4: Variation of Dry Density (MDD) against Moisture Content (OMC)

4.8. California bearing Ratio

The CBR values obtained from the results of untreated lateritic soil is 29%. The CBR results is presented in Table 4.8 and Figure 4.5.

Table 4.8: Summary of California Bearing Ratio Test Results of YPA-Cement as a Stabilizing Agent

Percentage of YPA-C (%)	California Bearing Ratio CBR values (%)
0	29
3	38
6	40
9	32
12	30

Peak values of 40% at 6% YPA content, 38% at 3% YPA content, 32% at 9% YPA content, 30% at 12% YPA content and 29% at 0% YPA content were recorded.

The reason for slight increment in strengths could be due to adequate amounts of calcium required for the formation of calcium silicate hydrate (CSH) which is the major element for strength gain. But usually, a minimum CBR value of 60 to 80% is required for bases and from 20 to 30% for sub-bases both when compacted at optimum moisture and 100% intermediate/West African Standard (Osinubi, 2001) [12]. However, the optimum CBR values met the minimum specified by the Nigerian General Specification (1997).

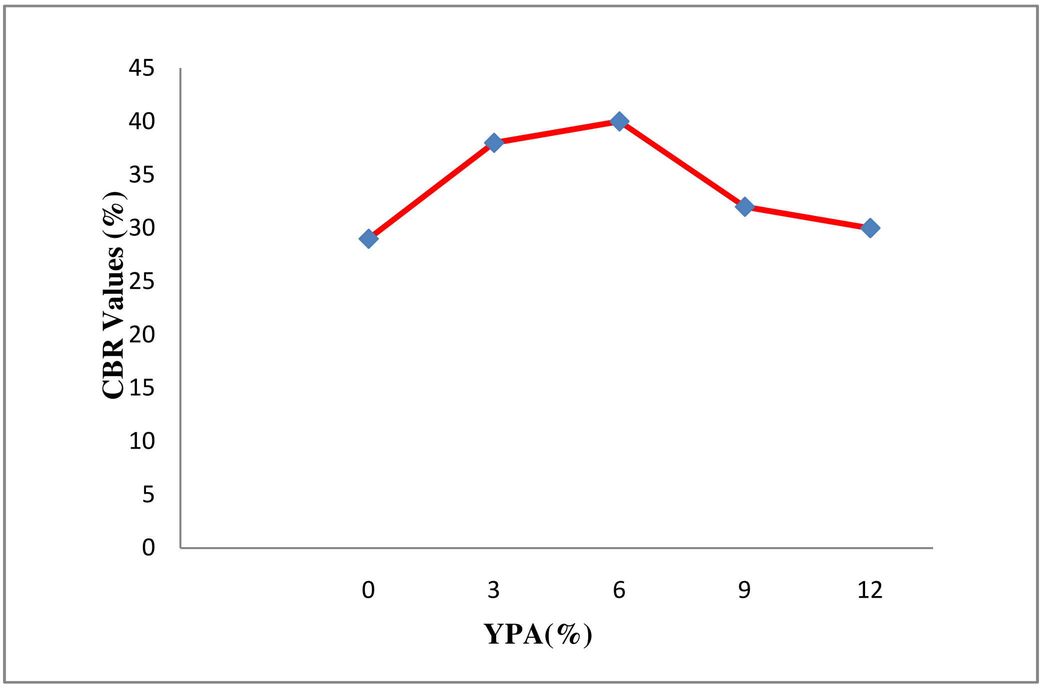

Figure 4.5: CBR value versus YPA (%) Stabilization

5. CONCLUSION

The following conclusion was drawn out from the study. The lateritic soil used in this study was classified as A-7-6 (AASHTO, 1986). This study took into consideration the lateritic samples obtained from lateritic soilchanage 1 + 500 to 1000 along Ikirun to Osogbo Road, Osun State. Therefore, it cannot be used for judgement or analysing laterites form other groups as it has been revealed from previous research work that physical properties of lateritic soil vary from place to place depending on the geology condition, geographical condition and environmental condition under which they are performed. The natural soil is inorganic clay with 30.00 % passing the BS No. 200 sieve, moisture content of 22.55%, liquid limit of 59.0, and plastic limit of 23.63 and plasticity index of 35.37. The CBR values obtained from the results of untreated lateritic soil is 29% while the optimum CBR values obtained for the stabilized lateritic soil is 40% at 6% YPA content. The values obtained met the minimum specification by the Nigerian General Specification (1997) of 10% for soaked CBR for a subgrade material. The results obtained show that YPA can be more profitably used as an admixture with a conventional stabilizer such as cement or lime.

However, from this investigation there was an improvement in California bearing ratio (CBR) of soaked samples from 38% to 40 at 3-6% YPA content.From the tests results and discussion, it has shown that treating soil brings about improved condition of the lateritic soil properties.In conclusion the effect ofYPAin geotechnics properties of lateritic soil (as stabilizing agent) brings considerable improvement on the physical characteristics of the lateritic soils as evidence by the results of the test carried out.

YPA can be consider as alternative stabilization agent for lateritic soil in roads construction

Further research should be carrying out to determine the variation of YPA and ordinary Portland cement in stabilization of lateritic soil.

The soil sample under study can be used as a sub-base material for road construction after it has been stabilized.

PHOTOS

Kisi Yams

Yam peel Ash

Automatic compactor machine

CBR Machine

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