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RESEARCH ARTICLE

EFFECT OF DRYING TEMPERATURE ON THE ENGINEERING PROPERTIES OF STABILISED AND NATURAL SOILS FOR ROAD CONSTRUCTION

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ABSTRACT

The aim of this investigation is to determine the effect of drying temperature on the geotechnical properties of natural soils and stabilised soils. Soil samples were taken along Supare Akoko- Emure Ekiti road from three locations at the depth of 1m each. Soil sample for location 1 soil was taken from a stable section while soil samples from locations 2 & 3 were taken from the failed portions of the road. The following laboratory analysis were conducted on the soil samples; atterberg limit test, grain size analysis, Linear shrinkage, Specific gravity, Compaction test and California Bearing Ratio test (CBR). The results show that sampled soil from location 1 has better engineering properties than soil samples from Loc. 2 and 3. This is an indication that the soils of locations 2 & 3 contributed to the failing of the failed part. These three soil samples were further tested by adding 6% (of the total weight of the sampled soils) of Saw dust ash (SDA) and Fine Palm kernel shells (FPKSA) to the soil as stabilisers. Both the index and strength properties improved upon the addition of stabilizers with SDA proving to be a better stabiliser. Under varying temperature of pretest drying with stabilisers (SDA and FKPSA) and without stabiliser; the same engineering properties were considered. The results show that temperature plays a major role to better the properties of the soil.

KEYWORDS

Index properties, strength properties, pretest drying, improved soil.

1. INTRODUCTION

Good roads are key to planning and national development; sadly, the same cannot be said of developing countries where some of its roads are badly affected by potholes and cracks. There is no doubt that this incessant bad road failure has done more harm than good in developing countries. Hundred of roads are open up yearly in Nigeria through construction; and several of the affected bad old roads are repaired by patching the failed sections without carrying out geotechnical evaluation on the subsoil that will carry the load so as to determine the maximum shear strength of the soil. There is no better return on investment than to provide a lasting and productive road for transportation.

Roads are constructed on geologic materials (of different grading) and these materials' properties impact their behaviour as transport medium (Gupta and Gupta, 2003; Meshida, 2006; Olofinyo et al., 2019). In Nigeria, lateritic soil is the only available earth material that is available for construction (foundation or landfill for roads) which is a residual product of tropical weathering of most rocks (Malomo, 1979). The major components of several typical flexible highway pavements from the base to the top include the subgrade, sub-base, base course and highway surfaces (Gupta and Gupta, 2003; Adeyemi et al., 2013). More often than not, the Subbase is the main load bearing layer of the pavement while the subgrade soils are in-sutu soils that have been compacted to carry part of the load that will be transferred from the pavement to the subsurface. Most times subbase and base materials are imported from different location and depending on the pressure that will transmitted from pavement; subbase layer maybe exempted if the pavement is design for foot traffic. All soils are essentially formed from physical and chemical in-situ weathering of igneous, sedimentary and metamorphic rocks with the influence of varying climatic conditions. Their behaviour is strongly influenced by the genesis, degree of weathering, chemical and mineralogical composition and other environmental conditions (Pandian et al., 1993a; Pandian et al., 1993b). The properties of tropical soils are generally different from those found in cold and temperate region soils as highlighted by (Frempong and Yanful, 2008).

A group researchers have all recently worked on the engineering properties of subsoils in the different part of southwestern Nigeria and they all came to the conclusion that poor soils play a major part in failed portions of the road (Olabode, 2019; Ademila et al., 2020; Oluwakuse et al., 2020; Adekeye et al., 2021; Ale, 2021). Ademila emphasized on the need to document geotechnical data in pavement design and construction of roads in Nigeria as reference in rehabilitation and construction of sustainable roads (Ademila, 2017). This research will help to reveal/provide relevant information into the causes of the failed sections, effect of stabiliser on the soil samples and also the effect of varying drying temperature on the stabilised and unstabilised soils. This will in turn increase the available geotechnical data and also guide the engineers on how to improve on the design of roads.

A group researchers evaluated the influences of some locally available additives on soils in Akure, Ondo State and Efon Alaaye Local Government Area, Ekiti state respectively (Ogunribido, 2012; Adetoro and Adam, 2020). In Akure, the additive of Sawdust Ash was added to the soil samples at 0%, 2%, 4%, 6%, 8%and 10% proportions. The soils were optimally improved by adding saw dust ash. Optimum results were achieved by adding 6% of saw dust ash as to the lateritic soils weight. Additives were added to the soil samples at 0%, 2%, 4%, 6% and 8% proportions. (i.e. Palm Kernel Shell Ash - PKSA and Sawdust Ash - SDA) on geotechnical

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properties of Efon Alaaye Local Government Area soil. It showed that the LL, PI and MDD values decrease with increase in additives contents. The soil samples also responded more to SDA additive than PKSA additive. These results indicated that addition of the additives really improve the geotechnical properties of the soil in the study area, thus making it good for construction purpose. Some researchers examined the influence of drying temperature on the index properties, compaction characteristics and California bearing ratio of three soils namely lateritic soil, lithomargic clay and bentonite. They attributed the changes in the soil properties to aggregation of particles (Sunil and Deepa 2016). They also found out that the effect of drying strongly depended on soil type, mineralogy or presence of cementing agents. The observed changes were found to be permanent and the implications are that these changes may affect the field performance of test soils. The present investigation will determine the effect of drying temperature on the geotechnical properties of natural soils and stabilised soils and to better understand the behaviour and performance of natural soil, SDA improved soil and FPKSA soil under pretest drying temperatures.

2. Study Area

The study area is Supare Akoko road in Southwestern Nigeria. This area lies between latitudes 070 27'N and 070 31'N and longitude 0050 43'E and 0050 47'E of the Greenwich Meridian (figure 1). Supare Akoko area that is moderately populated and has gain more population recently because staff and students of the Adekunle Ajasin University Akungba Akoko in a neibouring town of Akungba Akoko now prefer to live in Supare because of its serenity. Supare Akoko is surrounded by settlements such as Akungba Akoko, Iwaro Oka, Etioro Ayegunle, Oba Akoko,and Emure Ekiti.

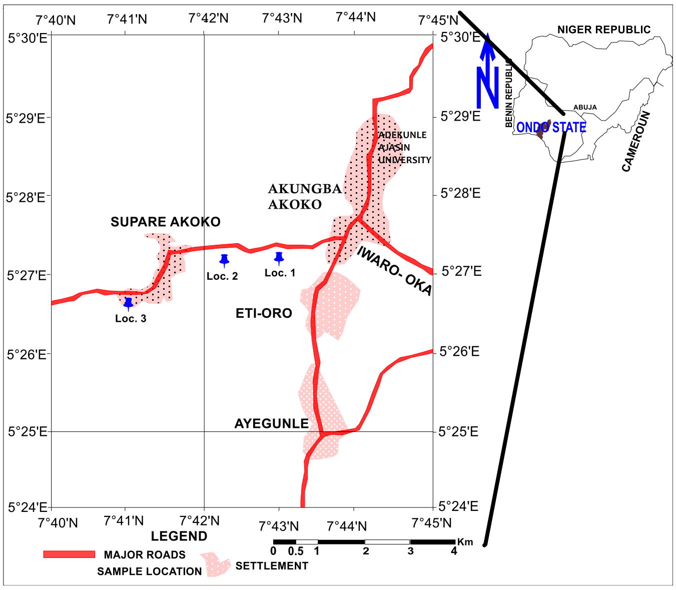

Figure 1: Road map of Supare Akoko- Emure Ekiti area

3. Materials and Method

Field reconnaissance was carried out to visually assess the local condition/detailed mapping of the surface condition. The number of samples taken, spacing between them and depth are based on finding during the field reconnaissance (type of construction, highway). Three disturbed subsoil samples were collected from three different location pits along Suupare Akoko – Emure Ekiti road in Southwest Nigeria. One of the samples (location 1) was collected from a stable section of the road which served as the controlled sample while the other two samples (locations 2 & 3) were taken from the failed sections. Soil samples were taken at a depth of 1m for true representation and were collected into polythene nylon bags. The soil for natural moisture content was collected into tightly nylon to prevent moisture loss and determined immediately in the Engineering Geology Laboratory of the Adekunle Ajasin University Akungba Akoko. Soil samples were air dried for two weeks before conducting other analysis. Soil index properties tests and strength properties tests were conducted on both unstabilised soil and stabilized soils (with two different types of stabilizers namely Fine Palm kernel shells and Sawdust ashes mixed with soil samples at 6% of the weight of the soil samples which was the optimum performance (Ogunribido, 2012; Adetoro and Adam, 2020). All the tests were carried out in accordance with British standard code of practice (BS1377: (1990)). The behavior of the geotechnical properties of both unstabilised and stabilized soil were tested under varying drying temperature (Sunil and Deepa, 2016). These pretest conditions are airdried (soil samples air dried under normal ambient temperature in shade, between 25 and 30 _C) conditions as well as conditions obtained by drying the soils at 50 ± 5, 75 ± 5 and 110 ± 5 _C in a thermostatically controlled oven. The oven-dried condition at 110 ± 5 _C is considered as the extreme condition. Soil samples were divided into three parts before oven drying at varying temperature; a part was mixed with Fine Palm kernel shells at 6% of the weight of the soil samples, the second part was mixed with Sawdust ashes at 6% of the weight of the soil samples while the third part was oven dried naturally. Again, each of the three parts is further divided into four to represent the four-pretest drying temperature above. To carry out Atterberg limits tests (liquid limit, plastic limit and linear shrinkage), the soil samples were passed through a test sieve of No. 40 (425µm). The soils samples are mixed with water to achieve the desired standard and allow the condition to stand for 24 hours. Liquid limit test is done in accordance with ASTM D4318 and AASHTO T 89 for air-dried soils, stabilised air-dried soils and oven dried soils. Plastic limit test is done in accordance with ASTM D4318 and AASHTO T 90 for air-dried soils, stabilised air-dried soils and oven dried soils. Linear Shrinkage test is done in accordance with ASTM D4943 for air-dried soils, stabilized air-dried soils and oven dried soils. The water pycometer method of particle size analysis was used and the procedure was carried out in accordance with ASTM D854 and AASHTO T 100 standard. The particle-size analysis of soil samples were done in accordance with ASTM D422-63 standard for air-dried soil samples and were used for particle size distribution. Set of sieves used consist of the following sizes: 4.75mm, 2.36mm, 1.18mm, 850µm, 425µm, 300µm, 150µm, 75µm and pan. Standard Proctor tests for air-dried soil samples, stabilised air-dried soil samples and oven-dried soil samples were carried out in accordance with ASTM D 698 specification. Before carrying out the analysis to determine the maximum dry density and optimum water contents of soil samples; the soil samples were passed through 425 lm sieve (No. 40). The CBR of air-dried soil samples, stabilised air-dried soil samples and ovendried soil samples were determined for soil fractions passing 425 lm sieve (No. 40). To determine the penetration resistance of soil samples, CBR tests were carried out in accordance with ASTM D1883-05. All the analyses were carried out at the Engineering Geology laboratory of Adekunle Ajasin University Akungba Akoko. The results of the geotechnical properties of unstabilised and stabilised soils under varying drying temperature were compared with each other and also with the regulating standard. Fine Palm kernel shells (FPKSA) are the crushed outer part of palm kernel nut derived after the extraction of palm oil (Olutoge, 2010). The Palm kernel shells were oven dried at 1100C for 48 hours after which was grinded and passed through sieve cell of 75µmm before using them for this study. Sawdust ashes (SDA) are loose particles or wood chippings obtained as by-products from sawing of timber into standard useable sizes. Some cleaned quantities of sawdust obtained were also oven dried at 1100C for 48 hours after which was passed through sieve cell of 75µmm before using them for this study (Olutoge FA, 2010). These two addictives were chosen because of their availability and the cheap cost of acquiring them. It was generally observed that the additives (i.e. FPKSA and SDA) have positive influences on the geotechnical properties of the soil in the study area. The addition of addictives was most effective at 6% of the weight of the sampled soil for both FPKSA and SDA

4. Index and Strength Properties of The Subsoil (Adjusted)

The values of Natural Moisture Content are 15%, 18% and 18% for locations 1 to 3 (Table 1 & fig. 2). The value of location 1 sampled soil falls within the acceptable average range of 5%–15% as specified by FMWH for engineering construction (FMWH, 2010). Values of soil samples from location 2 & 3 are higher than the prescribed standard. This implies that the soil samples have high adsorption capability and can cause a great deal of problem if not properly managed. Sieve analysis test measures the grain-size distribution of a soil when it is passed through a series of sieves. Engineers prefer in-situ soils because they are better graded and naturally more compacted than transported soil. The coarse contents of the sampled soils from location 1 to 3 are 74.2%, 40.3% and 52.9% while the fine contents are 2.8% 59.7% and 47.1% as presented in table 1. According to Federal Ministry of Works and Housing general specification requirements for roads and bridges, Again, only loc 1 sampled soil is suitable for sub-grade, sub-base and base materials as the percentage by weight finer than NO 200BS test sieve is less than 35% (FMWH, 1997).

Loc. 2 & 3 sampled soil have fine contents greater than 35% which make them poor for highway pavement construction works but location 3 sampled soil has more coarse-content than fine-content. Soil samples from Loc. 2& 3 can be affected by seasonal variation change. All the soil samples from the three locations are well graded because of the wide range of particle sizes on the grain size distribution curve from fine to coarse (Figure 3). The values of liquid limit (37.8%, 53.8% and 47.4%); plastic limit (17.8%, 28.1% and 26.4%) and plasticity index (20%, 25.7% and 21.1%) are presented in table 1. Federal Ministry of Works general specification requirements for roads and bridges recommend liquid limit not greater than 80% and plasticity index not greater than 55% for subgrade materials (FMWH, 1997). All the sampled soils fall within this specification. Again, liquid limit and plasticity index should not be greater than 35% and 12% respectively for both sub-base and base materials. None of the sampled soils fall within this specification. The lower the liquid limit, and plasticity index of a soil, the better the soil material for foundation and highway pavement construction purposes. Casagrande plasticity chart uses atterberg limit to create a distinction between clay and silt of fine grain soil. Based on Casagrande's plasticity chart classification; all the sampled soils are above the A-line with two samples (from location 1& 3) within clay medium compressibility (CI) while Loc. 2 sampled soil falls within clay high compressibility (CH) (figure 4) (Casagrande, 1947). The activity of clay is the ratio of plasticity index to clay fraction as percentage. The activity value of the soil samples is presented in table 1 and on activity chart in figure 5 & 6. The activity values range from 0.67 to 1.40. In clay classification, activity less than 1 signify kaolinite, while activity between 1 and 2 corresponds to illite and greater than 2 corresponds to montmorillonite. In the same vein, activity values less than 0.75 implies that the mineral is inactive, between 0.75 and 1.25 is regarded as normal, and value greater than 1.25 is active (Skempton, 1953). This implies that the clay activities of the sampled soils is from normal to active clays; Loc. 1 & 3 sampled soils fall within the normal while loc. 2 falls within the active clay based on Skempton interpretation (Table 1) (Skempton, 1953). All the soil samples have predominant clay mineral present to be illite and possess low to very high expansion potential as indicated by the activity chart (Figure 6). The results of the sampled soils for linear shrinkage test are 7.1%, 8.6% and 10.7% (Table 1). A researcher stated that linear shrinkage value below 8% is an indicative that a soil is good as either a base, subbase and sub-grade materials (Brink *et al.,* 1982). Only loc. 1 sampled soil falls within this specification. Gidigasu (1974) also stated that a soil with below 10% is good; soils samples from loc. 1& 2 meet this specification. The specific gravity of the tested soil samples are 2.65, 2.68 and 2.62 (Table 1). These range of values obtained are within the reportedly Maignien results on the tropical African lateritic soils which range between 2.5 and 3.6 (Maignein, 1966). The specific gravity values are relatively low which indicate coarse soils. Also, correlation of the results with Bowles classification shows that these laterite soils are either sand or silty sand (Table 1) (Bowles, 1992). According to AASHTO soil classification, Location 1 soil sample is classified as A-2-6 materials (granular material) with rating of good material for road works having satisfied all the conditions for constructing sub- grade and sub-base materials (AASHTO, 1993). Soil samples of loc. 2 & 3 are classified as A-7-5 which are rated as poor sub-grade materials. The higher value of G in location 2 shows that the soil is poorer when compared with location 3 of a smaller G value (Table 1). The Maximum Dry Density (MDD) for the sampled soils are 1978kg/m3, 1562 kg/m3 and 1756kg/m3 while that of optimum moisture content (OMC) ranges from 13.4%, 21.5% and 17.2% for the three locations (Table 1). According to Wood classification, location1 soil sample has a good rating; sample from loc. 3 has poor rating while sample from loc. 2 has very poor rating (Woods, 1937). For efficiency, productivity and longevity of any construction works, soil that will support load on any construction site for either pavement or foundation purposes must be compacted to about 95% of the maximum dry density achieved in this area. The California Bearing Ratio is used to evaluate the mechanical strength of subgrades and base course materials as well as to determining the thickness of the pavement requirement (Simon et al., 1973; Bell, 2007). The unsoaked California bearing ratio values of the sampled soils are 43, 22 and 31for the three locations (table 1). Federal Ministry of Work and Housing recommended unsoaked CBR for sub-grade, sub-base and base soils not less than 5%, 30% and 80% respectively (FMWH, 1997). The result for soil samples shows that all the soils are suitable for sub-grade course and not base course but sampled soils from Loc. 1 & 3are good as sub-base materials because they have higher values than the 30% stipulated in the specification (Table 1). A soil will have better CBR values when the percentage of coarse content is increased relatively to the fine content. Location 1 sampled soil has higher CBR values when compared to soil samples from location 2 and 3 because of the large amount of coarse grained particles in the soil

Table 1: Summary of the index and strength properties of the sampled soils for the three locations

S/N	NMC	LL (%)	PL (%)	PI (%)	LS (%)	%FINE	% Coarse	CLAY	AASHTO (GI)	SG	Activity	MDD	OMC	CBR
L1	15	37.8	17.8	20	7.1	25.8	74.2	23.6	A-2-6(0)	2.65	0.85	1978	13.4	43
L2	18	53.8	28.1	25.7	8.6	59.7	40.3	18.3	A-7-5(12)	2.68	1.40	1562	21.5	22
L3	18	47.4	26.4	21.0	10.7	47.1	52.9	31.4	A-7-5(6)	2.62	0.67	1756	17.2	31

NMC = Natural Moisture Content, LL = Liquid limit, PL = Plastic limit, PI = Plasticity Index, LS = Linear Shrinkage, SG = Specific Gravity, CBR = California Bearing Ratio, MDD = Maximum Dry Density and OMC = Optimum Moisture Content.

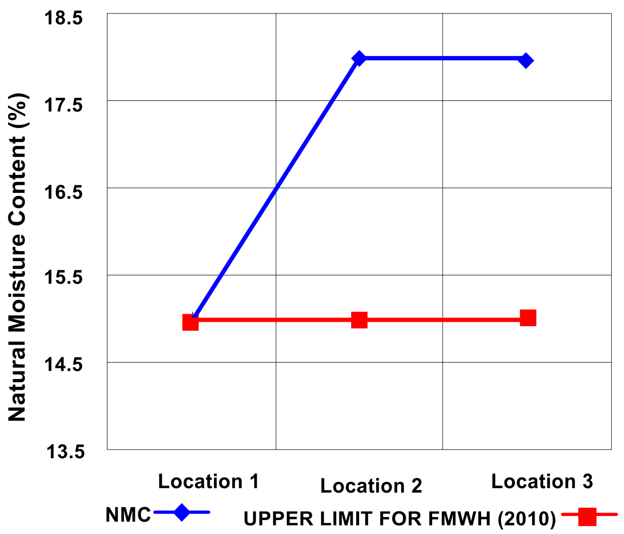

Figure 2: Natural Moisture Content values for the three locations

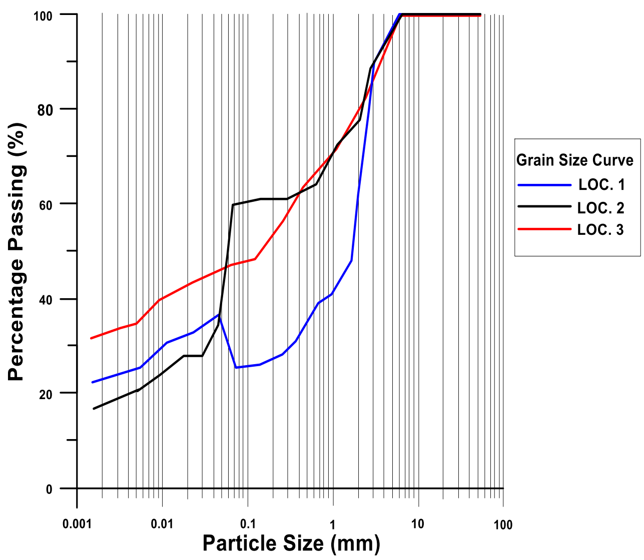

Figure 3: Grain Size Analysis for the sampled soils from the three locations

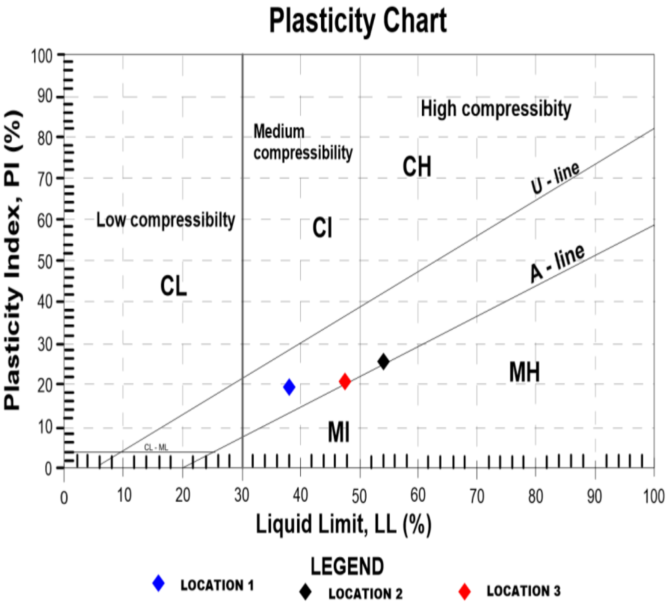

Figure 4: Plots of the three sampled soils on Casagrande Plasticity chart (ASTMD 2487)

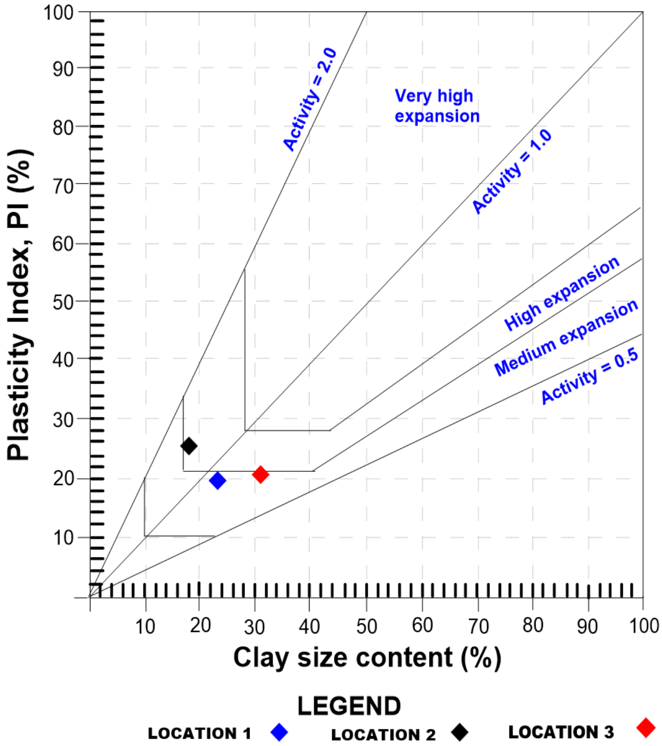

Figure 5: Plots of the three sampled soils on activity chart for the study area

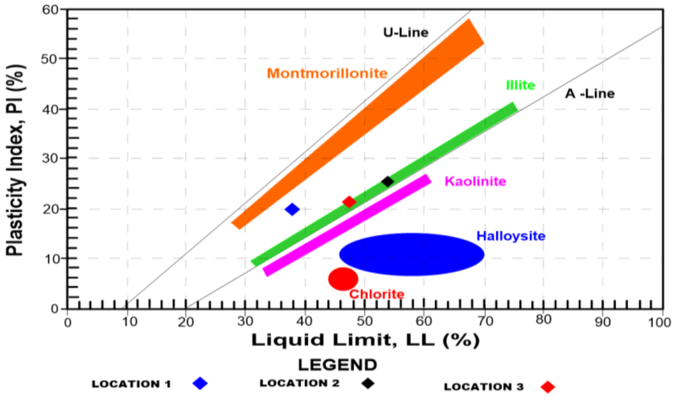

Figure 6: Plots of the three sampled soils activity character of all the sampled soils

5. Index and Strength Properties of Subsoil With Sawdust Ash and Fine Palm Kernel Shell Ash

The original liquid limit values of 37.8 %, 53.8%, and 47.4% for the three sampled locations decreased to 36.1%, 52.1% and 44.7% for SDA improved soils and 36.2%, 52.6% and 44.4% for FPKSA soils respectively (table 2). Again, the initial values of plasticity index of 20.0%, 25.7% and 21.0% have decreased to 9.3%, 25.4% and 20.6% for SDA improved soils and to 11.0%, 27.5% and 19.2% for FPKSA soils respectively (table 2). On the other hand, the values of plastic limit increased for location 1 and decreased for location 2 & 3 for both SDA and FPKSA improved soils (table 2 & figure 7). The addition of these stabilisers to the sampled soils produced a corresponding decrease in the values of Liquid Limit and Plasticity Index while the Plastic limit increased for location 1 and decreased for loc. 2 & 3. The uses of these stabilizers have positive effects on the soil's strength properties.

The linear shrinkage test results of natural soils with SDA and FPKSA stabilisers were constant in location 1 and 3 but produced decrease in values in location 2 (table 2). The specific gravity values of the sampled soils reduced slightly for location 1 and 2 when the two stabilisers were added while there were no changes in location 3 sampled soils when the stabilisers were added (table 2). The CBR values for unsoaked soil samples increased on the addition of both stabilisers from 43%, 22% and 31% to 46%, 27% and 33% for SDA improved soils and to 46%, 25% and 35% for FPKSA improved soils respectively (table 2 & figure 8). The natural soils improved better with the addition of SDA as stabiliser.

The addition of SDA and FPKSA to sub-soils as stabiliser increased the strength and stiffness of the subsoil, which will in turn help to transfer the load into the ground with much less potential for failure. Despite the improvement in the CBR values none of the sampled soils met the requirement for base material in pavement design. The maximum dry density of 1978 Kg/m^3, 1562 Kg/m^3 and 1756 Kg/m^3 gotten from normal sampled soils increased to 2011 Kg/m^3, 1742 Kg/m^3 and 1824 Kg/m^3 for the SDA improved soils and to 1998 Kg/m^3 , 1604 Kg/m^3 and 1803 Kg/m^3 for FPKSA improved soils (table 2 & figure 9). The values of OMC for the natural soils also decreased with corresponding increase in MDD values on the addition of stabilisers. The effect is more pronounced when SDA is added as compared to when FPKSA was added.

Table 2: Summary of Index and strength properties of subsoil with SDA & FPKSA

TEST	LOCATION 1			LOCATION 2			LOCATION 3		
	USTS	FPKSA SOIL	SDA SOIL	USTS	FPKSA SOIL	SDA SOIL	USTS	FPKSA SOIL	SDA SOIL
LL	37.8	36.2	36.1	53.8	52.6	52.1	47.4	44.4	44.7
PL	17.8	25.2	26.8	28.1	27.1	26.7	26.4	25.2	24.1
PI	20.0	11.0	9.3	25.7	25.5	25.4	21.0	19.2	20.6
LS	7.1	7.1	7.1	8.6	7.9	7.9	10.7	10.7	10.7
SG	2.65	2.64	2.64	2.68	2.66	2.67	2.62	2.62	2.62
CBR	43	46	46	22	25	27	31	35	33
MDD	1978	1998	2011	1562	1604	1742	1756	1803	1824
OMC	13.4	12.8	12.4	21.5	20.4	15.4	17.2	16.7	16.2

LL = Liquid limit, PL = Plastic limit, PI = Plasticity Index, LS = Linear Shrinkage, SG = Specific Gravity,

CBR = California Bearing Ratio, MDD = Maximum Dry Density and OMC = Optimum Moisture Content.

SDA=Sawdust ashes improved soils, FPKSA=Fine Palm kernel shells.

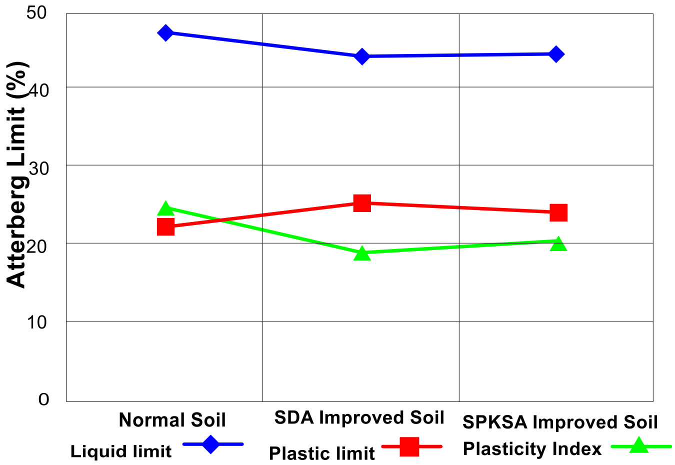

Figure 7: Atterberg limit for location 3 with SDA and FKPKSA stabilisers

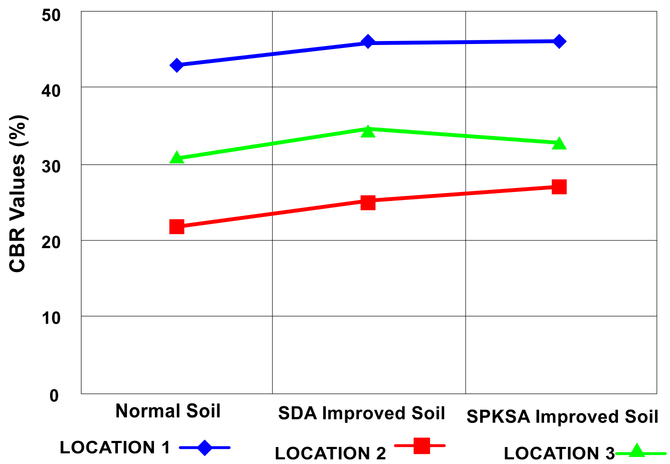

Figure 8: CBR values of the three locations with SDA and FKPKSA stabilisers

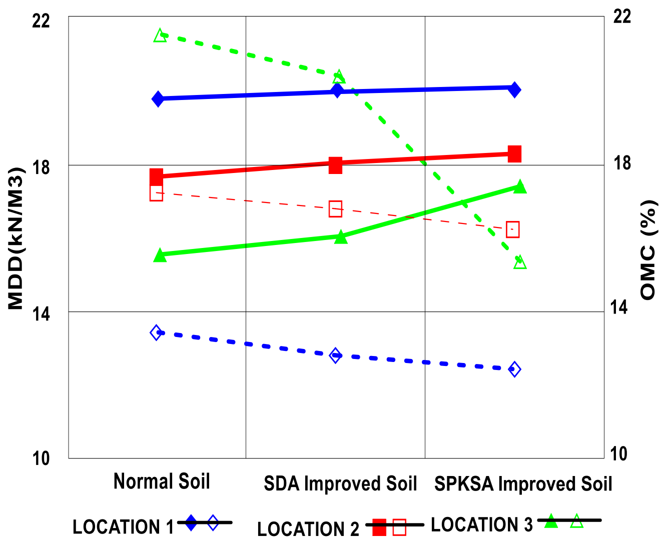

Figure 9: MDD and OMC values of the three locations with SDA and FKPKSA stabilisers

6. Effect of Drying Temperature on The Index and Strength Properties of Natural and Stabilised Soils

The effects of increased drying temperature on Atterberg limits of the natural and stabilised soils are presented in table 3, figs. 10& 11 respectively. The liquid limit values of 37.8 %, 53.8%, and 47.4% for the three sampled locations decreased to 35.4%, 50.4% and 42.8% at the final temperature of 110^{0}C ± 5. The SDA values (36.1%, 52.1% and 44.7%) and FPKSA values (36.2%, 52.6% and 44.4%) decreased to 35.0%, 46.9% and 40.4% for of improved soils for the three locations. The plasticity indexes for the natural soils from location 1 to 3 decreased from 20.0%, 25.7% and 21.0% to 12.1%, 24.1% and 18.7% respectively. The plasticity indexes for FKPSA improved soil for location 1 -3 decreased from 11.0%, 27.5% and 19.2% to 10.7%, 19.6% and 14.5% while the plasticity indexes for SDA improved soils decreased from 9.3%, 25.9% and 20.6% to 8.5%, 18.7% and 15.0% respectively. The effect of drying is more pronounced on natural soil than on the stabilised soils because clustering of particles is more in the former soil.

Clustering of particles lowers the surface area, and water that is absorbed which in turn lowers the liquid limit and because the plastic limit is relatively unchanged for both natural and stabilized soil, the plasticity index reduced. The obtained results for both natural and stabilized soils agree with the Sunil and Deepa that drying induce aggregation (Adetoro and Adam, 2020). The liquid limit and plasticity index values decreased upon drying for both stabilised and unstabilised soils. The values for linear shrinkage test results for both natural and stabilized soils decreases with increasing pretest drying temperatures. However, there were no changes in the values of linear shrinkage for both natural and stabilized soils (of the three locations) as the drying temperature increased from *75 ± 5 to 110 ± 5* (table 3 & figure 12). The variation of specific gravity of the test soils upon drying for all soils is presented in table 3. The increase or decrease in specific gravity values due to drying are not regular therefore making it are not very significant and therefore one cannot infer or make reasonable conclusion from the test. As such, varying temperature does not really affect the specific gravity properties of the tested soils.

The effect of pretest drying temperature on CBR values for natural and stabilised soils are shown in table 3 & Figs. 13. Values of CBR result test increased with increasing drying temperature for both natural and stabilized soil samples. The result of drying temperatures on MDD and OMC values of natural and stabilised soils are presented in table 3. Drying caused an increase in the maximum dry density and a decrease in the optimum moisture content in all cases. The increase in MDD values was higher in the three natural soils than in the stabilised soils (table 3, figure 14 & 15). Sunil and Deepa believed that the changes in the compaction characteristics of natural soils and by extension to the stabilised soils under varying pretest temperatures are partly due to aggregation effect of the clay material (Adetoro and Adam, 2020).

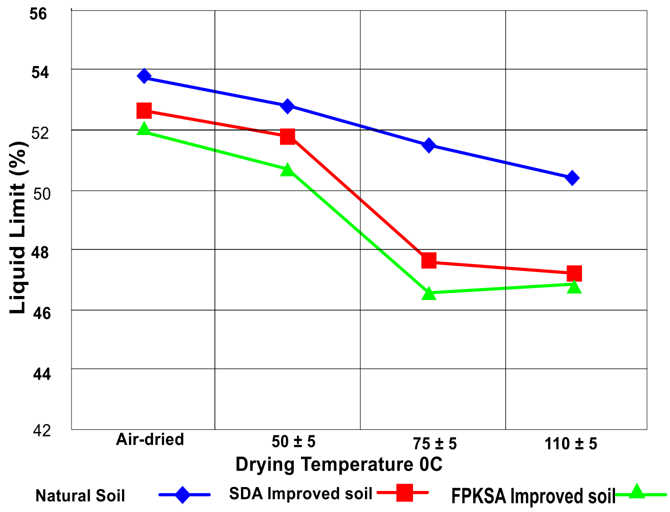

Figure 10: Liquid limit values under varying temperature for loc. 2

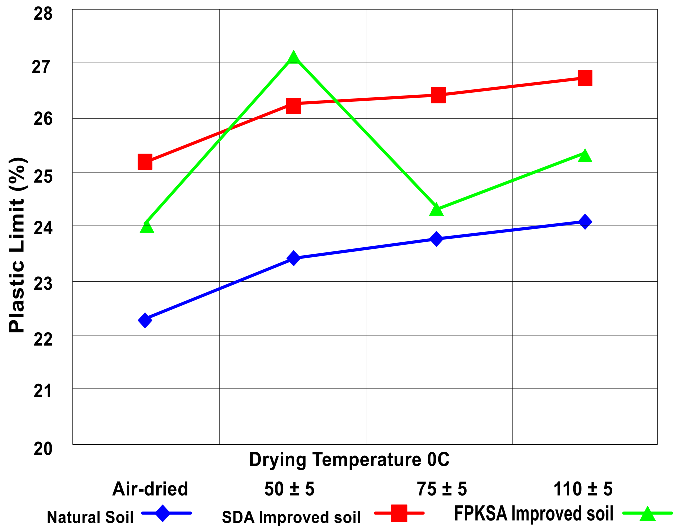

Figure 11: Plastic limit values under varying temperature for loc. 3

Table 3: Summary of effect of drying temperature on the Index and strength properties of natural and improved soils

	LOCATION 1			LOCATION 2			LOCATION 3		
LIQUID LIMIT									
	USTS	FPKSA SOIL	SDA SOIL	USTS	FPKSA SOIL	SDA SOIL	USTS	FPKSA SOIL	SDA SOIL
Air-dried	37.8	36.2	36.1	53.8	52.6	52.1	47.4	44.4	44.7
50 ± 5	36.6	35.4	35.2	52.8	51.8	50.8	46.8	43.8	43.4
75 ± 5	35.6	35.0	35.2	51.5	47.6	46.7	43.2	41.2	41.5
110 ± 5	35.4	34.8	35.0	50.4	47.3	46.9	42.8	41.2	40.4
PLASTIC LIMIT									
	USTS	FPKSA SOIL	SDA SOIL	USTS	FPKSA SOIL	SDA SOIL	USTS	FPKSA SOIL	SDA SOIL
Air-dried	17.8	25.2	26.8	28.1	27.1	26.7	26.4	25.2	24.1
50 ± 5	23.2	20.4	25.2	22.7	27.2	27.0	23.4	26.2	27.1
75 ± 5	23.3	23.5	26.8	23.5	26.2	27.7	23.8	26.4	24.4
110 ± 5	23.3	24.1	26.5	26.3	27.7	28.2	24.1	26.7	25.4
PLASTICITY INDEX									
	USTS	FPKSA SOIL	SDA SOIL	USTS	FPKSA SOIL	SDA SOIL	USTS	FPKSA SOIL	SDA SOIL
Air-dried	20.0	11.0	9.3	25.7	25.5	25.4	21.0	19.2	20.6
50 ± 5	13.4	15.0	10.0	30.1	24.6	23.8	23.4	17.6	16.3
75 ± 5	12.3	11.5	9.4	28.0	21.4	19.0	19.4	14.8	17.1
110 ± 5	12.1	10.7	8.5	24.1	19.6	18.7	18.7	14.5	15.0
LINEAR SHRINKAGE									
	USTS	FPKSA SOIL	SDA SOIL	USTS	FPKSA SOIL	SDA SOIL	USTS	FPKSA SOIL	SDA SOIL
Air-dried	7.1	7.1	7.1	8.6	7.9	7.9	10.7	10.7	10.7
50 ± 5	7.1	7.1	5.7	7.9	7.1	7.1	10.7	8.6	8.6
75 ± 5	5.7	5.0	5.0	7.1	5.7	5.7	7.9	7.9	7.9
110 ± 5	5.7	5.0	5.0	7.1	5.7	5.7	7.9	7.9	7.9
SPECIFIC GRAVITY									
	USTS	FPKSA SOIL	SDA SOIL	USTS	FPKSA SOIL	SDA SOIL	USTS	FPKSA SOIL	SDA SOIL
Air-dried	2.65	2.64	2.64	2.68	2.66	2.67	2.62	2.62	2.62
50 ± 5	2.63	2.64	2.63	2.65	2.67	2.67	2.62	2.61	2.62
75 ± 5	2.64	2.63	2.64	2.65	2.66	2.67	2.61	2.62	2.60
110 ± 5	2.64	2.64	2.63	2.65	2.66	2.66	2.62	2.62	2.61
CBR TEST									
	USTS	FPKSA SOIL	SDA SOIL	USTS	FPKSA SOIL	SDA SOIL	USTS	FPKSA SOIL	SDA SOIL
Air-dried	43	46	46	22	25	27	31	35	33
50 ± 5	48	47	48	24	25	28	32	35	35
75 ± 5	50	49	48	28	26	28	36	36	36
110 ± 5	52	50	49	30	26	28	38	37	38
COMPACTION TEST									
	USTS	FPKSA SOIL	SDA SOIL	USTS	FPKSA SOIL	SDA SOIL	USTS	FPKSA SOIL	SDA SOIL
Air-dried	1978	1998	2011	1562	1604	1742	1756	1803	1824
	13.4	12.8	12.4	21.5	20.4	15.4	17.2	16.7	16.2
50 ± 5	1997	2019	2022	1645	1624	1768	1872	1806	1853
	12.8	12.0	12.1	20.2	20.0	14.7	16.3	16.4	15.9
75 ± 5	2056	2048	2068	1748	1664	1777	1964	1842	1872
	11.3	11.6	11.3	16.2	19.6	14.4	13.4	16.3	15.7
110 ± 5	2094	2088	2074	1798	1688	1780	1982	1883	1904
	10.2	10.6	10.9	14.0	19.1	14.2	13.0	15.7	13.7

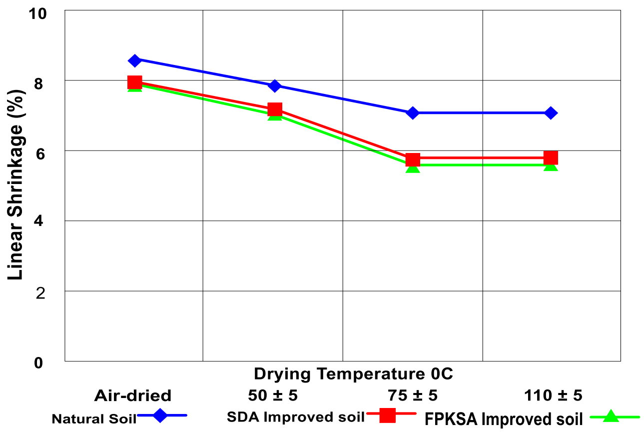

Figure 12: Linear Shrinkage under varying temperature for location 3

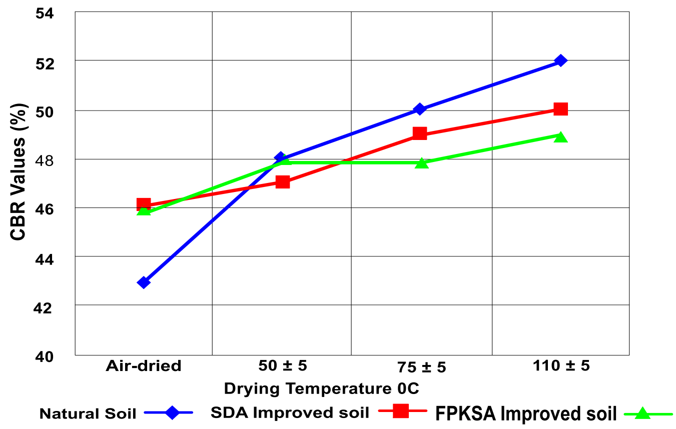

Figure 13: CBR values under varying temperature for location 1

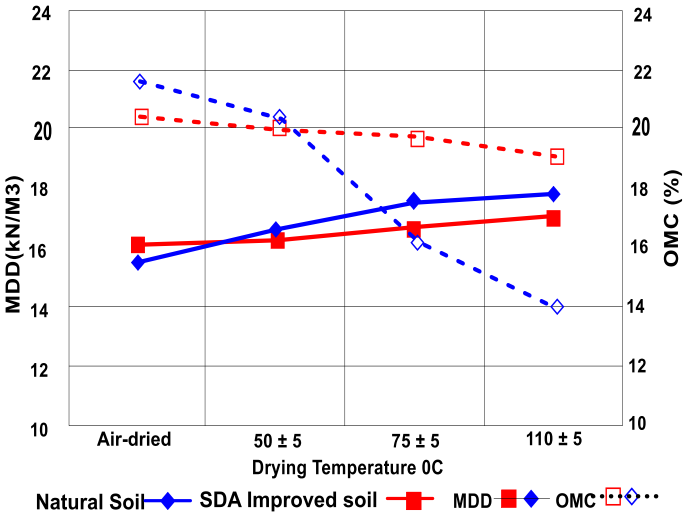

Figure 14: MDD and OMC values under varying temperature for loc. 2 natural and SDA improved soils

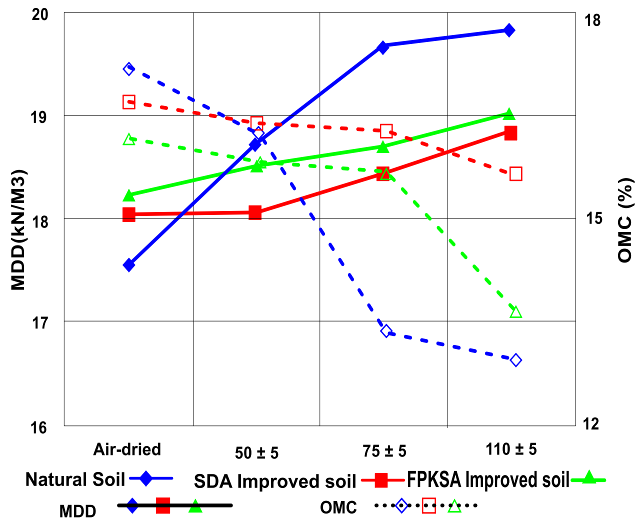

Figure 15: MDD and OMC values under varying temperature for loc. 3 natural and SDA & FPKSA improved soils

7. Conclusion

Soil sample of location 1 taken from the stable section of the road has better and good rating of engineering properties (both index and strength properties) than soil samples taken from location 2 and 3 that have poor ratings. The sampled soil from locations 2 & 3 are part of the many causes of the failed sections. On the addition of sawdust ash and fine palm kernel shell ash to the sampled soil; the obtained results show that both sawdust ash and fine palm kernel shell ash greatly improved the index and strength properties of the sampled soils. Under pretest drying temperatures; the liquid limit, plasticity index, linear shrinkage and optimum moisture content decrease from air-dried to 110 ± 5 _C while maximum dry density and California bearing ratio for both natural and improved soils increased from air-dried to 110 ± 5 _C. Plastic limit and specific gravity of the tested soil were not consistent with pretest drying. Effect of drying temperatures was greater on natural soil i.e. the natural soil improved better under increased drying temperature than the (SDA & FPKSA (improved soils. This is because drying improves the cementation of the soil particles and clay is a better binder to SDA and FPKSA. This study has revealed that natural soil performs better under increased pretest drying temperatures than SDA & FPKSA improved soils.

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