

Effect of Untreated Textile Effluent on Some Geotechnical Properties of Lime treated Lateritic Soil

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ABSTRACT

This study investigates the utilization of untreated Textile Effluent (TE) on some geotechnical properties of Lime (L) treated lateritic soil. Tests carried out includes specific gravity, Atterberg limits and compaction using British Standard Light (BSL), West African Standard (WAS) and British Standard Heavy (BSH). The specific gravity of the soil decreased from its natural value of 2.66 to 2.54 for 0:25% L: TE concentration but increased to 2.58 for 0:75% L: TE. The specific gravity decreased significantly to a minimum value of 2.30 for 4:75% L: TE. Liquid limit decreased from 47.00% for the natural soil to 37.20% for 0:75% L: TE. However, it increased from 46.00% at 4:0% L: TE to 46.30% for 4:50% L: TE. Plastic limit decreased to a minimum of 23.57% at 0:75% L: TE but peaked to 30.95% for 8:0% L: TE. Both plasticity index and linear shrinkage decreased from their natural values of 19.73% and 11.43% to 14.02% and 5.00% at 0:100% L: TE and 0:75% L: TE respectively, while maximum dry density (MDD) and optimum moisture content (OMC) for the three compactive efforts (BSL, WAS and BSH) decreased and increased respectively. MDD decreased from 1.68, 1.76 and 1.87 mg/m³ to 1.56, 1.65 and 1.77 mg/m³ for 8:100, 8:50 and 8:50% L: TE, respectively. OMC increased from 20.20, 15.90 and 14.20% to 24.20, 20.60 and 17.20% for 6:0, 6:50 and 6:75% L: TE concentration, respectively. It can therefore be inferred that the untreated textile effluent had positive effect on the properties of soil.

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Introduction

There has been a great deal of concern about environmental pollution since the onset of industrialization. The attention is seen to be mainly because of incidents of contamination. The rapid growth in population and industrialization causes generation of large quantities of effluent. So, the bulk effluents generated from industrial operations are discharged either treated or untreated, leading to a change in the balance of the environment for one or more of the natural agents viz., air, water and soil.

Contamination of the soil by effluents is a major environmental challenge faced by developing countries like Nigeria where most developmental activities take place. It is a problem because sustainability of the environment depends largely on the soil in which it's a contributing agent in the stability and functionality of every structure founded on it. Developing and especially densely populated countries like Nigeria has most of its water bodies contaminated by industrial effluents as river water is considered means of industrial effluent disposal (Kayode, 2010).

Textile effluent is an industrial wastewater of the textile industry. The wastewater is produced in large volume in many parts of the world, Nigeria inclusive. The textile industry deals with the design and production of various fabrics with a web of processes

intertwined to produce the final product. The production of the textile requires several stages of mechanical processing such as

be insulated from the wet treatment processes like sizing, de-sizing, scouring, bleaching, mercerizing, dyeing, printing and finishing operations.

The textile industry is very water intensive where it emits a wide variety of pollutants arising from the chemicals and insoluble substances and from all stages in the processing of fibres, fabrics and garment production. The water used for cleaning the raw material and for many flushing steps during the whole process of production leading to generation of wastewater. About 200L of water is used to produce 1kg of textile for both the application of chemicals onto textiles and rinsing the manufactured textiles (Ntuli *et al.*, 2009). The amount of water consumed by various types of fabrics varies from industry to industry depending on the dyeing process and the type of fabrics produced. It has been found that about 38 % of water is used during process of bleaching, 16 % in dyeing, 8 % in printing, 14 % in boiler and 24 % for other uses (Ntuli *et al.*, 2009).

The quest to reduce the cost of waste disposal, treatment and the attendant growing cost of conventional stabilizers has led to intense global research towards economic utilization of industrial wastes for engineering purposes. Hence, an attempt has been made by several researchers to study the behavior of discharged untreated textile effluent on the geotechnical properties of different soils as stabilizers, and to evaluate if there is value addition to the industrial



waste and at the same time environmental pollution can be minimized and saving cost.

Narasimha, and Chittaranjan, (2012) investigated the effect of textile, tannery and battery effluents on the compaction characteristics of expansive clayey soil and showed that when soil is treated with textile and battery effluents separately increase in optimum OMC and decrease in MDD was observed. But when it was treated with tannery effluent the opposite trend was observed. Hence, the strength characteristics such as CBR, UCS, Triaxial shear strength parameters which are obtained at OMC and MDD were strongly influenced by the effluents.

Chethan, (2017) studied the effect of industrial textile effluent interaction with both the laterite and expansive soils. He evaluated some index and engineering properties of both soils. The maximum dry density of the expansive soil decreased from 1.613mg/m³ to 1.482mg/m³ for 0 to 100 % textile effluent, while for the laterite soil the trend was the opposite, the MDD increased from 1.80kn/m³ to 1.90k/m³ for 0 to 100 % effluent respectively. For the optimum moisture content it increases from 21.75% to 27.00% for expansive soil with the increase in concentration of effluent and the OMC for the laterite soil decrease marginally from 13.80 % to 11.90 %. Unconfined compressive strength (UCS) increased for both the expansive and laterite soils with increase in the concentration of effluent mixed with the samples. And for the Atterberg limits (liquid and plastic limits) the values decreases from 0 to 100 % increment with effluent for the expansive while an increase in the values for the laterite soil with increment in effluent percentages.

Sreeja and Deepthy, (2017a) have compared the effect of treated and untreated textile effluent on the strength, plasticity and pH characteristics of kaolinite clay. In their findings the reported that for the untreated effluent the plasticity increases with increment in effluent while unconfined and pH values decreases with the same increment of the effluent. And for the treated textile effluent where coagulants such as lime and alum where used. The plasticity index slightly increases with treated effluent. The increase of plasticity index is higher for lime treated effluent than alum treated effluent. And for the pH the soil sample mixed with alum treated effluent remains neutral whereas that of lime treated effluent remains alkaline in nature, while the unconfined compressive strength increases with increase in concentration of treated effluent and the strength of the soil mixed with 100% treated effluent is more than the strength of the of the original soil. The strength is more for alum treated effluent than lime treated effluent.

Narasimha, and Indiramma, (2009) have studied the effect of textile effluent on geotechnical properties of black cotton soil. The geotechnical properties considered are compaction, swelling, strength characteristics (CBR and UCS). They found that the stability of soil mass increased due to the textile effluent.

Mallikarjuna *et al.*, (2008) in their investigation studied the influence of spent orange dye effluent from a Textile industry on clayey soil. The soil was mixed with spent orange dye effluent and

tested for index properties and engineering properties after varying curing periods. The dye effluent and its constituents were found to induce cementation/bonding and flocculation to the soil resulting in improved engineering properties.

Vaddi, *et al* (2015a & b) investigated the consequence of textile effluent on the differential free swell and Atterberg's limits of an expansive soil of effluent with percentages (0, 20, 40, 60, 80 and 100 %). There results found the decreasing in liquid limit, plastic limit, plasticity index, pH values and differential swelling index with increased in percentages of the textile effluent.

Sreeja and Deepthy, (2017b) also conducted their research works on the textile effluent interaction on the geotechnical properties of clayey soil. The determined its influence on the Atterberg limits, compaction characteristics and the strength characteristics of the soil. The result of their investigation reveals that the liquid limit and maximum dry density (MDD) decreases with increase in concentration of textile effluent, while the optimum moisture content (OMC) increases. The unconfined compressive strength of the soil mixed with 100% textile effluent is approximately 200 % more than the strength of the original soil sample. The bonding of the effluent with the soil particles is the reason for the higher strength of soil. The strength of the soil mixed with textile effluent increases in concentration of textile effluent and with increase in curing period. From the available literature it is found that no research has been done to evaluate the effect of textile effluent on conventional stabilizing agents treated soils. This work therefore is aimed at evaluating the potential utilization of untreated textile effluent on some geotechnical properties of lime treated lateritic soil.

The lateritic soil used for this study was collected by method of disturbed sampling from a lateritic soil formation located in Shika Zaria, Kaduna state of Nigeria (Latitude 11°15' N and longitude 7° 45' E). The soil sample was collected at depths between 1.5 and 2.0 m corresponding to the B – horizon usually characterized by accumulation of material leached from the overlying A - horizon. The samples were collected in large bags while a sizeable quantity was collected and sealed airtight in a polythene bag in order to obtain the natural moisture content immediately upon returning to the laboratory. The soil bags were then transported to the Soil Mechanics research laboratory of the Department of Civil Engineering, Nigerian Defense Academy, Kaduna, Nigeria; thereafter, the soil samples were then air-dried before pulverized to obtain particles passing BS No. 4 Sieve (4.76 mm aperture). The Physical properties of natural lateritic soil is shown in Table 1 and the particle size distribution curve for the natural soil is shown in Figure 1.

Table 1: Physical properties of natural lateritic soil.

PROPERTY	QUANTITY
Percentage passing BS Sieve No 200 (%)	64.00
Natural moisture content (%)	16.70
Liquid limit (LL) (%)	47.00
Plastic limit (PL) (%)	27.30
Plasticity index (PI) (%)	19.70
Linear shrinkage (LS) (%)	11.43
Specific gravity (GS)	2.66
AASHTO Classification	A-7-6
USCS	CL
Group index (GI)	12
pH	7.65
CEC (cmol/kg)	0.56
Maximum Dry Density (MDD) (mg/m ³)	-
British Standard light (BSL)	1.68
West African Standard (WAS)	1.76
British Standard Heavy (BSH)	1.87
Optimum moisture content (OMC) (%)	-
British Standard light (BSL)	20.20
West African Standard (WAS)	15.90
British Standard Heavy (BSH)	14.20
Color	Light Brown
Dominant Clay mineral	Kaolinite

SiO ₂	3.61	41.05
Al ₂ O ₃	4.57	24.16
Fe ₂ O ₃	0.25	10.16
CaO	48.32	0.23
MgO	2.27	0.21
SO ₃	0.01	1.04
Na ₂ O	1.22	1.37
K ₂ O	2.00	0.34
TiO ₂	0.09	0.39
P ₂ O ₅	0.20	1.31
MO ₂ O ₅	0.01	0.02
Rb ₂ O ₅	0.01	0.27
PbO	ND	0.01
Cr ₂ O ₃	0.01	0.02
MnO	0.01	ND
LOI	37.02	19.35

***ND = NOT DETECTED**

The Textile effluent was obtained from African Textile manufacturers limited located at Challawa industrial estate. It lies between latitude 11° 53' N and longitude 8° 28' E, in Kumbosto Local Government Area of Kano State Nigeria. The effluent was obtained fresh after textile production processes are complete into dry, clean rubber containers from the outfall of the effluent discharge pipe. The chemical and physical characteristic of the effluent is shown in Tables 3 and 4. Laboratory tests were conducted to determine the index properties of the natural Lateritic Soil and Soil-Lime-Textile effluent mixtures in accordance with BS 1377 (1990), BS 1924 (1990).

Results and Discussion

Identification of Natural Soil Sample

The summary of results of the tests conducted to determine the geotechnical properties of the natural soil samples are presented in Table 1. The particle size distribution curve is also shown in Figure 1. The soil is light brown in colour with liquid limit of 47.00 %, plastic limit of 27.30 % and plasticity index of 19.70 %. The soil is classified as CL soil in the Unified Soil Classification System, USCS (ASTM, 1992) or A-7-6 (12) according to AASHTO soil classification system (AASHTO, 1996). The natural soil also has a linear shrinkage of 11.43 % and specific gravity of 2.66 with 64.00 % passing BS Sieve No 200 (0.075mm aperture).

Table 3: Chemical Characteristics of Textile Effluent.

CHEMICAL PARAMETER	CONC. MEASURED (mg/l)	MAXIMUM PERMISSIBLE LEVELS	
		WHO	NIS
Nickel ; Ni	4.975	0.07	0.02
Chromium; Cr	7.040	0.05	0.05
Cadmium; Cd	0.162	0.003	0.003
Lead ; Pb ⁺	1.204	0.01	0.01
Magnesium ; Mg	2.667		0.20

Table 2: Chemical composition of Hydrated lime and lateritic soil used.

ELEMENTAL OXIDE	(%) COMPOSITION	
	HYDRATED LIME	LATERITIC SOIL

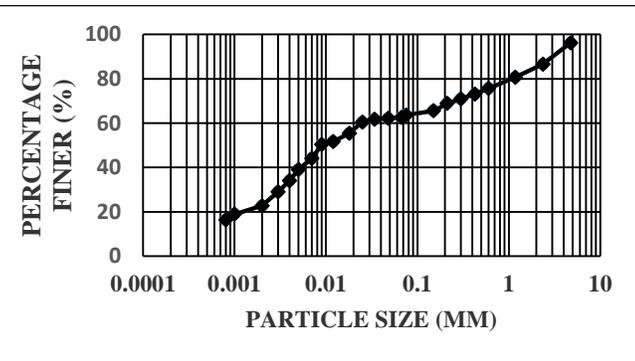


Fig. 1: Particle size distribution curve for the natural soil.

The lime used for the study is hydrated lime and was purchased in the open market at Bayyajidda Street, Kaduna central market, Kaduna. Nigeria. Chemical composition of the hydrated lime is presented in Table 2.



Sodium ; Na ⁺	3393	200	200
Calcium ; Ca ⁺	21.79	200	75
Potassium ; K ⁺	179.03	120	
Zinc ; Zn	0.100	4	3
Copper ; Cu	0.311	2	1
Iron ; Fe ²⁺	10.30	0.30	0.30
Chloride ; Cl ⁻	190	200	250
Sulphate ; So ₄ ²⁻	90	250	100

Table 4: Physical Characteristics of Textile Effluent

PARAMETER	CONC. MEASURED	MAXIMUM PERMISSIBLE LEVELS	
		WHO	NIS
pH	12.80	6.5-8.5	6.5-8.5
Colour (Hazen)	6.0	15	15
Turbidity (NTU)	210	5	5
Total dissolved solids (mg/l)	2950	500	500
Total Alkalinity (mg/l)	2230	500	-
Total suspended solids (mg/l)	1260	30	-
Biochemical oxygen demand (mg/l)	35	10	-
Chemical oxygen demand (mg/l)	1100	10-20	-
Electrical conductivity (µs/cm)	6010	1000	1000
Dissovled oxygen	110	-	5.0
Specific gravity	1.001	-	-

Influence of Textile Effluent on Soil Properties

(a) Specific gravity

Specific gravity of soils indicates how much heavier or lighter the soil particles are compared to water at 25^oc. The variation of specific gravity of the natural and lime treated lateritic soil with textile effluent is shown in Fig.2. The specific gravity of the soil generally decreased with increase in both lime and textile effluent. Its value decreased from 2.66 for the natural lateritic soil to 2.54 and 2.30 at 0% lime and 25% effluent concentration and at 4% lime and 100% effluent concentration respectively. The decrease was due to the lower specific gravity (2.10) of the lime to that of the natural soil (2.66), which gradually replaces the soil material. Another reason for the decrease could be due to the low density of the effluent having a specific density of 1.001 compared to the natural soil (2.66) and hydrated lime (2.10) (Mahdi, and Mahmoud, 2015). (Mahmoud, and Dhergham, 2015).

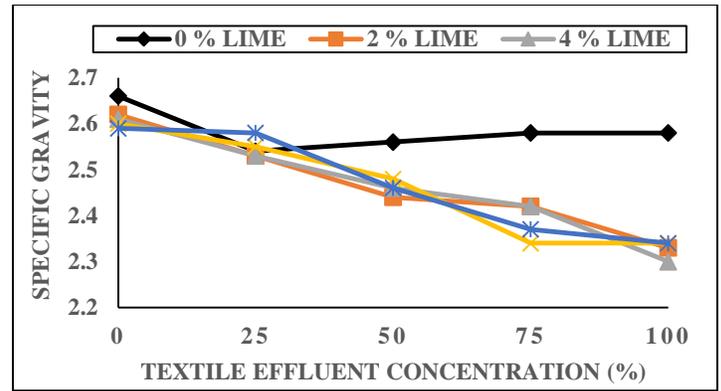


Fig. 2: Variation of specific gravity of soil-lime with textile effluent concentration.

(b) Atterberg limits

The variation of liquid limit of lateritic-lime mixtures with textile effluent is shown in fig. 3. The results show a decrease in the liquid limit with increase in textile effluent concentration alone. And it was observed that when treated with 2, 4, 6 and 8% lime the liquid limit decrease less than the natural soil. But when lime/TE concentrations were increased together the liquid limit also increased with values higher than those with 0% lime. The decrease may be attributed to the flocculation and agglomeration arising from the cation exchange reactions whereby Ca²⁺ in the lime and textile effluent reacted with ions of lower valence in the clay structure. This findings is in agreement with the findings reported by Obeahon (1993), Osinubi and Umar (2003), Osinubi and Alhassan (2008), Al-zoubi (2008), Ramesh *et al* (2013) and Portelinha *et al* (2012). The addition of lime and textile effluent introduced Calcium for its strength which caused a decrease in the repulsive force of the soil mixture; thereby needing more water to take the soil to its dynamic shear strength (Osinubi, 1995). In other words, first Calcium hydrate is dissolved and the resulting OH combined with Si and Al in the clay fraction and hydroxides with Ca²⁺. Silicate and aluminate are produced. The reduction in liquid limit from 47.00% for the untreated soil to a minimum value of 39.20% was recorded at 0% lime/75% TE treatment. This corresponds to a decrease of 16.60%.

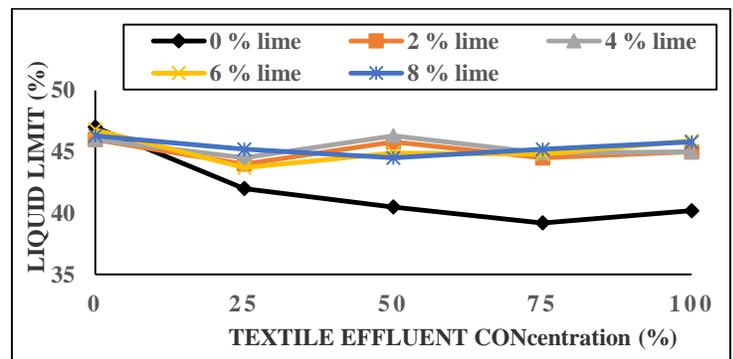


Fig.3: Variation of liquid limit of lateritic soil – lime mixtures with textile effluent concentration.

The variation of plastic limit of lateritic soil-lime mixtures with textile effluent concentration is shown in fig.5. The results depicted a decrease in the liquid limit when only textile effluent was increased for up to 100%. The plastic limit of the natural soil decreased from 27.20% to a minimum value of 23.57% at 0% lime/75% textile effluent concentration, while with increase in lime content only the liquid limit generally increased from 27.20% for the natural soil to 30.95% at 0% TE/8% lime content. On treatment with both lime content and textile effluent concentration for up to 8% and 100% respectively, the plastic limit progressively decreased. The decrease may be due to cation exchange reaction that liberated adsorbed water particles in the soil leading to flocculation and aggregation of the soil (Osinubi, 1995). This trend is in conformity with the report by Amadi, (2010) and Ramesh *et al.* (2013).

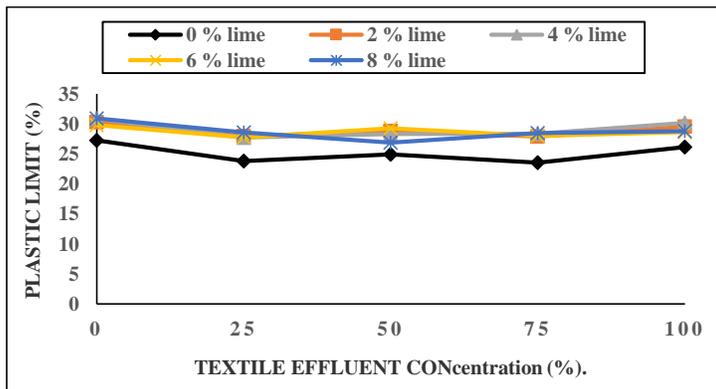


Fig. 4: Variation of plastic limit of lateritic soil–lime mixtures with textile effluent concentration.

The variation of plasticity index of lateritic soil-lime mixtures with textile effluent concentration is shown in fig.5. The results observed a decrease in plasticity index when solely textile effluent was added from 25% up to 100% concentration. The plasticity index of the natural soil decreased from 19.73% to 14.02%. On treatment with only 2, 4, 6 and 8% lime content, the plasticity index decreased to a minimum value of 15.12% at 4% lime/0% TE. But with the combination of lime content and textile effluent concentration the plasticity index increased to maximum values of 16.98%, 17.99%, 17.26% and 17.6% for up to 8% lime and 100% respectively.

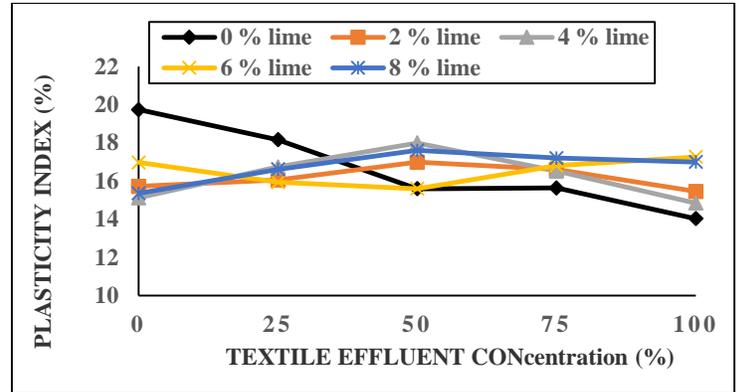


Fig. 5: Variation of plasticity index of lateritic soil – lime mixtures with textile effluent concentration.

The variation of linear shrinkage of lateritic soil-lime mixture with textile effluent concentration is shown in fig.6. The linear shrinkage results show a decrease in linear shrinkage from 11.43% for the natural soil to 5.0% at 0%L/75% TE concentration. On treatment with 2, 4, 6 and 8% lime alone the linear shrinkage decreased less than the value for the natural lateritic soil with a minimum linear shrinkage value of 9.28% at 8%/0% TE concentration. On further treatment with all percentages of lime contents and up to 100% TE concentration the linear shrinkage progressively increased. This increase suggests that the use of lime in conjunction with TE resulted in a soil of higher shrinkage when compared with TE treatment alone. It was observed that specimens which were not treated with lime (i.e., specimens treated with TE only) yielded shrinkage values that are lesser than the values obtained for specimens treated with both lime and TE blend.

Compaction Characteristics

(a) Maximum dry density

The variation of maximum dry density (MDD) of lateritic soil-lime with Textile effluent concentration for BSL, WAS and BSH compactions are shown in Figure 7. Generally, MDD values decreased with increasing combination of lime content and Textile effluent concentration considered. For the British Standard Light (BSL) compaction, it was observed that the MDD decreased generally with increase in Textile effluent concentration from a value of 1.68 mg/m³ for the natural soil to a minimum value of 1.56 mg/m³ for 8% lime/100% Textile effluent concentration treatment.

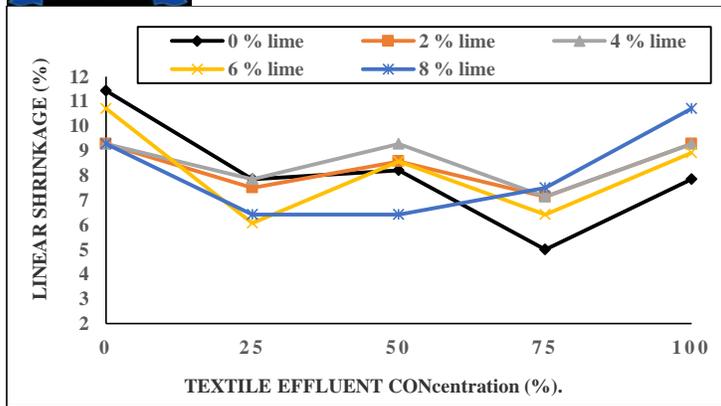


Fig.6: Variation of Linear shrinkage of lateritic soil-lime mixtures with textile effluent concentration.

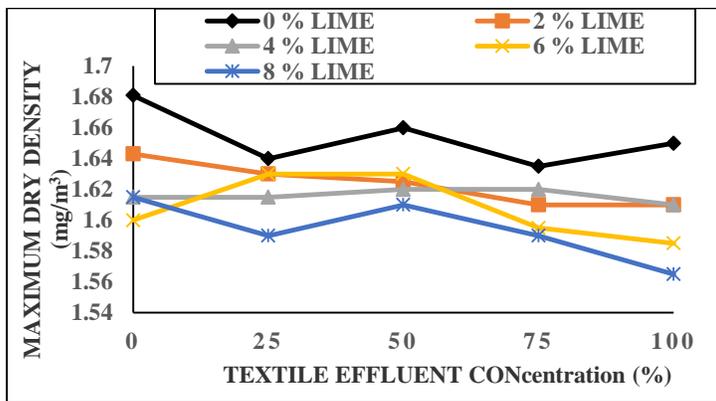


Fig.7: Variation of maximum dry density of soil-lime with textile effluent concentration at BSL Compactive effort.

The trend observed for the BSL compaction was also recorded for WAS and BSH compactions. For WAS and BSH compaction, MDD values decreased from 1.76 mg/m³ and 1.87 mg/m³ for the natural soil to reduced values of 1.65 mg/m³ and 1.75 mg/m³ for both at 8% lime/50% Textile effluent concentration treatments, respectively. The decreased in MDD recorded for all the compactive efforts may not be unconnected due to the specific gravity of lime having a lower specific gravity of 2.10 compared to the natural soil having a value of 2.66. Similar trend was also reported by Phanikumar *et al* (2004), Osinubi and Stephen, (2007), Jadhao and Nagarniak (2008) as well as Kumar and Puri (2013).

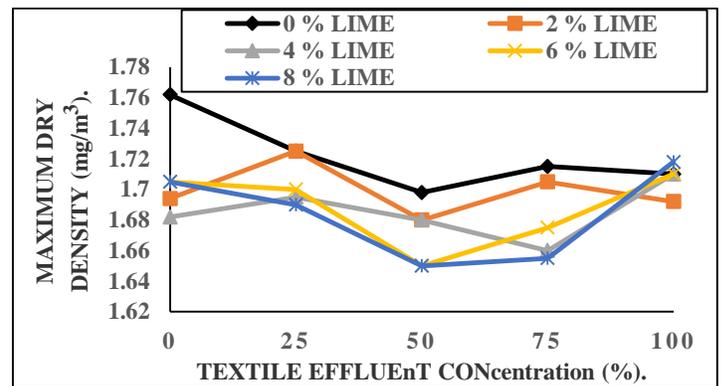


Fig. 8: Variation of maximum dry density of soil-lime with textile effluent concentration at WAS Compactive effort.

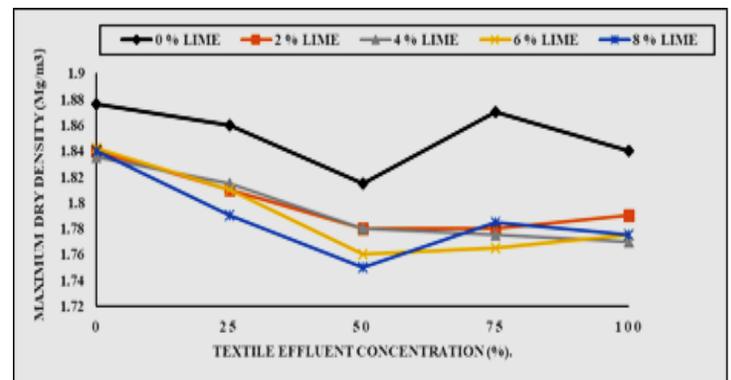


Fig. 9: Variation of maximum dry density of soil-lime with textile effluent concentration at BSH Compactive effort.

Another reason for the decrease in MDD can be explained on the basis of soil plasticity. MDD with effluent addition obtained through compaction tests tend to decrease with plasticity index of soil. Similar phenomenon was previously observed by other researchers; Pandian *et al* (1997) and Sridharan and Nagaraj (2005). Increase in concentration makes the soil plastic, thereby leading to a decrease in MDD. Partly also, the decrease in MDD could probably be due to the flocculated and agglomerated clay particles occupying larger spaces leading to corresponding decreases in the MDD (O'Flaherty, 1988).

(b) Optimum moisture content

The variation of Optimum moisture content (OMC) of lateritic soil-lime mixtures with Textile effluent concentrations for BSL, WAS and BSH compactive efforts are shown in Figs. 10-12. It was observed that there was a general but slight increase in OMC with Textile effluent treatment for specimens compacted with BSL, WAS and BSH compactive efforts. The OMC increased continuously with the increment in both lime content and effluent concentration. For all the compactive efforts the BSL, WAS and BSH the OMC increased from 20.2%, 15.90% and 14.20% for the natural soil to

peak values of 23.00% at 6% lime/100%, 20.6% at 6% lime/50% and 17.20% at 6% lime/75% Textile effluent concentration respectively. The increase in OMC was due to the corresponding increase in the effluent concentration which makes the soil more plastic, thereby leading to an increase in OMC.(Pandian et al,1997; Sridharan and Nagaraj. 2005; Muhammad et al, 2018).

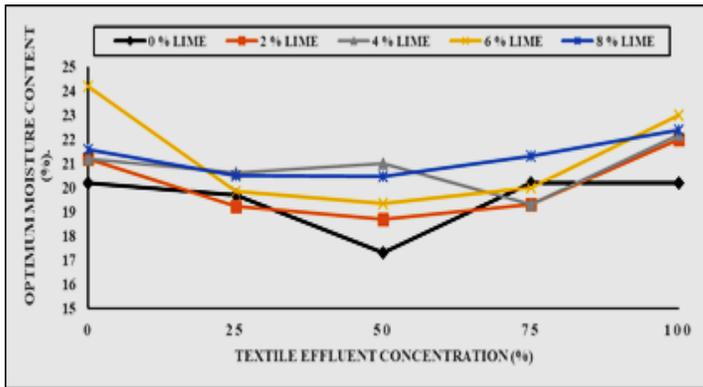


Fig.10: Variation of Optimum moisture content of soil-lime with textile effluent concentration at BSL Compactive effort.

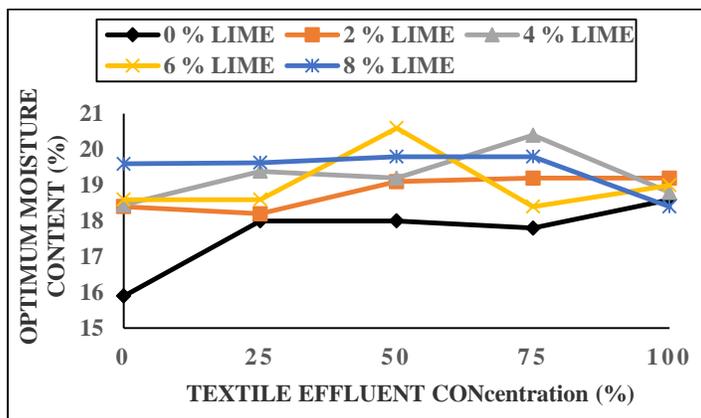


Fig.11: Variation of maximum dry density of soil-lime with textile effluent concentration at WAS Compactive effort.

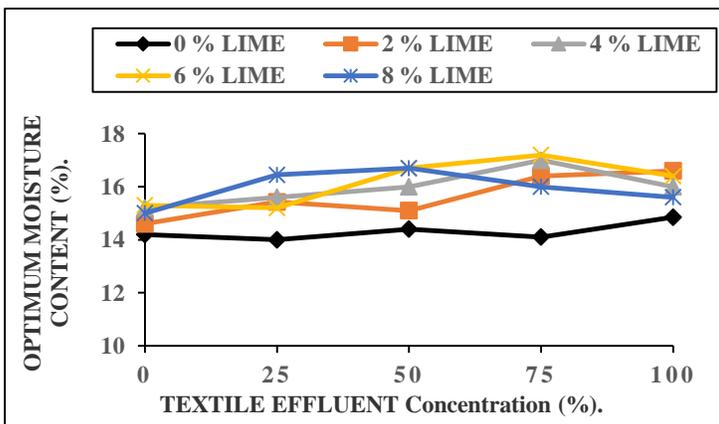


Fig.12: Variation of Optimum moisture content of soil-lime with textile effluent concentration at BSH Compactive effort.

Conclusion

In this study, an attempt has been made to evaluate the study of textile effluent on the geotechnical properties of lime treated lateritic soil. From the results presented in this paper, it can be concluded that the lateritic soil used for this study was classified as A-7-6(12) soil based on the AASHTO soil classification system or CL based on Unified soil classification system, USCS. The particle size distribution revealed that the parent sample is predominantly fine-grained soil with a percentage of 64.00% passing 75µm BS sieve. And with these properties the soil in its natural state was adjudged unsuitable for some engineering construction work. Also, the maximum dry density generally decreases for all compactive efforts with increase in percentages of both lime and textile effluent. This is due to the lower specific gravity of the additives and also due to flocculation and agglomeration. Furthermore, the optimum moisture content showed a general trend of increase for all efforts utilized with increase in lime and textile effluent. This was due to the higher water holding capacity within the voids of flocculated structure.

Textile effluent has a positive effect on the lateritic soil. The liquid limit decreased with higher percentages of textile effluent only than when treated with both lime and effluent. This is as a result of decreased in diffused double layer thickness. The plasticity index decreases with only increase in textile effluent concentration. It decreases from 19.73% for the natural soil to 14.02% at 0% lime/100% TE concentration, which shows an improvement but did not meet the 12% plasticity index specified by clause 6201 of the Nigerian General Specification (1997) for sub base materials.

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