© JUN 2025 | IRE Journals | Volume 8 Issue 12 | ISSN: 2456-8880

Stabilization of Railway Right of Way Silty Soil Using Shredded Rubber Tire

LAWAL ABBA ADAMU[1], JOHN E. SANI[2], A.Y ABDUFATAH[3]
[1] *Department of Civil Engineering, Nigerian Defence Academy Kaduna*
[2,3] *Department of Civil Engineering, Bayero University Kano*

Abstract- As rail modernization in Nigeria experiences a breakthrough in achieving one of its most remarkable milestone, railway embankment faces significant challenges due to the unsuitable soil for its subgrade. Little research has been successfully done to stabilize the silty soil for railway subgrade. The aim of this study is to stabilise the right of way silty-soil using shredded rubber tyre. The soil was collected at DK967+200 from the right-of-way of the Kaduna-Kano Railway Modernization Project at Zawaciki Kumbotso Local Government Area of Kano State, the shredded rubber tyre was collected from a local tyre rethreding center. The mixed sample were subjected to Standard Proctor Test, California Bearing ratio (CBR) unsoaked and Unconfined Compression Strength (UCS) tests. The test results of the studied soil indicate a significant improvement of CBR and strength parameters. The result shows a significant improvement in the strength parameters with the addition of shredded rubber. The Maximum Dry Density (MDD) decreased with increasing Optimum Moisture Content (OMC), while the unsoaked CBR values increased from 18.9% to 47.1% for BSH and 27.9% to 48.3% for BSL at 8% Shredded tyre addition. The UCS values increased from 140 kN/m² to 320 kN/m² for uncured samples and from 340 kN/m² to 560 kN/m² for cured samples at 8% shredded tyre addition. The regressional analysis performed on the experimental data yielded high coefficients of determination ($R^2 > 0.97$), indicating strong correlations and enabling the prediction of optimum rubber content for maximum strength. These findings demonstrate the potential of shredded rubber tyre as an effective additive for silty soil stabilization in railway subgrade construction.

Indexed Terms- Shredded rubber tyre, Carlifornia Bearing Ratio, Unconfined Compressive Strength

I. INTRODUCTION

Soils are formed by the physical and chemical disintegration of rocks which differ from their parent materials in their characteristics (Kolhe & Langote, 2018). The engineering properties of the soil are important not only in foundation materials for the projects, but also in the materials for construction in embankments, dams, and other construction works. The way soil responds to different types of stresses or loads determines how suitable it is for use in construction. However, it is crucial to improve the characteristics that have been shown to fall short of the bare minimum requirements.

Engineering used to focus on traditional approaches and chemical based modifications to produce and resolve environmental, structural, geotechnical and mechanical challenges many decades ago. One of the fundamental techniques by which the properties of natural materials can be improved is stabilization (Yilmaz & Degirmenci, 2009). Stabilisation is a process of fundamentally changing the chemical properties of soft or unsuitable soils by adding binders or stabilizers, either in wet or dry conditions to increase the strength and stiffness of the originally weak soils (Celik et al, 2019). The physical and chemical improvements, as well as the replacement of weak soils are the most common treatment methods used worldwide to improve low-strength soils (Hambirao & Rakaraddi, 2014).

One of the main global environmental challenges is the management of solid waste (Kaza et al , 2018). As per the 2018 World Bank report ‘‘What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050” (Yang et al., 2020). The global annual waste generation is expected to grow by 70%to 3.4 billion tons over the next 25 years; it was about 2.01 billion tons in 2016. Globally, it has been recognized that the manufacture, use and throw model is unsustainable and has detrimental impact on the economic, environmental and public health fronts. Realising these concerns, governments, organizations, private stakeholders and thescientific community have joined hands to look for the scientific solutions for the recycling of all forms of waste and out of use materials that can support closed loop circular economy. Recycling solutions for various forms of waste materials are currently being investigated. This will not only would create new business and employment but would also help in minimizing the generation of waste materials. This generally implies that significant trash output reduction is required and recycling rates must rise.

Waste tyre use in geotechnical engineering has received a lot of attention recently, particularly with regard to soil reinforcing technology (Rajeev et al., 2020). Recycling of the 'end of life tyres' (ELT) is one of the major concerns shared by the scientific community and the environmental organizations because of their large volume of production and non-biodegradable properties (Celik et al., 2019). This is the process of recycling vehicles' tyres that are no longer suitable for use on vehicles due to wear or irreparable damage (Xu et al., 2020). With regards to soil reinforcement materials, the study and use of rubber reinforced soil have emerged as a research hotspot. This is because rubber reinforced soil primarily refers to a novel geotechnical material created by combining soil materials with waste tyres (AbdelRazek et al., 2018). The method of turning waste tyres into geotechnical materials is to cut into fragments and strips, or to grind into particles and then mix with soil for utilisation. Numerous researchers have examined the characteristics of rubber-reinforced soil and discovered that it can increase the ductility of sandy soil and boost soil shear strength (Gao et al., 2022).

The aim and objectives of this study are highlighted as follows:
To improve the right of way silty-soil using shredded rubber tyre by determining the engineering properties of the natural soil, the properties of the soil with different percentages of shredded rubber tyre, and to compare and analyse the results then finally determine the optimum percentage of the shredded rubber tyre for optimum strength of the clayey subgrade soil.

II. MATERIALS AND METHOD

A. Materials

Soil sample for this study as shown in Figure 1 was collected from the right-of-way of the Kaduna-Kano Railway Modernization Project at Zawaciki Kumbotso Local Government Area of Kano State. The soil was collected at DK967+200, at a depth of one meter using an excavator. The soil was subsequently kept for an extended period to ensure moisture removal.

Figure 1: Site where soil was obtained

The Shredded rubber tyre as shown in Figure 2 was collected from a local tyre rethreding center. This facility specialises in disposing of used tyre and have shredded rubber tyre material available for research purposes. The tyre was obtained by cutting scrap tyre into small chips, manually shredded to sizes. After obtaining the rubber tyre and before using it for experiment, it was poured in refilling box as shown in Figure 2 to assure every size (3mm to 5mm) was present in the sample. These rubber tyre chips do not possess steel wires or any form of reinforcement.

Figure 2: Shredded Rubber Tyre Sample and Refilling Box

B. Experimental method

The experimental methodology involved conducting tests on natural soil and then subsequently replaced the weight of the soil with percentage of shredded tyres at 2%, 4%, 6%, 8% and 10% respectively. The following experiments were conducted:

The soil sample was collected, dried, ground, and sieved to a uniform size before undergoing chemical analysis, typically using X-ray fluorescence (XRF) spectroscopy, to determine its oxide composition. The analysis measured the percentages of major oxides such as Silicon Dioxide (SiO_2) at 47.30%, Aluminum Oxide (Al_2O_3) at 7.45%, Iron Oxide (Fe_2O_3) at 1.43%, Carbonate (CO_3) at 0.77%, Magnesium Oxide (MgO) at 1.63%, and trace amounts of Manganese Oxide (MnO) at 0.15%, along with negligible levels of CuO, ZnO, V_2O_5, and Cr_2O_3. These values were recorded and interpreted to assess the soil's chemical characteristics, noting that trace oxides are naturally occurring micronutrients with minimal effect on soil properties unless mobilized by environmental conditions.

The Pycnometer method determines the specific gravity of soil, which is the ratio of the weight of soil solids to the weight of an equal volume of water. It involves weighing the Pycnometer alone (W1), with dry soil (W2), with soil and water (W3), and with water only (W4). The specific gravity (G) is calculated using:

G = "(W2-W1)" /"(W2-W1) - (W3-W4)"

Typical values range from 2.60-2.80 for inorganic soils, with variations depending on mineral content and organic matter.

The grain size distribution test, as specified in BS 1377: Part 2: 1990, determines the percentage of different particle sizes in a soil sample to aid in classification and assess its engineering properties. It involves sieve analysis for coarse particles, where the soil is dried, washed, and passed through a stack of sieves arranged from largest to smallest, then shaken and the retained soil on each sieve is weighed. For fine particles, hydrometer analysis is used by mixing the fine portion with a dispersing agent, transferring it into a sedimentation cylinder, and taking hydrometer readings at specific time intervals to determine the suspension's density, which reflects the particle size distribution.

This test, as specified in BS 1377: Part 2: 1990, determines the liquid, plastic, and shrinkage limits of soil. The liquid limit was measured using the fall cone method, where an 80g, 30° cone penetrates 20mm into the soil in about 5 seconds. The plastic limit is the moisture content at which soil crumbles when rolled into 3.2mm threads.

The Compaction Test, specified in BS 1377: Part 4: 1990, determines the relationship between soil moisture content and dry density using Proctor's method. It involves compacting soil in layers with controlled water content to identify the optimum moisture content (OMC) and maximum dry density (MDD). The process includes mixing soil (with or without additives), compacting it in a mold using a rammer, weighing, trimming, and testing for moisture content, repeated until peak density is achieved.

The California Bearing Ratio (CBR) test, as specified in BS 1377: Part 4: 1990, measures subgrade strength for pavement design by assessing resistance to penetration of a standard plunger. Conducted on remolded, compacted soil samples at optimum moisture content, the test determines soil strength as a percentage of standard crushed aggregate resistance. The procedure involves weighing, mixing soil with water (and possibly rubber tyre), compacting in layers, and measuring penetration resistance using a CBR machine.

The unconfined compression test, as per BS 1377: Part 1990, is used to determine the undrained shear strength and stress-strain behavior of cohesive soils or rocks without lateral confinement. A compacted soil sample is loaded vertically until failure, and the shear strength is calculated. The test helps assess soil strength for geotechnical designs like foundations, slopes, and embankments. Failure modes include plastic, semi-plastic, and brittle, and moisture content is also determined.

III. RESULTS AND DISCUSSIONS

A. Oxide Composition of Soil

Figure 3 and Table 1 reveals the analysis of the oxide composition of the soil sample in which Silicon Dioxide (SiO_2) dominated with a value of 47.30%, moderate Aluminum oxide (Al_2O_3) at 7.45%, low Iron oxide (Fe_2O_3) at 1.43% ,Carbonate content (CO_3) at 0.77%, Magnesium Oxide (MgO) at 1.63%, trace amounts of Manganese Oxide (MnO) at 0.15% and negligible levels of CuO, ZnO, V_2O_5, and Cr_2O_3 at 0.004%, 0.007%, 0.009% and 0.003% respectively. These oxides exist in trace quantities, consistent with their natural occurrence as micronutrients or trace elements in soils. Their presence is unlikely to have significant effects on soil properties or fertility unless mobilized under specific environmental conditions.

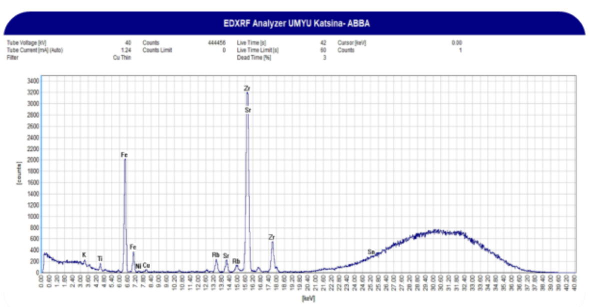

Figure 3.Graph for Oxide composition of natural soil.

Table 1: Oxide composition of natural soil

S/No.	Chemical Composition (oxides)	Value (%)
1.	SiO_2	47.30
2.	Al_2O_3	7.45
3.	Fe_2O_3	1.43
4.	CO_3	0.77
5.	MgO	1.63
6.	MnO	0.15
7.	CuO	0.004
8.	ZnO	0.007
9.	V_2O_5	0.009
10.	Cr_2O_3	0.003

The soil is thus non lateritic soil (SiO2/FeO2+Al2O3 = 5.33) and based on AASHTO it is A-6, and based on USCS it is CL (Silty with Low plasticity).

B. Specific Gravity

The specific gravity exhibited an intriguing trend. Upon the addition of shredded rubber tyre particles to the soil, there was a noticeable increase in specific gravity at lower rubber content percentages (2% and 4%). This phenomenon may be attributed to the introduction of rubber particles, which possess a higher specific gravity compared to the soil matrix. However, as the rubber content was further increased (6%, 8% and 10%), a reverse trend was observed, with a subsequent reduction in specific gravity.This changes has shown that when materials of different specific gravity are mixed,the resulting mix specific gravity will not be linear (Masad et al., 1996). It should be noted that the higher the specific gravity, the higher the strength of soil.

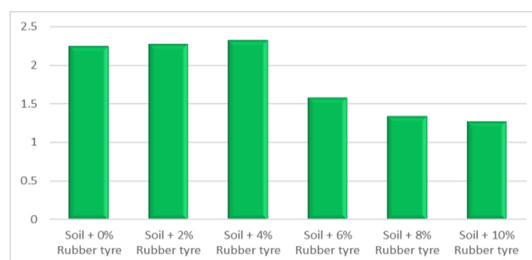

Figure 4: Specific Gravity Chart.

C. Grain Size Distribution

From the sieve analysis result, it shows that percentage passing through sieve No. 200mm or 0.075µm are 68.80%, for natural soil sample, and 50.00% shredded rubber tyre sample respectively. According to the project quality assurance and quality control plan of the Kaduna to kano railway project (QACP), the percentage passing through sieve No. 200mm or 0.075µm should be less than or equals to 35%. In this research, all the soil samples fall under group A-4 to A-7 which is silty or clayey sand, according to the American Association of Highway and Transport Officials (AASHTO) soil classification system. The soil is thus non lateritic soil ($SiO2/FeO2+Al2O3$ = 5.33) and based on AASHTO it falls within A-4 to A-7, and based on USCS it is CL (Silty with Low plasticity). It should be noted that both the natural soil and the rubber-soil mix exceed the QACP threshold specification indicating that they do not meet the project's requirements.The soil especially the rubber-soil mixtures may require further treatment to meet the QACP's specification.

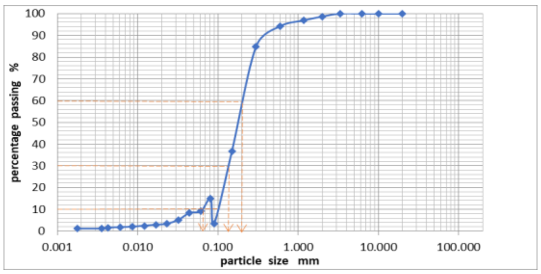

Figure 5: Sieve Analysis

D. Atterberg Limits

The Atterberg limits result shown in Table 2 has the liquid limit of 28% for natural soil sample, 34% for 2% of shredded rubber, 47% for 4% of shredded rubber, 41% for 6% of shredded rubber, 30% for 8% of shredded rubber and 20% of 10% of shredded rubber. We have plastic limits of 20% for natural soil sample, 0% for 2%, 4%, 6%, 8% and 10% of shredded rubber. We also have plasticity index of 8% for natural soil sample, 34% for 2% of shredded rubber, 47% for 4% of shredded rubber, 41% for 6% of shredded rubber, 30% for 8% of shredded rubber and 20% for 10% of shredded rubber respectively.

According to the project quality assurance and quality control plan of the Kaduna to kano railway project (QACP), for packing in groups for group A, B and C soils may be selected for Grade II railway line. When packing group C is selected for the regions, its plasticity index shall not be more than 12% and the liquidity limit should not be more than 32%. In this present study, all the liquid limits are well below 32% with the exception of 2%, 4% and 6% content of shredded rubber tyre, and all the plasticity index are well above the threshold with the exception of the natural soil. This indicates that adding rubber significantly alters the Atterberg limits of soil, particularly the plasticity index as the rubber paricles can interfere with the soil's cohesive behaviour (Rao G.V & Dutta D, 2006).

TABLE 2: Liquid limit, Plastic limit, plasticity index and linear shrinkage of natural soil and soil-shredded rubber tyre mix of varying percentages

S/No	Percentage of Shredded Rubber tyre	Liquid limit (%)	Plastic limit (%)	Plasticity index (%)	Linear shrinkage (%)	Aashto classification	Uscs classification
1.	Soil + 0% Rubber tyre	28	20	8	2	A – 4	CL
2.	Soil + 2% Rubber tyre	34	0	34	0	A – 6	CL
3.	Soil + 4% Rubber tyre	47	0	47	0	A – 7	CL
4.	Soil + 6% Rubber tyre	41	0	41	0	A – 7	CL
5.	Soil + 8% Rubber tyre	30	0	30	0	A – 6	CL
6.	Soil + 10% Rubber tyre	20	0	20	0	A - 6	CL

E. Compaction Test

Figures 6 and 7 below shows the variation of Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) of energy levels of British Standard Light (BSL) and British Standard Heavy

(BSH) with different percentages of shredded rubber tyre for each sample.

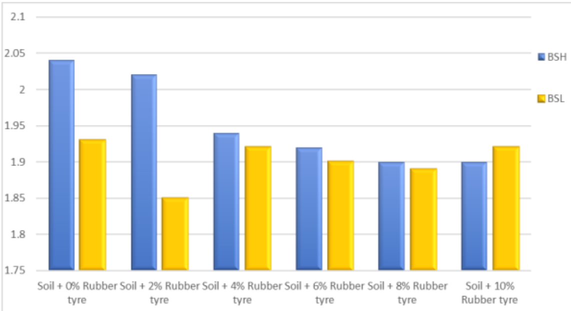

Figure 6: Maximum dry density.

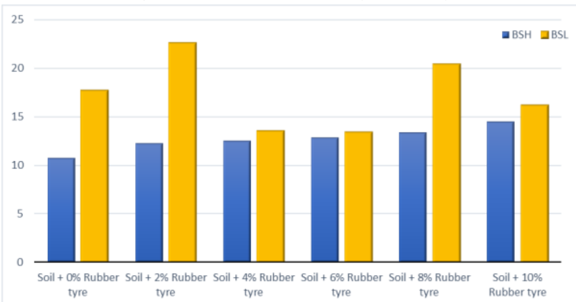

Figure 7: Optimum moisture content.

Choudhary et al. (2014) observed that adding shredded rubber to soil caused MDD to decrease because the lightweight rubber displaced denser soil particles. OMC shows a decrease due to the hydrophobic nature of rubber, which resists water absorption, reducing the amount of moisture required for optimal compaction. In this present study, the value of MDD decreases while the OMC increases with addition of different percentages of shredded rubber tyres of different sizes. Maximum value of decrease of MDD is at addition of 8% of shredded rubber tyre which is 1.9g/cm3, while the maximum value of increase of OMC is 14.5% for addition of 10% of shredded rubber tyres. This indicates that rubber reduces the soil's density and increases its water-holding capacity (Edil et al., 2004).

F. California Bearing Ratio Test

Figure 8 below shows the result of California Bearing Ratio (CBR), of the different soil samples with different energy levels of BSL and BSH.

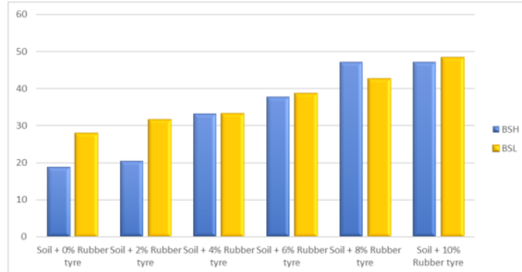

Figure 8: California bearing ratio.

According to the findings of the Carlifonia bearing ratio test included in the study of (P. Kolhe et al., 2018). The stabilization with waste tyre fibres increased CBR values with increase in percentage of rubber tyre shread and found to be maximum for 8% rubber tyre. Similarly, it is inferred from the Figure 8 that the 8% of tyre content is the optimum value. CBR value at 8% shredded tyre is 47.10% and the CBR value of natural soil is 18.90%, and improvement in CBR value from the experimental study was 28.20% higher than from the natural soil.

According to the project quality assurance and quality control plan of the Kaduna to kano railway project (QACP), the minimum CBR value for the subgrade is generally required to be 6% for railway formations. This is a standard threshold to ensure the stability and durability of the railway infrastructure, as lower values could lead to issues with load-bearing capacity and long-term performance.

If the CBR value is lower than this, the design may require additional treatment, such as strengthening the subgrade with base courses or other soil stabilization methods to achieve the necessary strength for railway operations. From the above result, it can be clearly seen that all the result in the BSL and BSH energy levels have met all the requirements.

G. Unconfined Compressive Srength Test

Figure 9 shows the variation of Unconfined Compressive Strength (UCS) values for natural soil and soil mixed with different percentages of shredded rubber tyre for each sample. UCS values increase as the percentage of shredded rubber tyres of a particular size is added (2%, 4%, 6%, and 8%), and then decrease with the increase in the percentage of shredded rubber tyres to 10%. The optimum increase in UCS value is 320 KN/m² for the addition of 8% shredded rubber tyre. Also, it illustrates the variation in UCS values for 7-day cured samples of natural soil and soil with different percentages of shredded rubber tyres. For the 7-day cured samples, UCS values also increase with the addition of shredded rubber tyres up to 8%, followed by a decrease at 10%. The optimum increase in UCS value for the 7-day cured sample is 320 KN/m² with 8% shredded rubber tyre. This has shown that addition of rubber improves the UCS,with 8% rubber being the optimal proportion (Fonseca et al., 2011). The rubber fibers acts as reinforcement, increasing the soil's resistance to compressive forces.

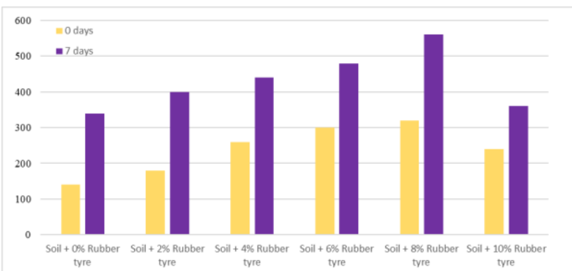

Figure 9: Unconfined compressive strength test.

H. Statistical Analysis

The CBR test results for samples compacted using the British Standard Light (BSL) compaction method which showed a continuous increase in CBR values with increasing shredded rubber tyre (SRT) content. As illustrated in Figure 10, a quadratic regression model was fitted to the data with the equation:

CBRBSL = 0.0893x2 + 1.1114x + 28.186 (R^2 = 0.9939)

where x is the percentage of shredded rubber tyre.

The high coefficient of determination (R^2 = 0.9939) indicates that 99.39% of the variability in CBR is explained by the shredded rubber content. The curve reveals a steadily increasing trend, suggesting that adding shredded rubber tyre improves the bearing capacity of the silty soil under light compaction. This improvement may be attributed to the enhanced interparticle friction and energy absorption properties of the rubber inclusions, which improve load resistance.

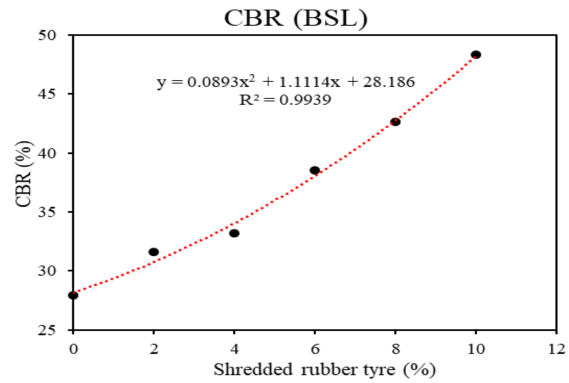

Figure 10: Regression analysis graph for CBR(BSL) with respect to Shredded rubber tyre percentages

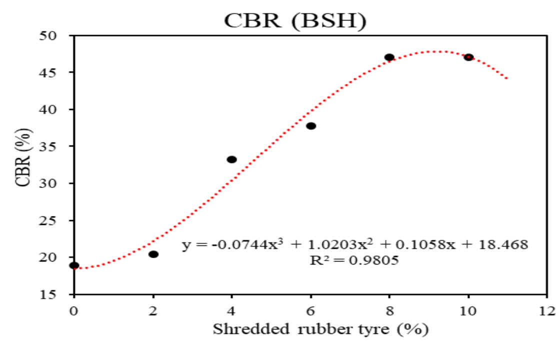

Figure 11: Regression analysis graph for CBR(BSH) with respect to Shredded rubber tyre percentages.

In contrast, the CBR values for samples compacted using the British Standard Heavy (BSH) compaction method followed a cubic trend, as shown in Figure 11. The regression equation is:

CBRBSH = -0.0744x3 + 1.0203x2 + 0.1058x + 18.468 (R^2 = 0.9805)

The model indicates a rise in CBR values up to an optimum shredded tyre content of approximately 8%, after which a decline is observed. This suggests that while moderate amounts of rubber enhance strength, excessive inclusion may negatively affect compaction efficiency or lead to increased compressibility and reduced interlocking among particles. The high R2 value of 0.9805 confirms the strong fit of the model to the experimental data. These findings demonstrate that the compaction effort significantly influences the behavior of shredded rubber stabilized soils. Under light compaction (BSL), the CBR continues to improve with higher shredded tyre content, whereas under heavy compaction (BSH), an optimum exists beyond which performance declines. The peak in the

BSH curve aligns with previous studies that observed similar trends of strength optimization at specific rubber contents.For instance, Yoon et al. (2008) observed a peak in CBR at around 10% waste tire content when mixed with granular soil. Similarly, Foose et al. (1996) reported a strength decline beyond 8% shredded rubber in a silty soil-rubber blend. These outcomes support the idea that while rubber inclusions are beneficial at moderate levels, excessive content could impair the mechanical integrity of the soil matrix.

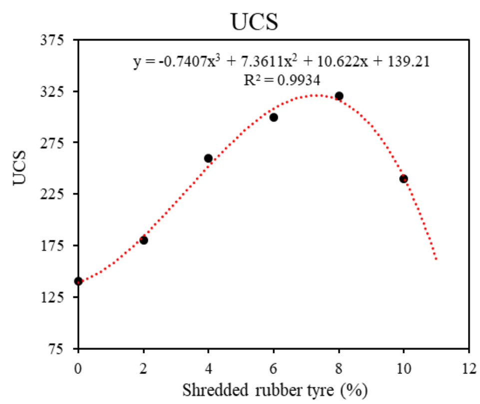

Figure 12: Regression analysis for uncured UCS

From Figure 12, A cubic regression model was fitted to the UCS values at 0-day curing, which indicates a very high goodness of fit, meaning the model explains over 99% of the variability in UCS. The curve fits the data points very closely. showing a strong correlation with an R^2 value of 0.9934. The regression equation is:

UCS0d = -0.7407x3 + 7.3611x2 + 10.622x +139.21

Where x is the percentage of shredded rubber tyre.

The UCS increased with increasing SRT content up to approximately 8%, reaching a peak value of approximately 325 kPa, after which a declining trend was observed. This suggests an optimal rubber content in this range for immediate strength improvement. Beyond this threshold, excess rubber content likely led to reduced soil cohesion and increased void ratios, decreasing the compressive strength.

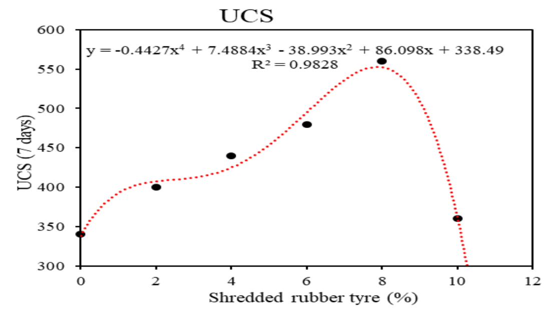

Figure 13: Regression analysis for cured UCS

In Figure 13, A quartic regression model was applied to the UCS values after 7 days of curing, with a high coefficient of determination (R^2 = 0.9828). The equation is as follows:

UCS7d = -0.4427x4 + 7.4884x3 – 38.993x2 +86.098x +338.49

The strength improved substantially over the curing period, with peak UCS increasing to approximately 555 kPa at the same optimal rubber content of 8%. Post-peak strength reduction was more pronounced at 7 days, suggesting that higher rubber content may inhibit bonding and continuity of the soil matrix despite extended curing.

A study by Singh et al. (2021) further validated the optimality of around 10% SRT for strength improvement. They noted that UCS and CBR increased with shredded rubber content up to 10%, after which the strength started to decline, likely due to increased void ratios and reduced inter-particle bonding. The UCS improvement pattern they observed closely matches the trend established in both the 0-day and 7-day regression models in this study.

CONCLUSION

The aim of this study is to stabilise the right of way silty-soil using shredded rubber tyre. The soil was collected at DK967+200 from the right-of-way of the Kaduna-Kano Railway Modernization Project at Zawaciki Kumbotso Local Government Area of Kano State, the Shredded rubber tyre was collected from a local tyre rethreding center. The mixed sample were subjected to Standard Proctor Test, California Bearing ratio (CBR) unsoaked and Unconfined

Compression Strength (UCS) tests. From the results of this study, the following conclusions are drawn.

1. The index properties of the natural silty soil sample was characterized with a specific gravity of 2.25, liquid limit of 28% plastic limit of 20% , plasticity index of 8% and linear shrinkage of 2%. These values, along with 68.80% passing the No.200 sieve, classified the soil as A-4 under the AASHTO system and CL under the USCS system. The maximum dry density (MDD) and optimum moisture content (OMC) were found to be 2.04g/cm3 and 10.7% respectively. The natural soil exhibited a CBR of 18.9% and UCS values of 340kpa (uncured) and 140kpa (cured).

2. The addition of shredded rubber tyre at (2%, 4%, 6%, 8% and 10%) significantly altered the soil properties. Specific gravity initially increased at 2% and 4% (2.27, 2.32,) ,then decreased at 6% , 8% and 10% (1.58, 1.34, 1.27). liquid limits varied (34%, 47%, 41%, 30%, 20%), while plastic limits remained 0% across all percentages. Plasticity index varied (34%, 47%, 41%, 30%, 20%) and with 0 linear shrinkage for all percentages. The MDD decreased with increasing rubber content and the OMC increased. CBR values increased with rubber content, reaching a peak of 47.10% at 8% and 10%. Unsoaked UCS increased to 320kpa at 8% and then decreased to 240kpa at 10% while soaked UCS increased to 540kpa at 8% and then decreased to 360kpa at 10%. The soil mixtures were generally classified as A-6 and CL, with the exception of the 4% mixture, which was classified as A-7.

3. The introduction of shredded rubber tyre led to noticeable changes in the soil's geotechnical properties. The specific gravity trend indicated the influence of rubber particle density. The decrease in MDD and increase in OMC with higher rubber content can be attributed to the lightweight nature of rubber. The CBR and UCS values showed significant improvements, particularly at 8% rubber content indicating enhanced strength characteristics. The optimum increase in CBR value from the natural soil to 8% shredded tyre with a value of 1.9g/cm3 and the optimum increase of OMC was at 10% shredded tyre with a value of 14.49%.

4. Based on the results, 8% shredded rubber tyre content was identified as the optimum for stabilizing the silty subgrade soil. This percentage yielded the highest CBR (47.10%) and UCS values (320kpa uncured, 560kpa cured), demonstrating the most significant improvement in soil strength.

5. Regression models showed a strong correlation between shredded rubber tyre content and soil strength improvements. CBR values increased consistently under light compaction ($R^2 = 0.9939$), while under heavy compaction, they peaked at 8% SRT ($R^2 = 0.9805$). UCS followed a similar trend, with 0-day and 7-day curing showing peak strengths at 8% Shredded tyre additon, supported by high R^2 values (0.9934 and 0.9828, respectively). These models confirm that 8% SRT offers optimal performance and validate experimental findings.

Based on the findings of this study, it is recommended that rubber plastic should not be incorporated into the soil when maximum compaction properties are desired. However, for optimal use of the soil as subgrade material, as well as to achieve the best strength properties, the incorporation of 8% rubber plastic into the stabilized soil is advised. This percentage was found to provide a balance between improved strength and acceptable compaction characteristics suitable for subgrade applications.

ACKNOWLEDGMENT

I am deeply grateful to everyone who supported me throughout the course of this work. My heartfelt appreciation goes to my supervisors and mentors for their invaluable guidance, encouragement, and insight. I also extend my sincere thanks to my colleagues, friends, and family whose unwavering support, patience, and love have been a source of strength throughout this journey.

Special thanks to all who contributed—whether through inspiration, conversation, or collaboration—to making this paper possible. This work is as much a

reflection of their generosity as it is of my own efforts.

REFERENCES

[1] AbdelRazek, A., El-Sherbiny, R. M., & Lotfi, H. A. (2018). Mechanical properties and time-dependent behavior of sand-granulated rubber mixtures. Geomechanics and Geoengineering, 13(4), 288–300. https://doi.org/10.1080/17486025.2017.1362177

[2] Celik, S., Majedi, P., & Akbulut, S. (2019). Granular soil improvement by using polyester grouts. Iranian Journal of Science and Technology, Transactions of Civil Engineering, 43(3), 599–606. https://doi.org/10.1007/s40996-018-0159-z

[3] Edil, T. B., Benson, C. H., & Park, J. Y. (2004). Interaction of compacted soil with shredded waste tires. Journal of Geotechnical and Geoenvironmental Engineering, 130(2), 163–172. https://doi.org/10.1061/(ASCE)1090-0241(2004)130:2(163)

[4] Fonseca, N., Ferreira, C., & Flores, F. (2011). Mechanical behaviour of soil-rubber mixtures. Geotextiles and Geomembranes, 29(6), 667–672. https://doi.org/10.1016/j.geotexmem.2011.06.002

[5] Foose, G. J., Benson, C. H., & Bosscher, P. J. (1996). Sand reinforced with shredded waste tires. Journal of Geotechnical Engineering, 122(9), 760–767. https://doi.org/10.1061/(ASCE)0733-9410(1996)122:9(760)

[6] Gao, M., Jin, X., Zhao, T., Li, H., & Zhou, L. (2022). Study on the strength mechanism of red clay improved by waste tyre rubber powder. Case Studies in Construction Materials, 17, e01416. https://doi.org/10.1016/j.cscm.2022.e01416

[7] Hambirao, G. S., & Rakaraddi, P. G. (2014). Soil stabilisation using waste shredded rubber tyre chips. IOSR Journal of Mechanical and Civil Engineering, 11(1), 20–27. https://doi.org/10.9790/1684-11112027

[8] Kolhe, P. V., & Langote, R. V. (2018). Performance of black cotton soil stabilized with rubber tyre shreds. Journal of Geotechnical Studies, 2(2), 1–8.

[9] Masad, E., Muhunthan, B., Shashidhara, N., & Little, D. N. (1996). Internal damage in asphalt mixtures. Journal of Engineering Mechanics, 122(6), 528–535. https://doi.org/10.1061/(ASCE)0733-9399(1996)122:6(528)

[10] Roychand, R., Gravina, R. J., Zhuge, Y., Ma, X., Youssf, O., & Mills, J. E. (n.d.). A comprehensive review on the mechanical properties of waste tyre rubber concrete.

[11] Rao, G. V., & Dutta, D. (2006). Use of shredded waste tire in road construction. Journal of Materials in Civil Engineering, 18(3), 412–419. https://doi.org/10.1061/(ASCE)0899-1561(2006)18:3(412)

[12] Singh, J., & Rattan, J. S. (2017). Soil stabilization of clayey soil using shredded rubber tyre. International Journal of Engineering Research & Technology (IJERT), 6(9), 1–5.

[13] Xu, J., Xu, J., Sun, C., He, W., Huang, J., & Li, G. (2020). High-value utilization of waste tyres: A review with focus on modified carbon black from pyrolysis. Science of the Total Environment, 742, 140235. https://doi.org/10.1016/j.scitotenv.2020.140235

[14] Yilmaz, A., & Degirmenci, N. (2009). Possibility of using waste tyre rubber and fly ash with Portland cement as construction materials. Waste Management, 29(5), 1541–1546. https://doi.org/10.1016/j.wasman.2008.10.014

[15] Yang, Z., Zhang, Q., Shi, W., Lv, J., & Ling, X. (2020). Advances in properties of rubber reinforced soil. Advances in Civil Engineering, 2020, 1–16. https://doi.org/10.1155/2020/8893107

[16] Yoon, S., Prezzi, M., Siddiki, N. Z., & Kim, B. (2008). Construction of a test embankment using a sand–tire shred mixture as fill material. Waste Management, 28(10), 1993–2004. https://doi.org/10.1016/j.wasman.2007.09.026