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Stabilization of Lateritic Soil with Scrap Tyre Crumb Rubber

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Abstract- Non - lateritic soils are commonly used for construction purposes. However, due to the variability of the properties of the soil, it does not meet the design requirement. In this study non - lateritic soil sample was taken from a borrow pits in Dungulbi (Bauchi-Gombe road, Bauchi State Nigeria). The materials were characterized and then stabilized with scrap tyre crumb rubber (STCR) in stepped concentration of 1, 2, 3, 4 and 5 % by dry weight of the soil for various sizes of scrap tyre crumbs rubber (STCR) in the range (i.e 0.212, 2.36, 3.35 and 4.75 mm). The test conducted on the non - lateritic soil- STCR include compaction using three energies level (i.e British Standard light, BSL, West African Standard, WAS, British Standard heavy, BSH) and California bearing ratio (CBR). The results obtained, indicate a general decrease in both optimum moisture content (OMC) and maximum dry density (MDD) as the STCR contents increases. There was increase in CBR values for both unsoaked and soaked condition up 3 % STCR replacement thereafter decrease with increase in STCR. Statistical analysis were also carried out using analysis of variance (ANOVA) to check the effect of STCR inclusion on the geotechnical properties of the non - lateritic soil to be used as a road construction material. The results of the multiple linear regression analysis showed that the predicted values are in good agreement with the experimental values. The stabilized soil showed satisfactory strength and can be used for construction of embankment and stabilization of subgrade, subbase and base course of road. This indicates the potential of using 3 % STCR for non – lateritic soil stabilization.

Indexed Terms- Non-lateritic Soil, Soil Stabilization, Scrap Tyre Crumb Rubber, CBR Test

I. INTRODUCTION

Nigeria is a developing country and may encounter challenges related to the prompt execution of capital projects because of dwindling reserve of good quality soils required for construction works. However, poor soils can be improved through modification / stabilization technique to meet the requirement of specific construction work (Craig, 2004; Das, 2009; Rao and Chittaranjan, 2011).

Soil modification / stabilization are the alteration of one or more engineering properties of soil by mechanical or chemical means to make it adequate for use. Change in soil's properties on minor level is referred to as soil modification method. In this context the term modification implies a minor change in soil properties (James and Pandian, 2016). However, soil stabilization methods in which the engineering properties of the soil have been changed enough to allow field construction to take place is used to reduce the permeability and compressibility of soil mass in earth work (structure), enhanced it shear strength and increase the bearing capacity of foundation soils (Osinubi, 1998; Ranjan and Rao, 2000; Singh and Mittal, 2014; RMA, 2016; Dukare *et al.*, 2016). Stabilization differs from modification in that a significant level of long term strength gain is developed through the additive reaction.

The development of new engineering materials with regulated properties from unconventional source materials has the potential of providing the sustainability of many engineering projects (Phani - Kumar and Sharma, 2004). In soil stabilization, Portland cement is one of the most commonly used additives for improving various types of granular soils (Lekha *et al.*, 2013). With more emphasis being placed now on engineering for sustainable development, there is need to extensively try various practical applications for waste material disposed and pass the practical information for proper implementation (Neville, 2012). The increasing number of cars all over the world results in millions of tonnes of scrap tyres annually. Nigeria is also one of the countries generating many used tyres. A small quantity of waste tyres is utilized for different application such as floor-mats, tarred road-making and locally to produce shoes. The remaining large quantity of scrap tyres is dumped illegally in different areas of the country.

The beneficial use of wastes do not only minimize their negative impact on human health and the environment but also reduce the cost of disposal, preserve and protect the environment as well as proffer solution to problems associated with the soils of low shear strength (Amari *et al.*, 1999 and Arulrajah *et al.*,2014). Therefore this study focused on the evaluation of the properties of a non-lateritic soil treated with scrap tyre crumbs rubber of different sizes when used as a road construction material.

II. MATERIALS

2.1 LATERITIC SOIL

The non-lateritic soil sample for this study was collected by method of bulk disturbed sampling, from a borrow pit at Dungulbi along Bauchi-Gombe Road. The soil samples were collected at a dept between 1.5 and 2.0 m to avoid top soil and ensuring non-inclusion of organic matter. The samples were collected in large bags, while a small quantity used for the determination of the natural moisture content was placed in a polythene bag and sealed to avoid loss of moisture during transportation to the Soil Mechanics Laboratory of the Department of Civil Engineering, Abubakar Tafawa Balewa University**,** Bauchi. The samples were air-dried, large lumps crushed and passed through BS No. 4 sieve (4.75 mm aperture).

2.2 SCRAP TYRE CRUMB RUBBER

The scrap tyre was collected from a dumping site in Bauchi, Bauchi Local Government Area of Bauchi state, Nigeria. Crumb rubber was obtained by cutting scrap tyre into small chips manually shredded to sizes that include 4.75 mm, 3.35 mm, 2.36 mm and 0.212 mm was prepared using machine.

2.3 WATER

Potable water was used for all the tests.

III. METHODOLOGY

3.1 COMPACTION

Three methods of compaction namely: British Standard Light (standard Proctor, BSL), West African Standard (intermediate, WAS) and British Standard Heavy (modified Proctor, BSH) were used. The BSL compaction method is equivalent to 595.96 kJ/m^3 of compaction energy of ASTM D 698-12 while the WAS compaction method is equivalent to 993.26 kJ/m^3 of compaction energy of ASTM D 698-12. The characteristics of the compaction methods used are presented in Table 1.

The laterite was allowed to dry at room temperature and pulverized to sizes small enough to pass 4.76 mm sieve aperture. A total of 315 mixes were prepared by adding STCR in stepped concentration of 0, 1, 2, 3, 4 and 5 % by dry weight of the soil for various sizes of scrap tyre crumbs rubber (STCR) in the range (i.e 0.212, 2.36, 3.35 and 4.75 mm) by dry weight of the soil. Moulding moisture contents used for preparation of the specimens ranged from 10 - 15 %. The control mix containing 0 % STCR was labeled C0 – 0STCR, and the remaining five mixes were labeled C1 – 1STCR, C2 – 2STCR, C3 – 3STCR, C4 – 4STCR and C5 – 5STCR reflecting the levels of addition of STCR to the soil by weight. For each percentage addition of STCR, three specimens were prepared and compacted. The average of optimum moisture contents (W_{opt}) and maximum dry density (Q_{dmax}) were determined.

3.2 CALIFORNIA BEARING RATIO (CBR)

The California bearing ratio (CBR) test is an empirical test developed by the California State Highway Department for the evaluation of subgrade strengths. In the test as given in BS 1377: 1990: part 4:7.4, the control mix containing 0 % STCR was labeled CBR0 – 0STCR, and the remaining five mixes were labeled CBR1 – 1STCR, CBR2 – 2STCR, CBR3 – 3STCR, CBR4 – 4STCR and CBR5 – 5STCR reflecting the levels of addition of STCR to the soil by weight. For each percentage addition of STCR, three specimens were prepared. The average CBR was determined for both soaked unsoaked condition. A total of 315 specimens which is 127 mm in height and 152 mm in diameter were prepared by compacting into the CBR mould. The specimens were prepared in 5 (five) layers and 4.5 kg rammer was used to give fifty – six (56) blows onto each layer. The load required to cause a circular; 49.65 mm in diameter, to penetrate the specimen at a specified rate of 1.25 mm per minute was then measured. From the test results, the CBR value was calculated. This is done by expressing the corrected values of forces on the plunger for a given penetration as a percentage of a standard force. The 2.5 mm and 5.0 mm penetration caused by 13.24 kN and 19.96 kN loads were used to compare the loads that caused the same penetration on the specimens. Mathematically the CBR is expressed as in Equation 1.

$$CBR=\frac{P_t}{P_s}\times 100 \qquad \cdots (1)$$

Where

P_t = Corrected unit (or total) test load Corresponding to the chosen penetration curve.

P_s = corrected unit (for total) standard load for the same depth of penetration as for P_s taken from standard code.

As was the case for compaction tests, six mixes were prepared at STCR contents in stepped concentration of 0, 1, 2, 3, 4 and 5 % by dry weight of the soil for various sizes of scrap tyre crumbs rubber (STCR) in the range (i.e 0.212, 2.36, 3.35 and 4.75 mm) and compacted using the three energy levels illustrated in Table1.

Table1: Characteristics of compaction methods used

Compaction method	Volume of mould (cm^3)	Weight of rammer (kg)	Height of fall (cm)	Number of layers	Numbers of blows	Work done (kJ/m^3)
BSL	1000	2.5	30	3	27	595.96
WAS	1000	4.5	45	5	10	993.26
BSH	1000	4.5	45	5	27	2681.81

IV. DISCUSSIONS OF RESULTS

4.1 CHARACTERIZATION OF MATERIALS

The results of classification tests carried out on the natural soil are summarized in Table 2. Physical observation showed that the soil is reddish brown in colour. The particle size distribution curve shown in Figure 1 depicts a well graded soil. The soil classifies as A - 2 – 7(0) and GW using the American Association of State Highway and Transportation Officials (AASHTO) ASTM D3282-09 soil classification system and Unified Soil Classification System (USCS) ASTM D2487-11, respectively. These classification systems show that the soil is coarse sand of low plasticity.

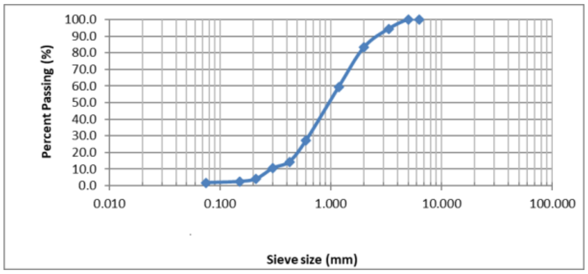


Fig. 1: Particle size distribution curve for the natural lateritic soil

Table 2: Properties of the Natural non-Lateritic Soil

Property	Quantity
Percentage passing No. 200 sieve (%)	1.6
Natural moisture content (%)	9.7
Liquid limit (%)	51.0
Plastic limit (%)	26.7
Plasticity index (%)	2.4.3
Linear shrinkage	11.4
Specific gravity	2.61
AASHTO Classification	A-2-7 (0)
USCS	GW
Group index	0
Percentage fine sand fraction	2.4
Percentage medium sand fraction	20.0
Percentage coarse sand fraction	60.8
Percentage fine gravel fraction	16.8
Maximum Dry Density (Mg/m^3)	
British Standard light	1.81
West African Standard	1.82
British Standard heavy	1.83

Optimum moisture content (%)	
British Standard light	14.4
West African Standard	13.8
British Standard heavy	13.6
Unsoaked California bearing ratio (%)	
British Standard light	35.6
West African Standard	38.6
British Standard heavy	46.8
Soaked California bearing ratio (%)	
British Standard light	10.7
West African Standard	13.1
British Standard heavy	21.0
Colour	Reddish Brown

Table 3: Index Properties of Scrap Tyre Crumb Rubber Stabilized Soil

	Mix proportion (%)		Linear shrinkage	Index properties (%)		
S/No.	Soil	STCR	W_S (%)	W_L	W_P	I_P
1	99	1	10.90	44.3	21.1	23.2
2	98	2	10.71	43.8	20.8	23.0
3	97	3	10.43	43.1	20.4	22.7
4	96	4	10.14	43.0	20.4	22.6
5	95	5	10.00	41.8	20.3	21.5

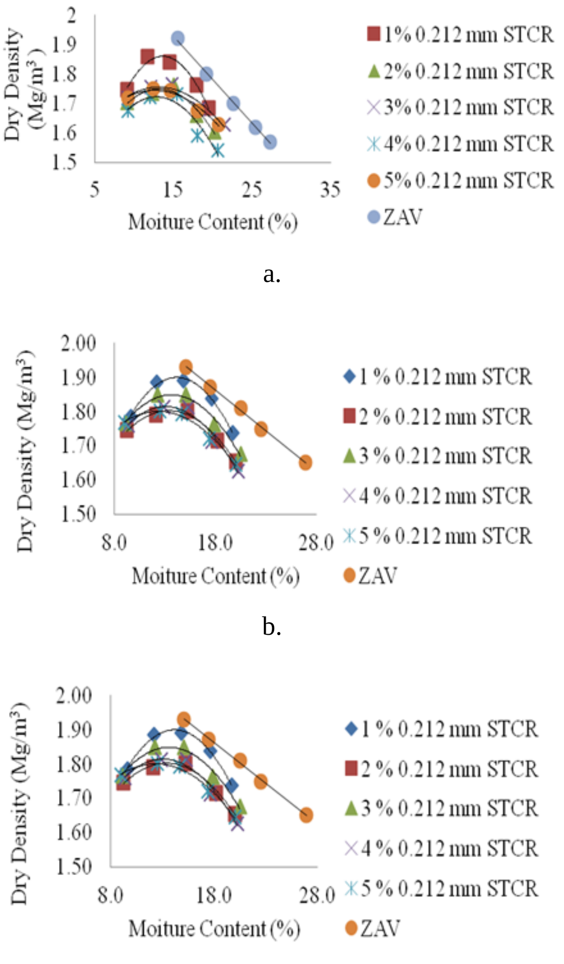
Table 4: XRF Results of the Natural non lateritic Soil

Oxides Composition	Concentration (%)
SiO_2	65.97
Al_2O_3	23.27
Ti_2O	0.71
Fe_2O_3	7.03
K_2O	1.06
MgO	ND
Na_2O	0.12
MnO	0.02
CaO	0.44
ZnO	ND
NiO	ND
SrO_3	0.03
Cr_2O_3	ND
S	0.01
P	ND
NbO_2	0.01
MoO_2	0.03
Zr_2O	0.02
SbO	ND
Cd_2O	0.02
Ag_2O	0.01
LOI	-

4.1 COMPACTION CHARACTERISTICS

The relationship between moulding water content and dry density for various soil- STCR mixtures is shown in Figure 2 - 5. Generally MDD decreased as the

STCR replacement level increased. The maximum dry density of soil mixtures expectedly decreased with higher STCR contents in the mixture from 1 to 5 %. The decrease in dry density with increase in STCR is expected because the addition of STCR with specific gravity of 1.17 resulted in mixtures with lower specific gravity which invariably resulted in reduced dry density, the effects of the various percentage replacement levels on moisture content showed a convergent behavior which could be attributed to low water absorption capacity of STCR. It is evidence from the plot of the OMC and MDD; the best results were achieved using British Standard heavy. As the STCR replacement level increased, the moisture content decrease which is an indication of better performance.

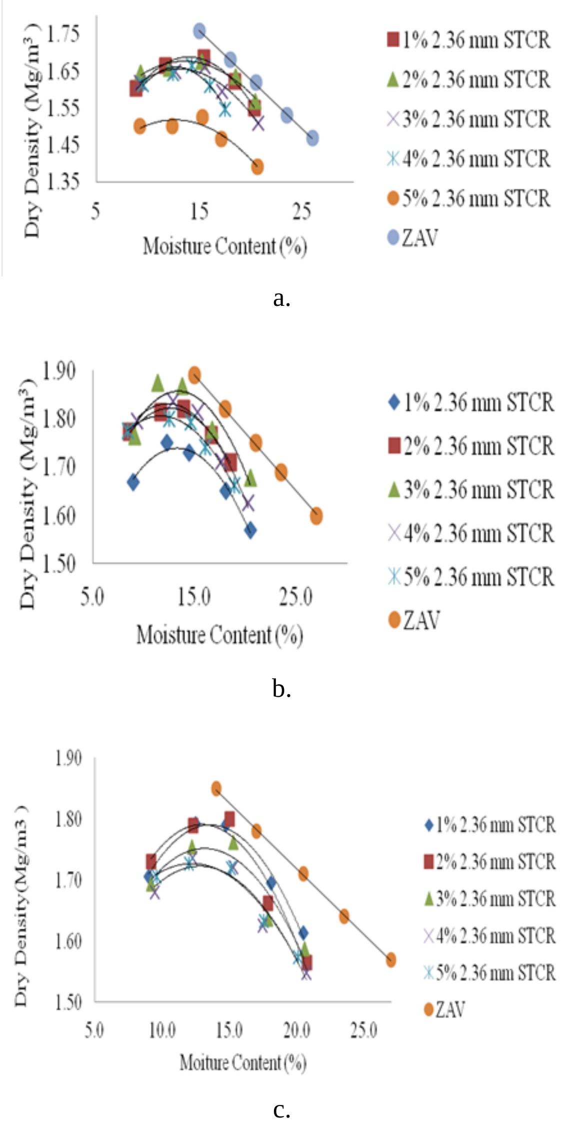


a.

b.

c.

Fig. 2: Moisture - Density Relationship of Non-lateritic Soil Stabilized with 0.212 mm STCR for: (a) BSL (b) WAS (c) BSH compaction



a.

b.

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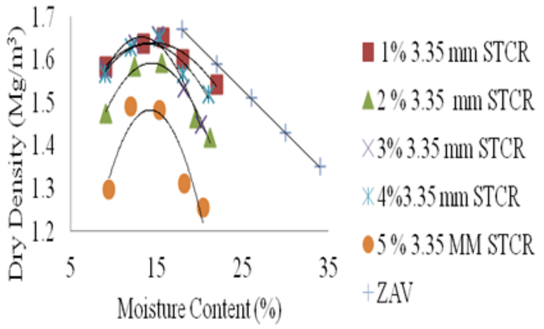
Fig. 3: Moisture – Density Relationship of Non-lateritic Soil Stabilized with 2.36 mm STCR for: (a) BSL (b) WAS (c) BSH compaction



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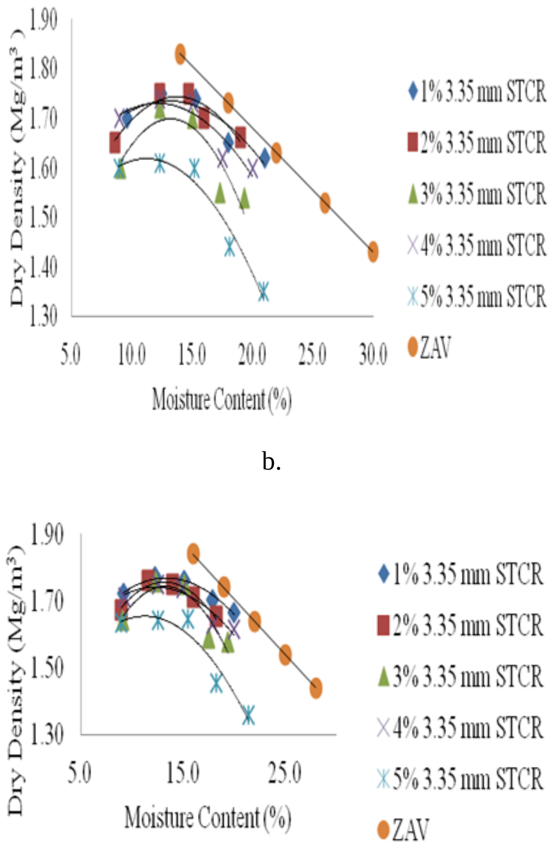
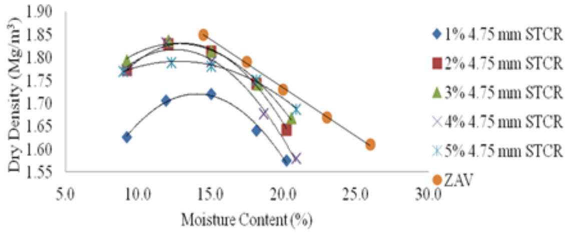


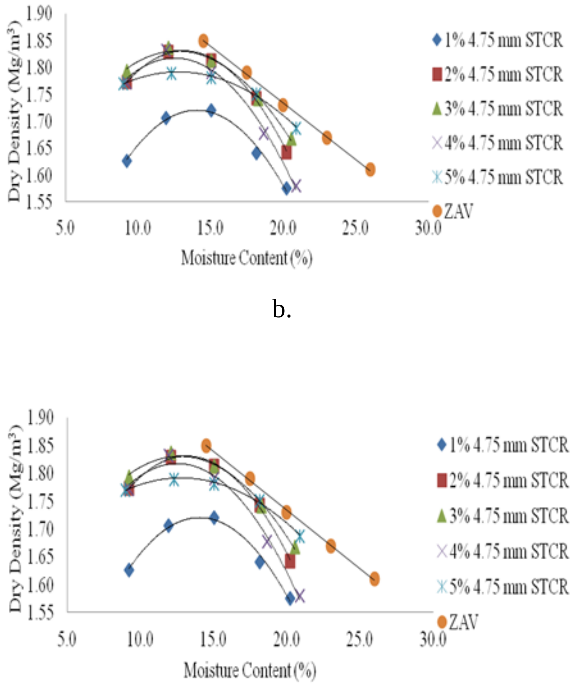
b.

c.

Fig. 4: Moisture – Density Relationship of Non-lateritic Soil Stabilized with 3.35 mm STCR for: (a) BSL (b) WAS (c) BSH compaction



a.



b.

c.

Fig. 5: Moisture – Density Relationship of Non-lateritic Soil Stabilized with 4.75 mm STCR for: (a) BSL (b) WAS (c) BSH compaction

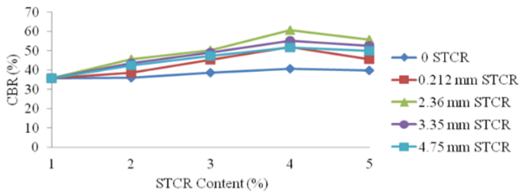
4.2 CALIFORNIA BEARING RATIO

The variation of the unsoaked California bearing ratio (CBR) of non-lateritic soil with scrap tyre crumb rubber (STCR) content is shown in Figure 6. For the three compaction energy levels used, the STCR values initially increased up to peak values at 3 % STCR content and thereafter decreased with increased STCR content. The results are in line with the results reported by Asif, 2016. For BSL, WAS and BSH compaction efforts the unsoaked CBR values increased from 35, 40 and 45 % for the natural non-lateritic soil to peak values of 60, 65 and 85 % for 3 % STCR content and 3.35 mm size. The observed decrease in the unsoaked CBR values beyond 3 % STCR content may be due to the presence of higher quantity of STCR that did not bond with the soil particles thus resulting in high compressibility of the mixture.

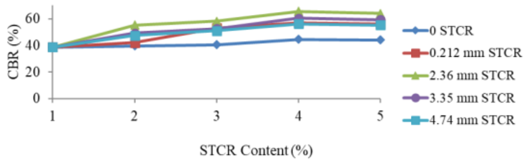
Specimens stabilized with up to 5 % STCR and compacted with the three energy levels considered the requirement of 30 % CBR of the Nigerian General

Specification (1997) for soil material to be used as subbase material and 2, 3, 4 and 5 % replacement for 3.35 mm STCR size and 3 % replacement for 4.75 mm size met the requirement of 80 % CBR for soil to be used as base materials for road construction.

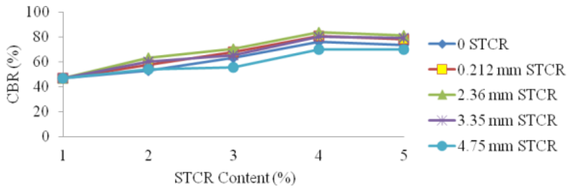
The variation of the soaked CBR of non-lateritic soil – STCR mixture is depicted in figure 7. For all the three different compaction energy levels used, the soaked CBR increased up to 3 % STCR content and thereafter decreased with increased in STCR content. For BSL, WAS and BSH compaction effort, the CBR values increased from 10.7, 13.1 and 21.0 % for the natural non lateritic soil to peak value of 18.3, 22.0 and 37.5 % for 3 % STCR content and 3.35mm STCR size respectively. The soaked CBR of non – lateritic is less than that of unsoaked condition, since under soaked condition the surface tension forces (which were offering additional resistance to penetration under the unsoaked condition) are destroyed (Sellaf *et al*., 2014).



(a) BSL Unsoaked CBR

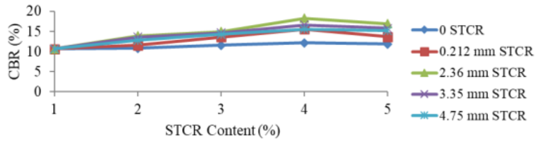


(b) WAS Unsoaked CBR

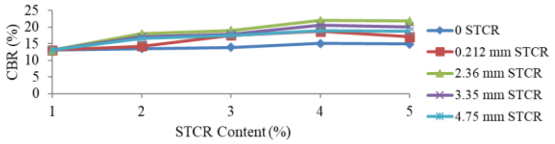


(c) BSH Unsoaked CBR

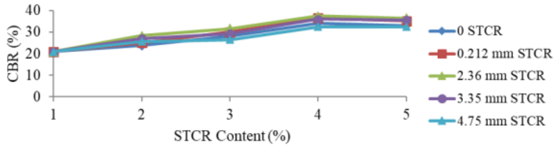
Fig. 6: Variation of California bearing ratio (unsoaked condition) of non lateritic soil with scrap tyre crumb rubber content



(a) BSL Soaked CBR



(b) WAS Soaked CBR



(c) BSH Soaked CBR

Fig. 7: Variation of California bearing ratio (soaked condition) of non-lateritic soil with scrap tyre crumb rubber content

4.3 STATISTICAL ANALYSES

Statistical analyses of the California bearing ratio results were carried out using the MINITAB 16.1 software for the various compactive efforts. A variety of studies have assumed that California bearing ratio of stabilized soil is log-normally distributed (Sellaf *et al.*, 2014; Priyadarshee *et al.*, 2018). The regression equation obtained from the analysis for unsoaked and soaked CBR for both Compactive efforts can be expressed as

$$UCBR_{bsl} = 35.0 + 1.96\ \text{STCR} + 2.29\ PR \qquad ...(2)$$

$$UCBR_{was} = 39.6 + 2.21\ \text{STCR} + 0.237\ PR \qquad ...(3)$$

$$UCBR_{bsh} = 59.0 + 4.69\ \text{STCR} - 0.780\ PR \qquad ...(4)$$

$$SCBR_{bsl} = 10.5 + 0.552\ \text{STCR} + 0.742\ PR \qquad ...(5)$$

$$SCBR_{was} = 13.1 + 0.664\ \text{STCR} + 0.920\ PR \qquad ...(6)$$

$$SCBR_{bsh} = 25.7 + 2.14\ \text{STCR} + 20.8\ PR \qquad ...(7)$$

Where;

U- CBR – Unsoaked California Bearing Ratio

S - CBR – Soaked California Bearing Ratio

bsl – British Standard Light

was – West Africa Standard

bsh – British Standard Heavy

STCR – Scrap Tyre Crumb Rubber

PR – Percentage Replacement

Equation 2-7 suggests that California bearing ratio of the stabilized soil increased with increasing compaction energy as well as decrease after 3 % addition of STCR.

4.4 SENSITIVITY ANALYSIS

To evaluate the relative effect of STCR and compactive effort on CBR of the stabilized soil, 5 % level of significance was used for the statistical analysis.

The two - way analysis of variance (ANOVA) results for the models are summarized in Table 5. As it can be seen from Table 5, the calculated F - statistics for BSL, WAS and BSH are statistically significant at 5 % level of significance as the values exceeded F critical (Fcr) value of 3.13. The results indicate that the relative effect of STCR on CBR is more pronounced as the model yielded the highest calculated F-statistics value of 19.40.

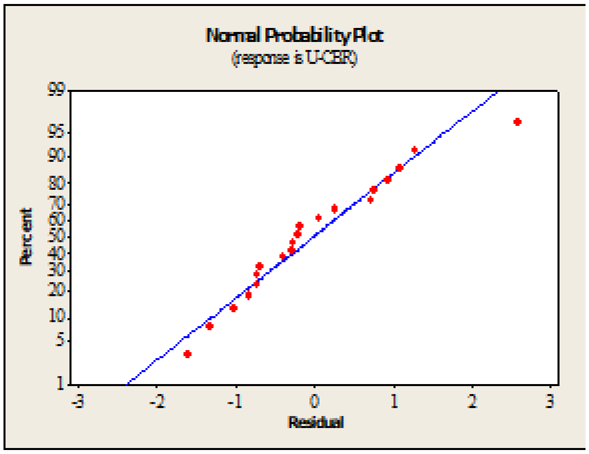
Furthermore, the regression analysis shows that the effects of STCR and compactive efforts on CBR are statistically significant as the probability values (p - values) are less than 0.05 in each case. The regression equation developed based on the lateritic - STCR mixtures yielded low coefficient of determination (R^2) of 0.45.

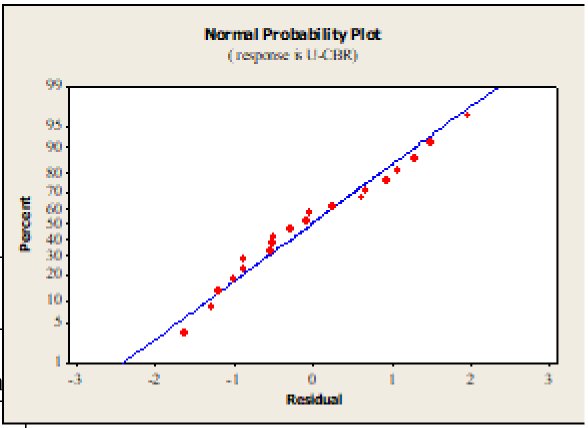
Table5: Two - way ANOVA table for the CBR models

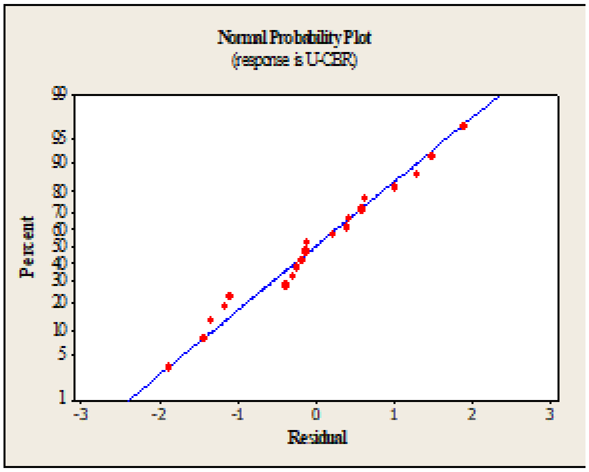
Compactive Effort		F	Fcr	R^2	R^2(Adj)	P-Value	Remark
BSL	Unsoaked	8.67	3.13	0.51	0.45	0.004	Highly Significant
	Soaked	6.86	3.13	0.45	0.38	0.000	Highly Significant
WAS	Unsoaked	16.36	3.13	0.66	0.62	0.017	Significant
	Soaked	8.50	3.13	0.50	0.44	0.003	Highly Significant
BSH	Unsoaked	8.53	3.13	0.50	0.44	0.000	Highly Significant
	Soaked	19.40	3.13	0.70	0.66	0.041	Significant

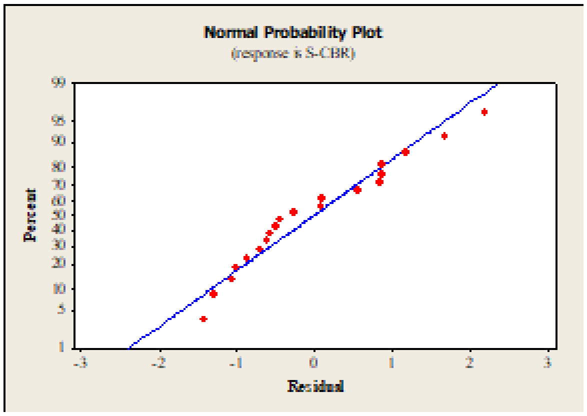
4.5 VALIDATION OF THE MODELS

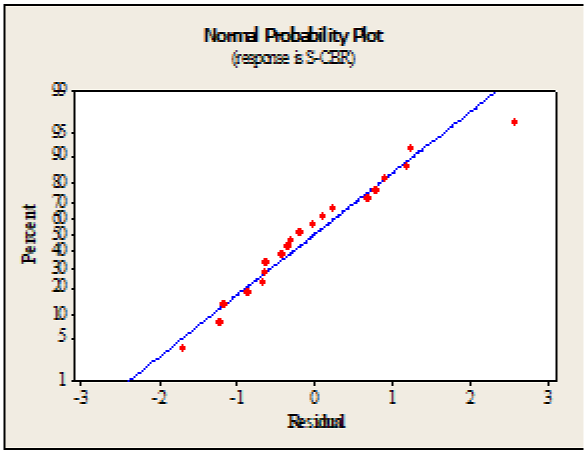
The relationship between the predicted and measured values of CBR of the STCR stabilized soil mixtures are shown in Figs. 8 and 9. The results demonstrate that measured CBR correlates very well with the estimated or calculated values. The R^2 values obtained for the developed regression equations using the laboratory CBR results (See Table 6 and 7) are in reasonable agreement with the R^2 values depicted in Figs. 8 and 9 for the two conditions. The developed regression model with STCR as stabilizer is therefore adjudged suitable for predicting the CBR value of stabilized soils to be used for road construction.











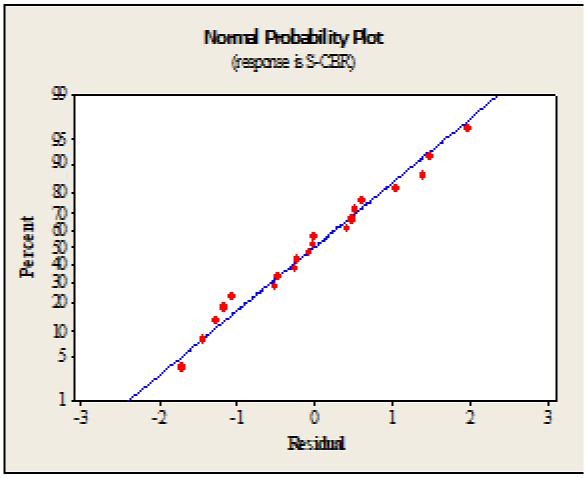


Fig. 8: Relationship between predicted and measured values of CBR of lateritic - STCR mixtures

Table 6: Measured and predicted values of unsoaked California bearing ratio for STCR stabilized soil

STCR Size	BSL			WAS			BSH		
	Measured	Predicted	Residual error	Measured	Predicted	Residual Error	Measured	Predicted	Residual error
0.212 mm	36.0	37.7	-1.7	39.7	40.3	-0.6	53.1	59.2	-6.1
	38.7	40.0	-1.3	42.1	40.5	1.6	57.4	58.4	-1.0
	45.5	42.3	3.2	55.3	40.8	14.5	63.2	57.7	5.5
	43.6	44.6	-1.0	49.1	41.0	8.1	60.3	56.9	3.4
	42.5	46.9	-4.4	47.4	41.3	6.1	54.1	56.1	-2.0
2.36 mm	38.6	41.9	-3.3	40.6	45.1	-4.5	63.1	69.3	-6.2
	45.4	44.2	1.2	53.1	45.3	7.8	67.7	68.5	-0.8
	50.1	46.5	3.6	58.1	45.5	12.6	70.2	67.7	2.5
	49.0	48.9	0.2	52.6	45.8	6.8	65.2	66.9	-1.7

	47.3	51.1	-3.8	51.1	46.0	5.1	55.6	66.2	-10.6
	40.7	43.9	-3.2	44.6	47.2	-2.6	76.1	73.9	2.2
	52.1	46.1	6.0	57.1	47.5	9.6	80.6	73.2	7.4
3.35 mm	60.7	48.4	12.3	65.5	47.7	17.8	83.5	72.4	11.1
	55.1	50.7	4.4	60.3	48.0	12.3	80.2	71.6	8.6
	51.7	53.0	-1.3	56.1	48.2	7.9	70.1	70.8	-0.7
	39.7	46.6	-6.9	44.0	50.3	-6.3	73.3	80.5	-7.2
	45.6	48.9	-3.3	56.2	50.6	5.6	78.3	79.7	-1.4
4.75 mm	55.8	51.2	4.6	64.0	50.8	13.2	81.4	78.9	2.5
	52.6	53.5	-0.9	59.3	51.0	8.3	79.3	78.2	1.1
	50.0	55.8	-5.8	55.2	51.3	3.9	69.7	77.4	-7.7

Table 7: Measured and predicted values of soaked California bearing ratio for STCR Stabilized Soil

STCR Size	BSL			WAS			BSH		
	Measured	Predicted	Residual error	Measured	Predicted	Residual Error	Measured	Predicted	Residual error
	10.8	11.4	-0.6	13.5	14.2	-0.7	23.8	47.0	-23.2
	11.6	12.1	-0.5	14.3	15.1	-0.8	25.0	67.8	-42.8
0.212 mm	13.9	12.8	1.1	18.0	16.0	2.0	28.4	88.6	-60.2
	13.7	13.6	0.1	17.1	16.9	0.2	27.0	109.4	-82.4
	12.8	14.3	-1.5	16.5	17.8	-1.3	25.7	130.2	-104.5
	11.6	12.5	-0.9	13.9	15.6	-1.7	15.1	51.6	-36.5
	13.6	13.3	0.3	17.5	16.5	1.0	18.7	72.4	-53.7
2.36 mm	15.0	14.0	1.0	19.0	17.4	1.6	22.0	93.2	-71.2
	14.7	14.8	-0.1	17.9	18.3	-0.4	20.5	114.0	-93.5
	14.3	15.5	-1.2	15.5	19.3	-3.8	19.0	134.8	-115.8
	12.2	13.1	-0.9	15.1	16.2	-1.1	34.2	53.7	-19.5
	15.6	13.8	1.8	18.7	17.2	1.5	36.3	74.5	-38.2
3.35 mm	18.3	14.6	3.7	22.0	18.1	3.9	37.5	95.3	-57.8
	16.6	15.3	1.3	20.5	19.0	0.5	36.0	116.1	-80.1
	15.6	16.1	-0.5	19.0	19.9	-0.9	32.5	136.9	-104.4
	11.9	13.9	-0.2	14.9	17.2	-2.3	33.0	56.7	-23.7
	13.7	14.6	-0.9	17.1	18.1	-1.0	35.2	77.5	-42.3
4.75 mm	16.9	15.3	1.6	21.8	19.0	2.8	36.5	98.3	-61.8
	15.8	16.1	-0.3	20.1	19.9	0.2	35.6	119.1	-83.5

15.2	16.8	-1.6	18.8	20.9	-2.1	32.4	139.9	-107.5

CONCLUSION

From the result of the investigation carried out within the scope of the study, the following inference in the context of utilizing STCR in soil stabilization can be drawn:

1) The non lateritic soil used for this study is classifies as A - 2 - 7 (0) and GW using the American Association of State Highway and Transportation Officials (AASHTO) ASTM D3282-09 soil classification system and Unified Soil Classification System (USCS) ASTM D2487 - 11, respectively. The liquid limit and plastic limit were observed to be 51.0 and 26.7 %, respectively, and the corresponding plasticity index is 24.3 % confirmed that the soil is low plastic soil.
2) General reductions in MDD and OMC with increase in STCR content were observed.
3) STCR stabilized soil showed improvement in California bearing ratio (CBR) up to 3 % and there onward decreased with further increase in STCR content. Percentages improvement in CBR value of the stabilized soil are 70.5, 69.7 and 78.4 % for unsoaked CBR and, 71.0, 67.9 and 78.6 % for soaked CBR using 3.35 mm STCR size and 3 % STCR content when compacted by BSL, WAS and BSH compactive effort respectively.

REFERENCES

[1] Amari, T., Themelis, N. & Wernick, I. (1999). Resource recovery from used rubber tires. *Resources Policy* 179 - 188.

[2] Arulrajah, A., Disfani, M. M., Horpibulsuk, S., Suksiri, P. & Prongmanee, N. (2014). Physical Properties and Shear Strength Response of Recycled Construction Materials in Unbound Pavement Base/Subbase Application. Construction and Buildind Materials.53,245-257.

[3] Craig, R. (2004). *Soil Mechanics.* London: Spon press.

[4] Das, B. (2009). *Priciples of Geotechnical Engineering.* Madrid: Cengage Learning

[5] Dukare, S., Barad, P., Gupta, M. & Barad, P. (2016). Effect of rubber Tyre Shread on Properties of Black Cotton Soil. International Conference on Science and Technology for Sustainable Development (ICSTSD). 2348-8352.

[6] James, J. & Pandian, P. K. (2016). Industrial Wastes as Auxiliary Additives to Cement/Lime Stabilization of Soils. *Advances in Civil Engineering*.

[7] Joachin, A. W. R & Kandiah, S. (1941). *The Composition of Some Local Soils Concretion and Clays.* Tropical Agriculture. 67.

[8] Lekha, B.M., Ravi, A.U. & Sarang, G. (2013). Fatque and Engineering properties for chemically Stabilized Soil for pavement. Indian Geotech Journal. 43 (1), 96-104.

[9] Neville, B. (2012). Towards a Sustainable Balance of Population and Resources. *Journal of Futures Studies*. 16(4), 107-116.

[10] O'Flaherty, C. A. (2002). Soil-Stabilized Pavements in Highways: The Location, Design, Construction and Maintenance of Pavements C. A. O'Flaherty(ed). Malta, Butterworth-Heinemann.

[11] Osinubi, K. J. (1998a). Permeability of Lime Treated Lateritic Soil. *Journal of Transportation Engineering, ASCE*. 124(5): pp. 465-469

[12] Phani Kumar, B. R. & Sharma, R. S. (2004). Effect of fly ash on engineering properties of expansive soils. *Journal of Geotechnical and Geoenvironmental Engineering*. *130*(7), 764-767.

[13] Ranjan, G. & Rao, A.S. (2000). Basic and applied Soil Mechanics. 2nd edition. New Age International Publisher. New Delhi, India.

[14] Rao, A. N. N. & Chittaranjan, M. (2011). Application of Agricultural and domestic wastes in Geotechnical application: An overview. Journal of Environmental Research and Development. 3 (5), 673-678.

[15] Reddy, C. N. V. & Rani, K. D. (2013). Potential of shredded scrap tyres in flexible pavement construction. *Indian Highways*. *41* (10).

[16] Sherwood, P. T. (1993). *Soil Stabilization with Cement and Lime: A State-of-The-Art Review* Department of Transport, Transport Research Laboratory, United Kingdom.

[17] Singh, M. & Mittal, A. (2014). A Review on the Soil Stabilisation with Waste Materials.

International Journal of Engineering Research and Applications. 2248-9622.

[18] Surya, S. T. & Siddhartha, P. (2015). Stabilization of subgrade soil of highway pavementusing waste tyre pieces. *International journal of innovative research in science, engineering and technolog. 4* (5), 3265-3273.

[19] Vasavi, B. S., Prasad, D. S. V. & Prasad, A. C. S.V. (2016). Stabilization of expansive soil using crumb rubber powder and cement. *International Journal of Innovative Research in Technology*. 2 (8), 26-31.