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INFLUENCE OF COMPACTIVE EFFORT ON THE STRENGTH CHARACTERISTICS OF LIME TREATED LATERITE SOIL MIXED WITH UNTREATED TEXTILE EFFLUENT

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Abstract
Industrial waste generated is a major contributor of total waste worldwide. The proper mechanism for management of these waste needs to be established, especially in developing countries. Therefore, this paper attempts to evaluate the influence of compactive effort on the strength characteristics of lime treated laterite soil mixed with untreated textile effluent. The study was carried out on the index properties, unconfined compressive strength (UCS) and California bearing ratio (CBR) in accordance with the procedures specified by BS 1377 (2) 1990, 1924 (2) and Nigeria General Specifications. Three compactive efforts namely; British Standard light (BSL), West African Standard (WAS) and British Standard Heavy (BSH) were used for the strength characteristics. The findings of the study showed that an increase in the values of lime-TE results in general increase in the strength tests. An improvement in the UCS for 7, 14 and 28days curing period was recorded at peak values of 1531.91, 2199.29 and 2560.48kN/m^2 for BSL, WAS and BSH at soil-lime-TE of 4% lime/75% TE, 8% lime/75% TE and 8% lime/50% TE respectively. For the CBR (soaked), the peak values were recorded at 49.70, 71.13 and 97.25% for BSL, WAS and BSH at soil-lime-TE of 6% lime/50% TE, 6% lime/50% TE and 8% lime/50% TE respectively. Considering the resistance to loss in strength, the values were also peaked at 71.77, 81.74 and 60.63kN/m^2 at mix ratios of 8% lime/100% TE, 6% lime/75% TE and 8% lime/25% TE respectively. On the bases of these test results, it can be concluded that the utilization of untreated Textile Effluent positively increased the strength characteristics of the lime treated soil, reduced environmental pollution and save construction cost.

Keywords: California bearing ratio, Compactive effort, Durability, Laterite soil, Lime, Textile effluent, Unconfined compressive strength.

1.0 INTRODUCTION

Environmental pollution is one of the major problems associated with rapid industrialization , urbanization and rise in living standard of people. For developing countries, especially Nigeria, industrialization was must and still this activity very much demands to build self reliant and uplifting the nation's economy. However, industrialization on the other hand has also cause serious problems relating to environmental pollution on air, water and soil. Therefore, wastes seem to be a by-product of growth and as such the cost of disposal or treatment of these wastes is continuing to grow day-by-day in our society. Also, the over dependent on the utilization of conventional soil additives; cement, lime and Bitumen etc have kept the cost of Civil engineering projects financially high. It has also been shown by [1] that Portland cement , by the nature of its chemistry, produces large quantities of CO_2 for every ton of its final product. So, the growth of by product or wastes is inevitable unless new and beneficial use options which are economically sound and environmentally friendly are developed and implemented. [2] recognized the importance of recycling industrial waste with regards to natural resources conservation and efficient landfill utilization. They added that this has led to research on alternatives uses of waste materials in different geotechnical application including soil improvement.

Textile effluent an industrial wastewater from the production of textile fabric; have the potentials to be useful in the stabilization of soil. [3] investigated the utilization of untreated textile effluent on some geotechnical properties of lime treated lateritic soil. Addition of effluent to the soil bring major changes in specific gravity, Atterberg limits and compaction characteristics. In their study, [4] reported the effect of acidic effluent from a silk dyeing industry. Moisture density relation and strength property were evaluated. It was observed that the addition of effluent concentration improves the maximum dry density and unconfined compressive strength marginally with peak strength value at 60% concentration, while the optimum moisture content decreased.

In another study by [5], textile effluent was found to decrease potential of hydrogen; pH, free swell index (FSI) and Atterberg limits values, while unconfined compressive strength and California bearing ratio values of the natural expansive soil improved. Likewise, [6] carried out tests on the effect of textile effluent on the geotechnical properties of expansive soil with varying concentration. It was concluded that the Atterberg limits, potential of hydrogen, differential free swell and maximum dry density decreased, while optimum moisture and unconfined compressive strength increased. The effect of three liquid effluent from textile, tyre and tube industries on some index and engineering properties of soil were studied by [7]. The addition of 5, 10 and 20% concentration of the different effluent decreased the liquid limit, angle of internal friction and cohesion while void ratio and compressibility increased.

[8] reported the potential utilization of untreated and treated textile effluent on some properties of cement and concrete which resulted in an increase in the setting time, workability, compressive strength and split tensile strength. The study revealed that the properties increased between 35 – 270mins, 50 – 130mm, 20.55 – 53.41N/mm^2 and 1.80 – 3.50N/mm^2 respectively. The influence of textile waste water on the compaction strength characteristics using two compactive efforts were investigated with concentration ranging from 10 to 100%. The result revealed that maximum dry density for both efforts decreased, while optimum moisture content increased. Furthermore, the treated soil recorded unconfined compressive strength values of 875.00 and 1033kN/m^2 at optimum 100% effluent concentration for both efforts and resistance to loss in strength were 25.3 and 26.80% respectively [9]. [10 - 11] conducted several tests on clayey soils with acidic effluent. In there findings the discovered from the ion exchange processes there was an increase in double layer thickness resulting in a greater compressibility of the soil. [12] suggested from there experimental work that acidic dyeing effluent added to expansive black cotton soil increased the maximum dry density and unconfined compressive strength, while the optimum moisture content values decreased.

2.0 MATERIALS AND METHODS

2.1 Materials

2.1.1 Soil sample

The soil used for this research work was a reddish brown laterite soil collected by method of disturbed sampling from a laterite soil formation located in Shika, Zaria, Kaduna state (Latitude 11^{0}15ʹ N and longitude 7^0 45ʹ 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 geotechnical research laboratory section of the Department of Civil Engineering, Nigerian Defence Academy, Kaduna. Thereafter, the soil samples were then air-dried before pulverized to obtain particles passing BS No. 4 Sieve (4.76mm aperture).

2.1.2 Lime

The lime that was used for the soil stabilization in this research work was Hydrated lime. The lime was purchased in the open market at Bayyajidda street, Kaduna central market, Kaduna.

2.1.3 Textile effluent

The textile effluent was obtained from African Textile manufacturers limited located at Challawa industrial estate. The Mill lies between latitude 11^o 53ʹ N and longitude 8^o 28ʹ E, in Kumbosto local government area of Kano state. The untreated effluent was obtained fresh after textile production processes are complete into dry, clean rubber containers from the outfall of the discharge pipe. The chemical and physical characteristics of the effluent are shown in Tables 3 and 4.

2.2 Methods

The laboratory tests carried out on the natural and stabilized soils include particle size distribution, Specific gravity, Atterberg limits, compaction, California bearing ratio (CBR), Unconfined compressive strength (UCS) for 7, 14 and 28 days curing periods and durability. The tests were carried out in accordance with BS 1377 (1990) and BS 1924 (1990) [13 - 14] for the natural and treated soils respectively. The California bearing ratio (CBR) tests were also conducted as recommended by Nigerian General Specifications for Roads and Bridges (1997) [15] with a CBR value of 180% to be attained in the laboratory for cement stabilized materials to be constructed by the mix-in-place method. The UCS and CBR tests were prepared at optimum moisture content (OMC) and compacted with British Standard light (BSL), West African Standard (WAS) and British Standard Heavy (BSH) efforts. Durability tests for all compactive efforts were determined as the ratio of the UCS of the specimen wax cured for 7 days, de-waxed top and bottom and then immersed in water for another 7 days to the UCS of specimen wax-cured for 14 days.

2.2.1 Unconfined compression strength test

The unconfined compression strength (UCS) was determined following the procedure outlined in British Standards 1377 and 1924 (BSI 1990) [13 - 14].

The UCS was evaluated as:

$$UCS = \frac{\text{Load at failure}}{\text{Cross sectiona area}} \quad (1)$$

2.2.2 California bearing ratio

The test was done in accordance with BSI 1377 and 1924 (1990) [13 - 14] for the natural and treated soils. The specimens were cured for a period of 6 days and after the sixth day the specimens were submerged in portable water for 24 hours before testing as specified by Nigerian General specifications for Road and Bridges (1997) [15].

The CBR was calculated as:

$$CBR = \frac{\text{Measured load}}{\text{Standard load}} * 100 \quad (2)$$

2.2.3 Durability characteristics

The durability is a measure of the resistance to loss in strength. The method adopted to assess durability of Soil-lime-TE treated soils in this research work is proposed by [16]. It is the ratio of unconfined compression strength (UCS) of specimen wax-cured for 7 days, and then de-waxed upper and lowest cross section of specimen to allow for water absorption in water tank for another 7 days to the UCS of specimen wax-cured for 14 days [16 - 17]. The resistance to loss in strength was calculated as:

$$\text{Resistance to loss in strength:} = \frac{\text{UCS (7 days cured+7 days soaked)}}{\text{UCS (14 days cured)}} * 100 \quad (3)$$

3.0 RESULTS AND DISCUSSION

3.1 Geotechnical Properties of the Natural Laterite Soil

The results of the preliminary tests carried out on the natural soil are presented in Table 1. The soil is classified as an A-7-6 (12) based on the American Association of State Highway and Transportation Officials classification system (AASHTO, 1986)[18] and CL, using the Unified Soil Classification System, USCS (ASTM,1992)[19]. The soil sample been classified as CL, is an indication of low plasticity clay [20-22]. The laterite soil has a liquid limit value of 47.00%, plastic limit 27.30%, plasticity index of 19.70%, linear shrinkage of 11.43% and specific gravity of 2.66 with 64.00% of the soil particles passing the BS No. 200 Sieve (0.075mm aperture). The predominant clay mineral is kaolinite. From the foregoing, the soil sample possesses poor engineering properties. The particle size distribution curve and its oxide composition are shown in figure 1 and Table 2.

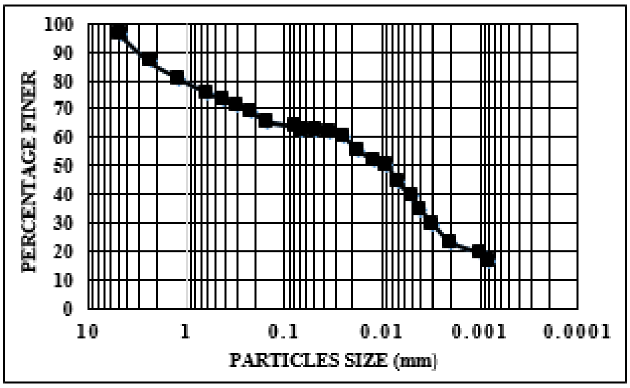

Figure 1: Particle size distribution curve of the natural soil

Table 1: Physical properties of the natural soil used for the study

PROPERTY	QUANTITY/DESCRIPTION
Natural moisture content (%)	16.70
Percentage passing BS sieve No. 200 (%)	64.00
Liquid limit (LL) (%)	47.00
Plastic limit (PL) (%)	27.30
Plasticity index (PI) (%)	19.70
Linear shrinkage (LS) (%)	11.43
Specific gravity	2.66

AASHTO classification	A-7-6
USCS	CL
Group index (GI)	12
pH	7.65
CEC (m/100meq)	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
Unconfined Compressive Strength (kN/m^2)	-
British standard light (BSL)	335.25
West African standard (WAS)	409.00
British standard heavy (BSH)	537.00
California Bearing Ratio (Unsoaked) (%)	-
British standard light (BSL)	12.68
West African standard (WAS)	19.56
British standard heavy (BSH)	24.15
California Bearing Ratio (24 hours soaking) (%)	-
British standard light (BSL)	5.76
West African standard (WAS)	15.17
British standard heavy (BSH)	22.87
Color	Light Brown
Dominant clay mineral	Kaolinite

Table 2: Oxide Composition of Natural soil and Hydrated Lime

Elemental Oxide	Composition (%).	
	Natural soil	Hydrated Lime
SiO_2	41.05	3.61
AL_2O_3	24.16	4.57
Fe_2O_3	10.16	0.25
CaO	0.23	48.32
MgO	0.21	2.27
SO_3	1.04	0.01
Na_2O	1.37	1.22
K_2O	0.34	2.00
TiO_2	0.39	0.09
P_2O_5	1.32	0.20
MO_2O_5	0.02	0.01
Rb_2O_5	0.27	0.01
PbO	0.01	ND
Cr_2O_3	0.02	0.01
MnO	ND	0.01
LOI	19.35	37.02
Gs	2.66	2.10

Table 3: Chemical Characteristics of Textile Effluent

Parameter	Concentration Measured (Mg/L)	Maximum Permissible Levels for Drinking Water Quality	
		WHO	NSDWQ
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	0.20
Sodium ; Na^+	3393	50	200
Calcium ; Ca^+	21.79	200	200
Potassium ; K^+	179.03	120	110
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 ; $So4^2$	90	250	100

(Source: [23] [24])

Table 4: Physical Characteristics of Textile Effluent

Parameter	Concentration Measured	Maximum Permissible Levels for Drinking Water Quality	
		WHO	NSDWQ
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	35	5	10
Chemical oxygen demand	1100	40	100
Electrical conductivity(µs/cm)	6010	1000	1000
Dissovled oxygen	110	< 8	100
Specific gravity	1.001	-	-

(Source: [23] [24])

3.2 Unconfined Compressive Strength

Unconfined compressive strength (UCS) is the common and adaptable method of evaluating the strength of stabilized soil. It is the general test recommended for the determination of the required amount of additive to be used in stabilization of soil [25]. The test results for the UCS are shown in figures 2 - 10. The UCS at 7 days curing period increased from 335.25, 409.00 and 537.00kN/m^2 for the natural soil to peak values of 670.63, 1000.80 and 1531.91kN/m^2 respectively at 6% lime/100% TE, 6% lime/25% TE and 4% lime/75% TE for BSL, WAS and BSH compaction energies, respectively.

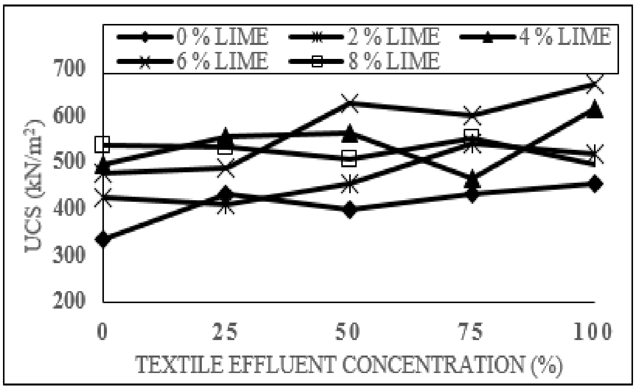

Figure 2: Variation of UCS (7 days curing period) of laterite soil-lime mixtures with textile effluent concentration (BSL)

The results obtained show that specimens treated with all compactive efforts did not meet the 7 days of

1710kN/m^2 specified by [26] as a criterion for adequate cement stabilization requirements as base materials. However, these values met the requirements of 687 – 1373kN/m^2 for sub-base as specified by [27].

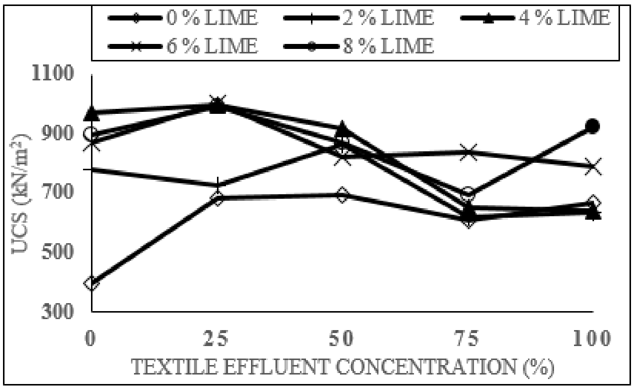

Figure 3: Variation of UCS (7 days curing period) of laterite soil-lime mixtures with textile effluent concentration (WAS)

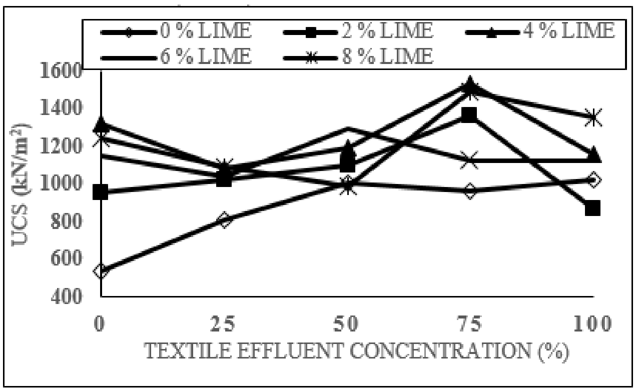

Figure 4: Variation of UCS (7 days curing period) of laterite soil-lime mixtures with textile effluent concentration (BSH)

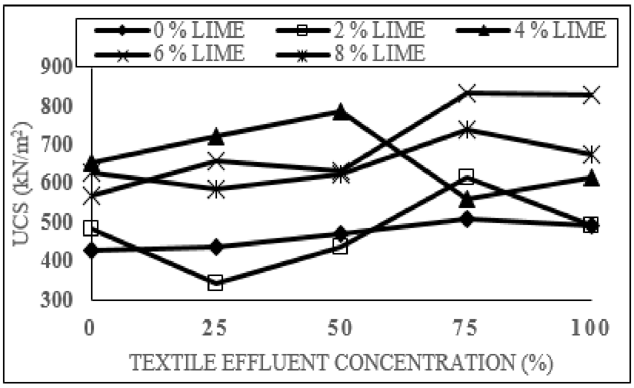

Figure 5: Variation of UCS (14 days curing period) of laterite soil-lime mixtures with textile effluent concentration (BSL)

For 14 days curing period, the UCS increased from its natural values of 430.75, 500.23 and 703.55kN/m^2 to peak values of 832.86, 1298.20 and 2199.29kN/m^2 at 6% lime/75% TE, 8% lime/75% TE and 8% lime/75% TE treatments for BSL, WAS and BSH compaction efforts, respectively. Furthermore, for the 28 days curing, UCS values also increased as the stabilizer, admixture and compactive efforts increased. The values increased from 425.00, 600.75 and 750.65kN/m^2 to peak values of 1075.57, 1745.20 and 2560.48kN/m^2 at 6% lime/100% TE, 8% lime/25% TE and 8% lime/50% TE for BSL, WAS and BSH compaction efforts, respectively.

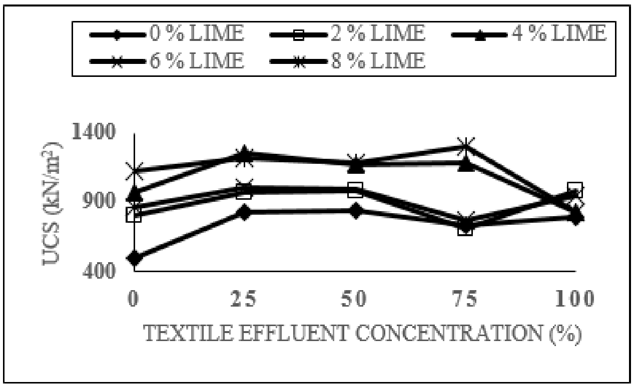

Figure 6: Variation of UCS (14 days curing period) of laterite soil-lime mixtures with textile effluent concentration (WAS)

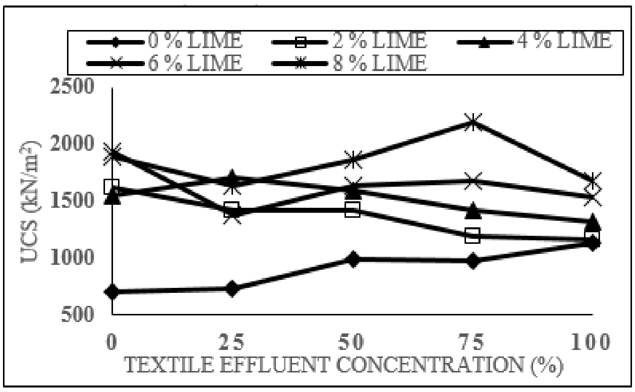

Figure 7: Variation of UCS (14 days curing period) of laterite soil-lime mixtures with textile effluent concentration (BSH)

The reason for the increase in UCS can be attributed to the flocculation and agglomeration of the clay structure enhanced by cation exchange within their surfaces. The Ca^{2+} in the lime and TE reacted with the lower valence metallic ions in the clay structure of the soil giving rise to rearrangement of the clay particles to form larger clogs. [28 - 29].

Moreover, the increase in strength could also be due to the dual effect of structural micro fabric changes imparted by compactive effort and the formation of various compounds such as calcium silicate hydrates

(CSH) and calcium aluminate hydrate (CAH). These compounds were induced by hydration reaction made effective by the oxides of Ca, Si and Al in the lime-TE-soil matrix. The present findings seem to be in agreement with other researchers which found the crystalline products (CSH and CAH) of hydration reaction acting as binding agent inside the soil structure and being responsible for strength development with age. [27, 30 - 34].

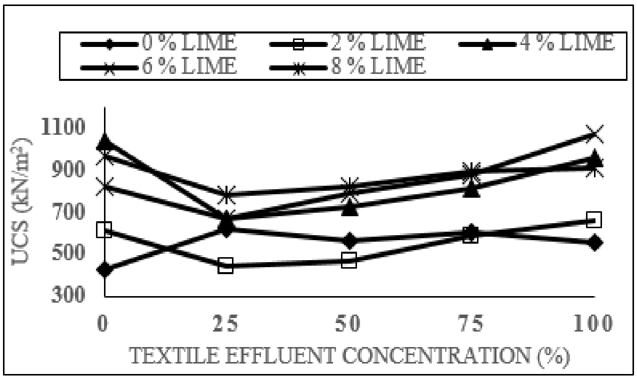

Figure 8: Variation of UCS(28 days curing period) of laterite soil-lime mixtures with textile effluent concentration (BSL)

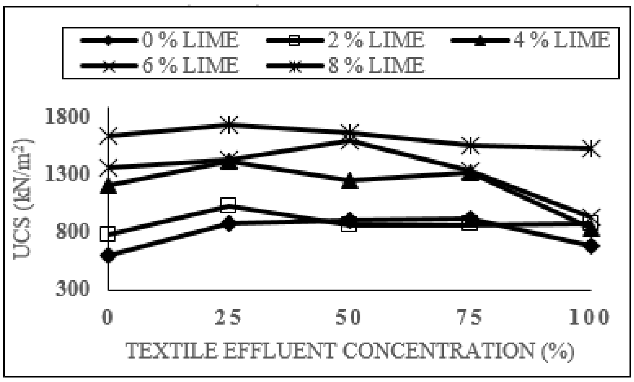

Figure 9: Variation of UCS (28 days curing period) of laterite soil-lime mixtures with textile effluent concentration (WAS)

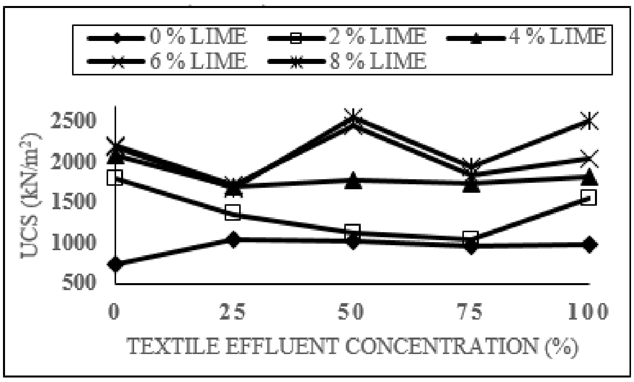

Figure 10: Variation of UCS (28 days curing period) of laterite soil-lime mixtures with textile effluent concentration (BSH)

3.3 California Bearing Ratio.

The California bearing ratio (CBR) value of soil/stabilized soil is an important parameter in assessing its suitability for engineering use. It gives the indication of the strength and bearing ability of the soil. The unsoaked CBR for BSL compaction gave a peak value of 56.68% at 6% lime/50% TE treatment from a natural value of 12.68%. For WAS and BSH compactions, the CBR values increased from 19.59 and 24.15% to 86.67 and 102%, respectively at 6% lime/ 50% and 8% lime/ 50% TE concentration treatment respectively. These increase could be due to the presence of adequate amount of calcium from the combined effect of additive and effluent that is required for the formation of calcium silicate hydrate (CSH) and calcium aluminate hydrate (CAH), which are the major compounds responsible for strength gain. The unsoaked CBR also showed an increase in the CBR values as the compactive effort increased, this indicates the denser the soil due to higher compactive effort, the greater the strength of the soil.

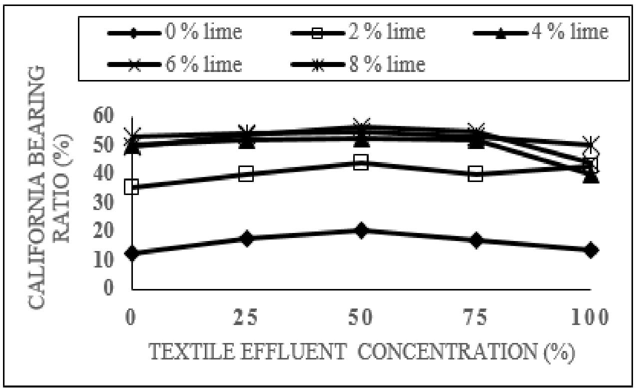

Figure 11: Variation of CBR (Unsoaked condition) of laterite soil-lime mixtures with textile effluent concentration (BSL)

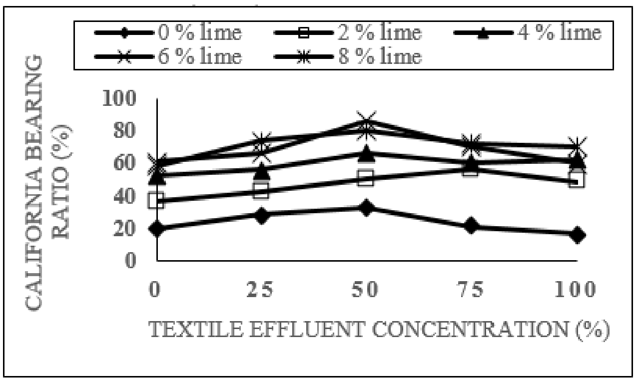

Figure 12: Variation of CBR (Unsoaked condition)

of laterite soil-lime mixtures with textile effluent concentration (WAS)

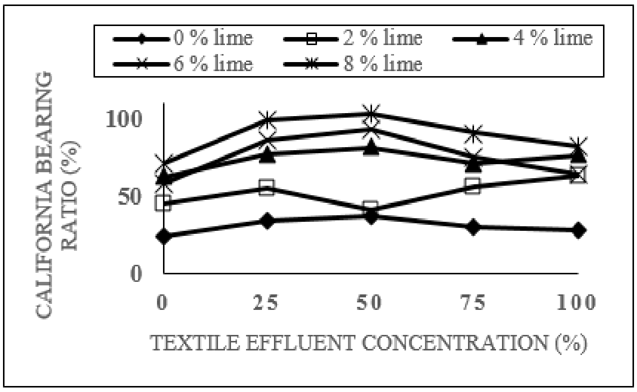

Figure 13: Variation of CBR (Unsoaked condition) of laterite soil-lime mixtures with textile effluent concentration (BSH)

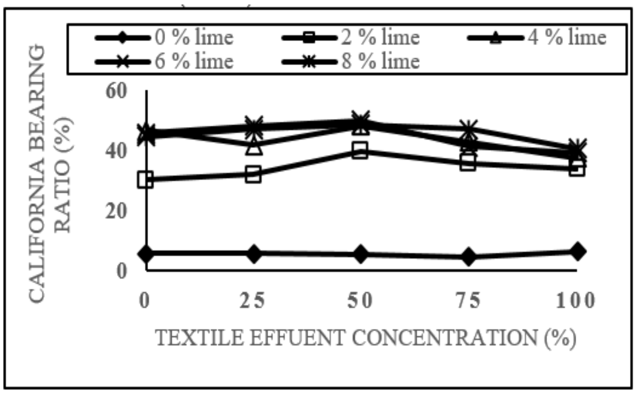

Figure 14: Variation of CBR (Soaked condition) of laterite soil-lime mixtures with textile effluent concentration (BSL)

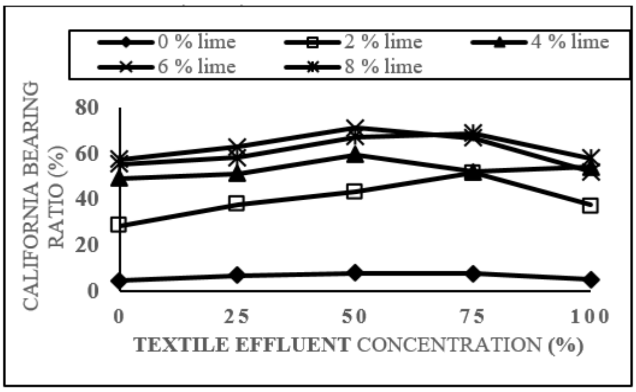

Figure 15: Variation of CBR (Soaked condition) of laterite soil-lime mixtures with textile effluent concentration (WAS)

The soaked CBR values also showed an increase with higher content and concentration of both lime and textile effluent and also with higher compactive efforts. Peak CBR values of 49.71, 71.13 and 97.25% for BSL, WAS and BSH compactive efforts were recorded at 6% lime/ 50% TE, 6% lime/ 50% TE and 8% lime/ 50% TE treatment respectively. The decrease in CBR values of soaked specimens when compared with the unsoaked CBR values could be due to the ingress of water into the specimens which weakened and reduced its strength. (see figures. 11 - 16).

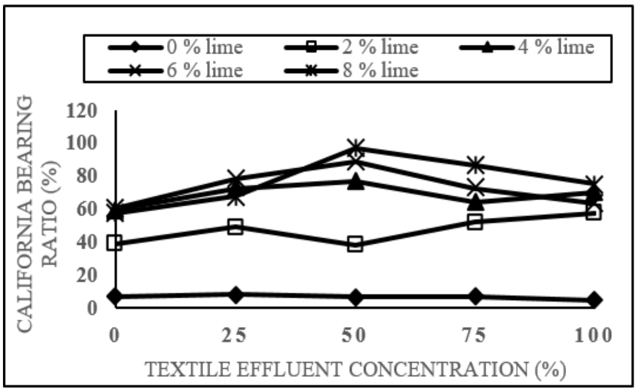

Figure 16: Variation of CBR (Soaked condition) of laterite soil-lime mixtures with textile effluent concentration (BSH)

3.4 Durability Assessement.

Durability of a treated soil is more important than the strength gained by the treated or stabilized soil. The variation of resistance to loss in strength for the soil-lime treated soil admixed with textile effluent concentration for BSL, WAS and BSH energy levels are shown in figures 17 - 19.

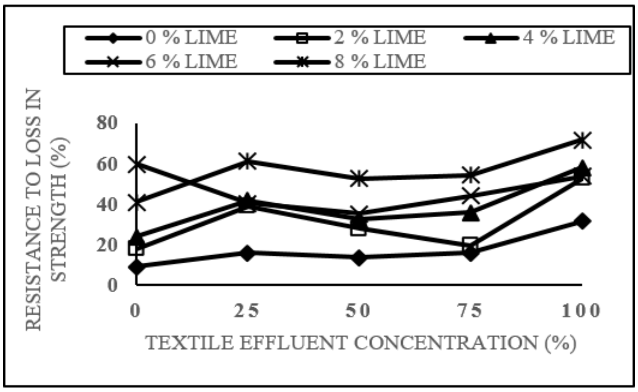

Figure 17: Variation of resistance to loss in strength of laterite soil-lime mixtures with textile effluent concentration (BSL)

Generally, the resistance to loss in strength increased with lime content and TE concentration up to 8% lime/ 100% TE, 6% lime/ 75% TE and 8% lime/ 25% TE treatments for BSL, WAS and BSH compactive efforts respectively. According to [35], resistance to loss in strength should be a minimum of 80% for 7 days curing and 4 days soaking periods. The peak resistance to loss in strength values for BSL, WAS and

BSH compactive efforts are 71.77, 81.74 and 60.63% respectively.

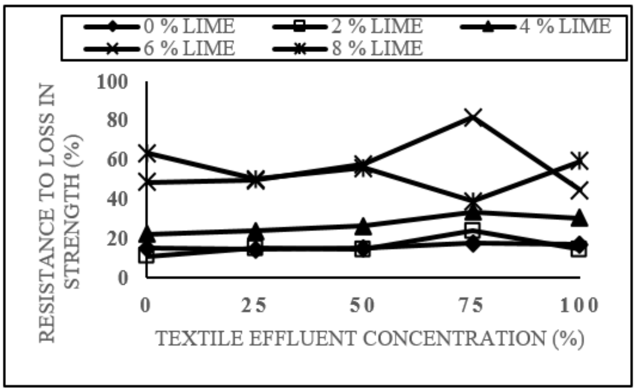

Figure 18: Variation of resistance to loss in strength of laterite soil-lime mixtures with textile effluent concentration (WAS)

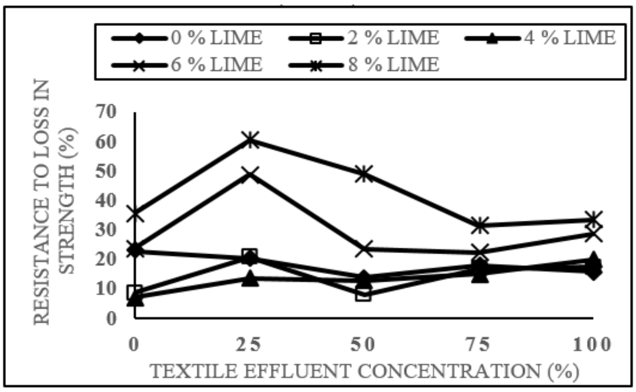

Figure 19: Variation of resistance to loss in strength of laterite soil-lime mixtures with textile effluent concentration (BSH)

The recorded peak resistance to loss in strength value for WAS compactive effort considered fell within the acceptable 80% earlier mentioned. However, the 71.77 and 60.63% resistance to loss in strength at 8% lime/ 100% TE and 8% lime/25% TE treatment of the soil when compacted with BSL and BSH energies may be acceptable since the limiting value reported by [35] is based on 4 days soaking and not the 7 days soaking period to which the specimens were subjected to.

4.0 CONCLUSION

The study has evaluated the effectiveness of different compactive effort on the strength characteristics of lime treated laterite soil mixed with untreated textile effluent. After analyzing the natural soil, the test results of the unconfined compressive strength (UCS), California bearing ratio, (CBR), and durability assessment for all compactive effort generally showed the potentials of using this industrial waste water for the improvement of strength properties of deficient soils. Thus, the combination 6% lime/50% TE and 8% lime/50% TE suggest it will really improve the stabilization of soils to be used as sub base material when WAS effort is utilized, reducing the cost of soil improvement and effluent treatment before disposal into the environment and will considerably add to the economic value chain of the textile mills.

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