Effect of Shredded Plastic Waste on Unconfined Compressive Strength of Cement-Stabilised Lateritic Soil

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Abstract

A study to evaluate the effect of shredded plastic waste material on cement-stabilized lateritic soil was undertaken. The air dried soil was treated with shredded plastic waste (SPW) at 0, 2, 4, 6, 8% and cement at 0, 1, 2, 3, 4% by dry weight of the soil. The index properties of the natural soil showed it to belong to A-7-6(12) based on AASHTO classification system and ML in accordance with the unified soil classification system (USCS). However, soils under this group are poor materials for road pavement construction. Compaction characteristics of the natural and treated soil samples were determined using British Standard Light, (BSL) compaction energy. The Maximum Dry Density (MDD) result for the untreated lateritic soil was 1.68 Mg/m^3 while the Optimum Moisture Content (OMC) value was 20.2%. There was a decrease in MDD as the result of introducing the shredded plastic waste and the minimum MDD value was recorded as 1.44 Mg/m^3 at 4% cement and 8% SPW and the OMC value of the natural state increased from 19.5% to a value of 21% at 3% cement 4% SPW. The unconfirmed compressive strength (UCS) value for the natural soil at 7days curing period was 323.91kN/m^2 which increased to a value of 950.76 kN/m^2 at 2% cement and 8% SPW and this value fell short of the requirement of 1710 kN/m^2 for base course of pavement. However, it met the requirement of 687 kN/m^2 for subbase of pavement. It can be recommended that 2% cement and 8% SPW when compacted at BSL can be used as a road sub-base material.

Keywords: Shredded Plastic Waste, Portland Cement, Unconfined Compressive Strength, Lateritic soil.

1.0 INTRODUCTION

Lateritic soils have various uses in the Nigerian construction industry, especially in road construction projects where they are used as backfilling materials and flexible pavement foundations. Their application as subbase and base course construction materials is mainly because they are easily adjustable on the road surface and with a suitable proportion of natural stable grading to act as binders. One of the major causes of road accidents is a bad road which is usually caused by wrong use of constructional materials, especially laterite as base and sub-base material by construction companies (Oke *et al*., 2009; Nwankwoala and Amadi, 2013).

For a lateritic soil to be used as a base course or sub-base course depends on its strength in transmitting the axle load to the sub-soil and/or sub-grade. The original characteristic of the soils and the specific use for which they have been utilised determine their success. The strength of lateritic soils as foundations for structure changes and depends on the nature of the soil, the degree of decomposition, terrain, drainage condition and importantly on the type of foundation, and the number of loads imposed (Ojo *et. al*, 2016).

The mineral content of lateritic soil has an impact on the geotechnical properties such as specific gravity, shear strength, swelling potential, Atterberg limits, bearing capacity (Amadi *et al*., 2012).

Soil stabilization means the enhancing of stability or bearing capacity of the soil by the use of assume compaction, ratio and/or the addition of good admixture or stabilizers. The basic steps of soil stabilization are: to know the properties of a given soil, deciding on the lacking properties of the soil and choosing a good and reliable method of soil stabilization, as well as designing the stabilized soil mix for stability and durability values (Divya *et al.,* 2017).

Plastics are known as one of the vital inventions which have reasonably helped in different fields of life whether it might be in scientific field or others. These plastics, when the contents are been used, are discarded as waste materials which can be shredded and reused to stabilize soil. The proper proportion of the shredded plastic in soil helps in controlling the compaction factor and also makes it useful. The plastic used in soil stabilization increases the shear strength of soil, tensile strength of soil and California bearing ratio of the soil. It can significantly assist the properties of the soil used in the road construction (Divya *et al.,* 2017). Research has been done to use plastic to stabilize soil but plastic alone cannot serve as a stabilizer to achieve the recommended strength so there is need to use shredded plastic together with cement to stabilize lateritic soil (Divya *et al*., 2017).

The aim of this study is to assess the effect of shredded plastic waste on unconfined compressive strength of Cement-Stabilised Lateritic Soil. These will be achieved by determining the index properties of the natural and treated soils, compaction characteristics of the soil and its unconfined compressive strength.

2. MATERIALS AND METHODS

2 .1 Soil

The lateritic soil sample was collected from a borrow pit at Shika, Zaria (latitude 11^0 15'N and longitude 7^0 45'E). The soil sample was collected at a depth of 1.5m below the earth surface to avoid organic matter impact.

2.2 Plastic Waste

The plastic waste was obtained from a dumping site along Kubwa Express Way Abuja, Nigeria. They were sorted out, washed and shredded by the shredding machine into chips. The shredded plastic waste passed through sieve size 4.76mm as to the required size. A pictorial view of the dump site of plastic waste is shown in plate 1, pictorial view of shredding process shown in plate 2 and shredded plastic waste chippings shown in plate 3

Plate 1: Showing a Picture of a Dump Site of Plastic Waste

Plate 2: Showing a Picture of the Shredding Process

Plate 3: Showing a Picture of the Shredded Plastic Chippings

2.3 Cement

Ordinary Portland cement was obtained from Dangote depot in Kaduna.

2.4 Compaction

Each soil sample was compacted in the compaction mould using British Standard Light or standard Proctor (SP) compaction energy in accordance with BS 1377 (1990) to determine the compaction characteristics (optimum moisture content and maximum dry density) of the natural and treated soils. Soil samples were passed through 4.76mm sieve. Soil samples were mixed with Shredded plastic waste and cement. Tests to determine the moisture–density relationships were carried out in accordance with BS 1377 (1990) for the BSL compaction energy.

2.5 Index Properties

The index properties of the soil was determined in accordance to specifications outlined in BS, 1377 (1990). The particle size analysis, specific gravity, natural moisture content were carried out. Also soil passing through British Standard No. 40 sieve (425 µm aperture) were used to determine Atterberg limits consisting of liquid limit, plastic limit and plasticity index. The soil specimen was first mixed uniformly by stirring into each soil sample the bacteria solution and cementitious reagent at the equivalent optimum moisture content of the natural soil; they were then air-dried at room temperature before the Atterberg limits tests were carried out.

2.6 Unconfined compressive strength

3 kg of air-dried soil sample was mixed with optimum moisture content derived from dynamic compaction of the soil sample. The conventional BS compaction mould was used. The sample was placed and compacted in the mould in three (3) layers and twenty-seven (27) blows of 2.5 kg rammer were given to each layer. The sample was then removed from the mould with aid of hydraulic

jack and three samples of 38 by 76 mm were cored out and wrapped in a polythene bag for the curing periods (i.e 7, 14 and 28 days) to allow for strength gain. It was then taken to unconfined compression test machine for the test, where axial stress was applied gradually until shear failure occurred. Failure is taken to have occurred when two or three subsequent readings are equal or reducing in descending order. The unconfined compressive strength was computed using eq. (1):

$$UCS\ (\delta) = PCr\,\frac{(100-\varepsilon\%)\ \mathrm{x}\ 10^{3}}{100\mathrm{Ao}} \quad (1)$$

where:
ε = Strain sustained sequent to failure = x/L_0
x = Strain dial reading in mm
L_0 = Initial length of tested sample (m)
A_0 = Initial cross-sectional area of tested sample (m^2)
P = Load proven ring reading sequent to failure (kN)
Cr = Compressive stress factor
δ = Compressive stress at strain ε (kN/m^2)

3. DISCUSSION OF RESULTS

3.1 Oxide composition of Lateritic soil

The results of X-Ray Fluorescence (XRF) carried out at the Nigeria Geological Survey Laboratory Kaduna, Kaduna State to determine the oxide compositions of the natural soil is shown in Table 1. The silica – sesquioxide ratio is 1.65, which is between 1.33 and 2.00 classifie the natural material as lateritic soil in accordance with the specifications given by Joachin and Kandiah (1941).

Table1: Oxide compositions of lateritic soil

Oxide	Concentration %
SiO_2	56.5
Al_2O_3	19.00
CaO	0.33
TiO_2	2.89
V_2O_5	0.061
Cr_2O_3	0.051
Fe_2O_3	15.41
MnO	0.075
CuO	0.056
ZrO_2	0.290
L.O.I	4.54

3.2 Properties of the Natural soil used

Preliminary tests conducted on the natural soil revealed that the soil has low moisture content of 18.4% because the samples were collected in July at the beginning of the rainy season. The index properties are summarized in Table 2 and the particle size distribution is shown in Fig. 1. The soil belongs to the ML group in the Unified Soil Classification System (ASTM, 1992) and A-7-6(12) soil group based on the AASHTO soil classification system (AASHTO, 1986). The soil is light brown in colour (from wet to dry states) with a liquid limit of 47%, plastic limit of 27.3% and plasticity index of 19.70%. The UCS value of 323.91 was recorded at 7 days curing. The soil was found to be highly plastic and falls below the standard recommendation for most geotechnical construction works especially highway construction (Osinubi and Medubi, 1997).

Table 2: Geotechnical Properties of the Natural Soil

Property	Quantity
Percentage passing BS No 200 sieve	64.00
Natural Moisture Content, %	16.40
Liquid Limit, %	47.00
Plastic Limit, %	27.30
Plasticity Index, %	19.70
Linear Shrinkage, %	6.43
Specific Gravity	2.40
AASHTO Classification	A-7-6 (12)
USCS	ML
Maximum Dry Density, Mg/m^3	
British Standard light	1.68
Optimum Moisture Content, %	
British Standard light	19.50
Unconfined Compressive Strength, kN/m^2	
British Standard light	323.91
Colour	Light brown
Dominant clay mineral	Kaolinite

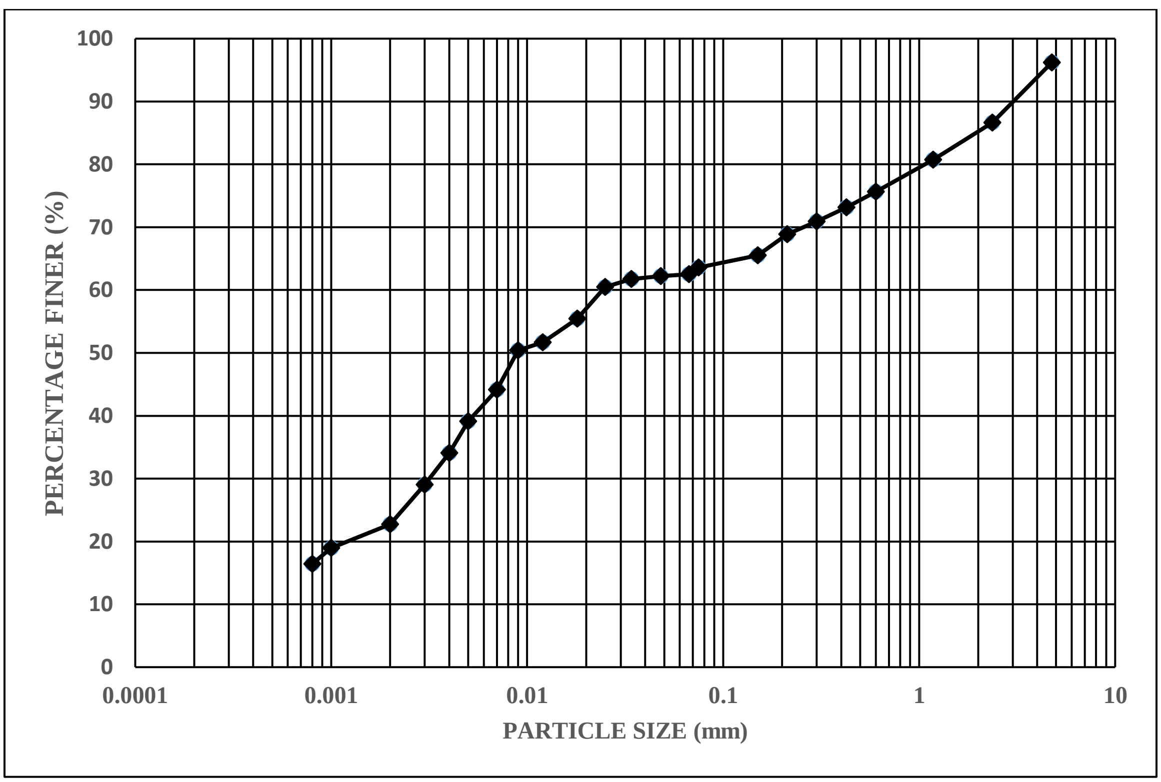

Fig. 1: Particle Size Distribution Curve of the Natural Soil

3.3 Compaction characteristic

3.3.1 Maximum dry density

The Variation in maximum dry density (mdd) of soil-cement mixtures with shredded plastic content is shown in Fig. 2. Generally, the mdd values decreased with higher shredded plastic waste (SPW) as a result of the shredded plastic being light in weight compared to the natural soil and it occupies much space in the soil matrix, thus reducing the compact nature of the soil mix and as such reducing the mdd.

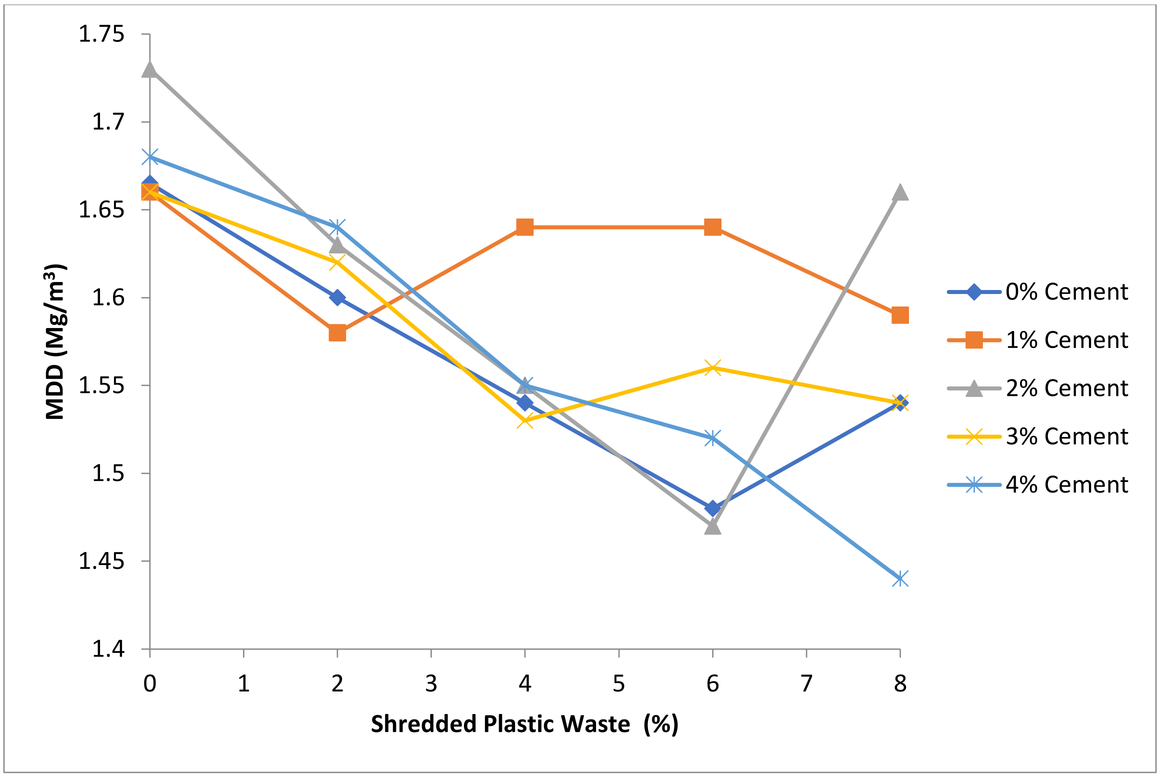

Fig. 2: Variation of Maximum Dry Density of Soil – Cement Mixture with Shredded Plastic

The MDD decreased as the percentage of cement increasedfrom 0 to 2% cement and the highest MDD was recorded as 1.73mg/m^3 at 2% cement and 0% shredded plastic The increase obtained at the mixture of cement may be due to the minimal effect of cement (with little calcium) on the workability of the stabilized soil. The trend of decreasing MDD with admixture contents was reported by Hausmann (1990) and Stephen (2006). The same trend was also reported by Osinubi *et al.*, (2007) and Sani *et al.*, 2017. Other probable reasons for the drop in MDD may be due to the product of reaction between cement-shredded plastic waste and the soil minerals which resulted in the flocculated and agglomerated clay particles.

3.3.2 Optimum moisture content

The variation of optimum moisture content of soil-cement mixtures with shredded plastic waste (SPW) contents is shown in Fig. 3. It is observed that the OMC values on compaction increased to peak values of 21.5% at3% Cement 0% SPW. Further addition of shredded plastic waste and cement led to a decrease in the OMC to a value of 16% at 4% cement and 8% shredded plastic waste. Similar trend was reported by Sani *et al.*, (2017).

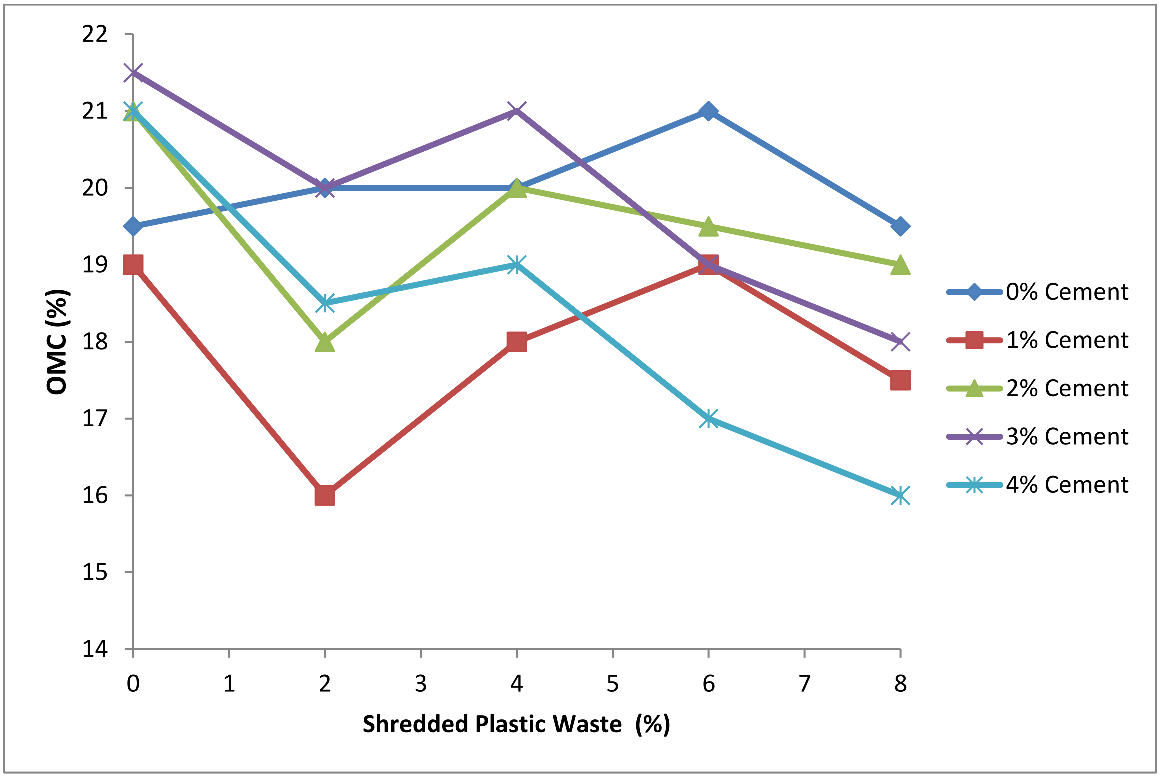

Fig. 3: Variation of Optimum Moisture Content of Soil – Cement Dust Mixture with Shredded Plastic Waste Content

3.4 Unconfined Compressive Strength

3.4.1 For 7days curing period

The variation of UCS of soil – cement –shredded plastic waste mixtures cured for 7 days is shown in Fig. 4.

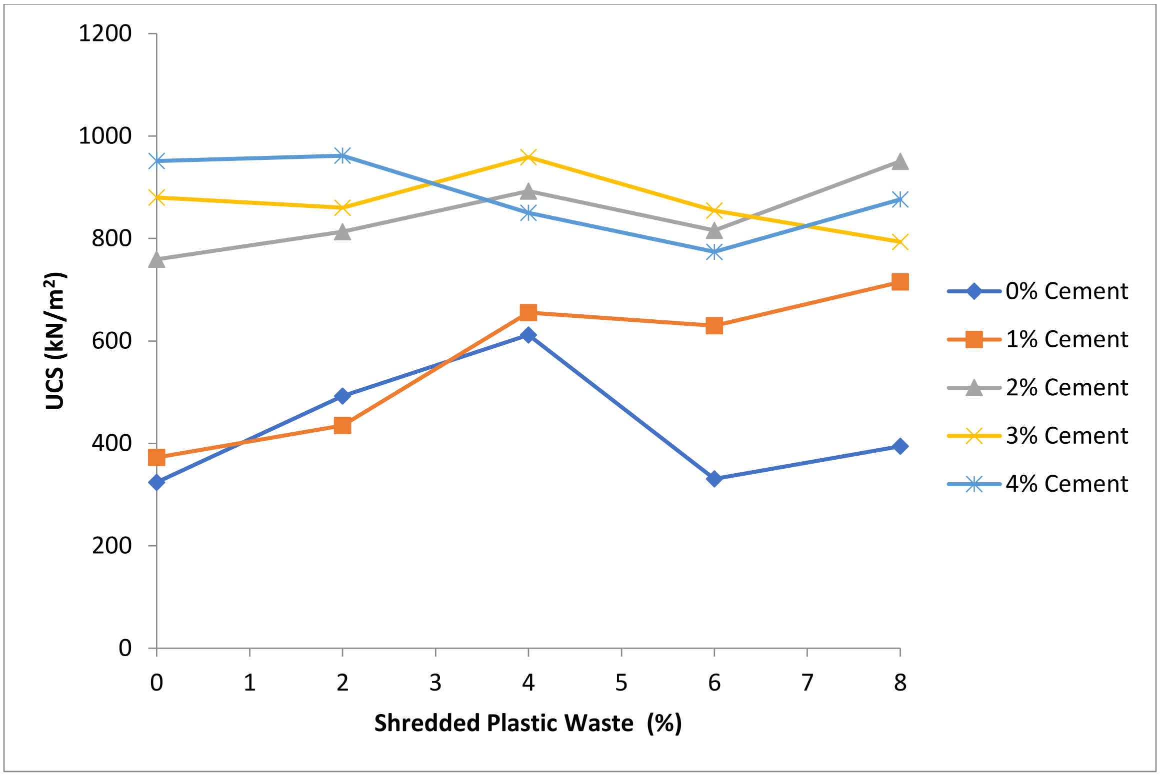

Fig. 4: Variation of UCS (7 Day Curing) of Soil -Cement Dust Mixture with Shredded Plastic Waste Content

The UCS values for the BSL compaction showed an increase from 323.91kN/m^2 for the natural soil to 950.76 kN/m^2 at 2% Cement and 8%SPW. At higher cement content peak value of 961.59kN/m^2 was obtained at 4%Cement and 2% SPW which subsequently decreased to a value of 876.23kN/m^2 as the shredded plastic waste increased to 8%

The increase in the UCS values (or the gain in strength) was primarily due to the formation of various compounds such as calcium silicate hydrates (CSH) and calcium aluminate hydrates (CAH) and micro fabric changes, which are responsible for strength development. Although the UCS values increased, the specimen compacted using BSL energy fall short of 1710kN/m^2 specified by TRRL (1977) as the criterion for adequate stabilization using Ordinary Portland Cement but met the requirement for sub-base of 687 kN/m^2 as recommended by Ingles and Metcalf 1972.

3.4.2 For 14 days curing period

The variation of UCS values (14 days curing) for soil-cement mixtures with SPW contents is shown in Fig. 5. This research has recorded increases in the UCS values for the natural soils from 380.63 kN/m^2 to a peak value of 973.81kN/m^2 at 4% Cement/0%SPW . The trend of increased unconfined compressive strength with curing period can be attributed to time dependent strength gain of the cement.

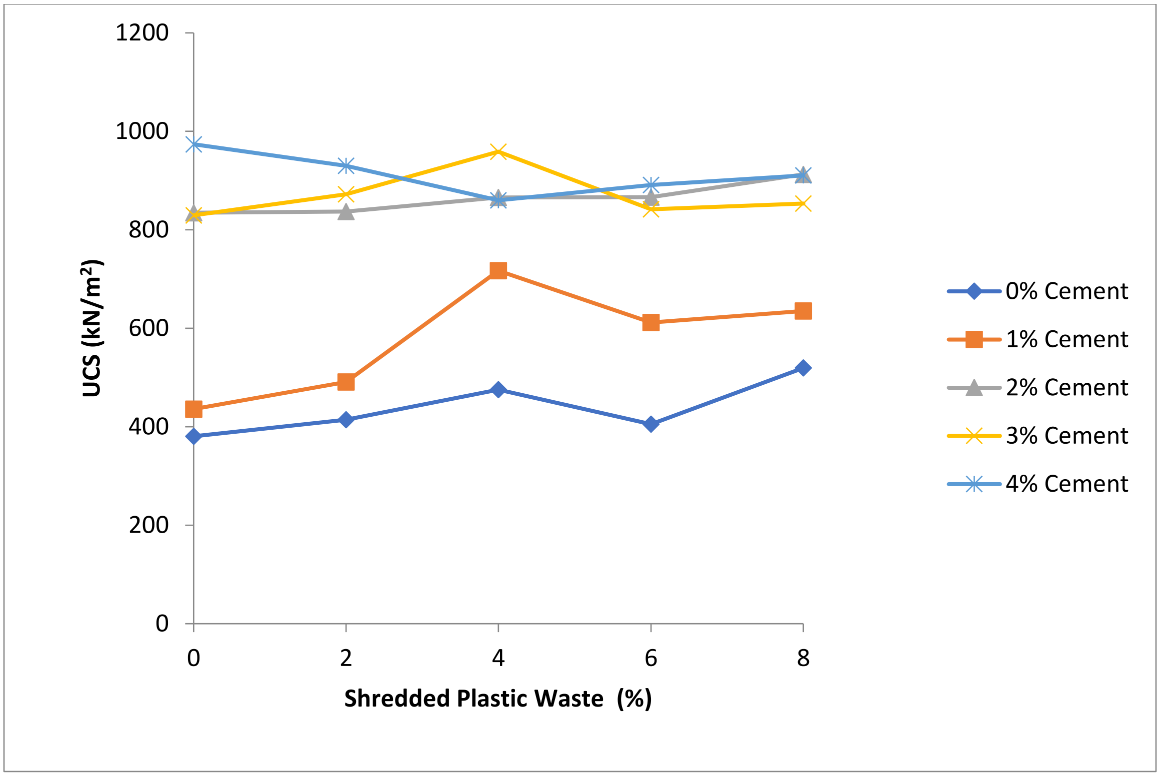

Fig. 5: Variation of UCS (14 day curing) of Soil – Cement Dust Mixture with SPW Content

3.4.2 For 28 days curing period

The variation of UCS (28 days curing period) of soil-cement mixtures with SPW contents is shown in Fig. 6. The same trend of increasing UCS values recorded for specimens cured for 7 and 14 days was also observed for 28 days curing period. The UCS for 28 days curing period increased from 618.91 kN/m^2 for the natural soil to 955.99 kN/m^2 at 3% Cement/4%SPW. Although, there were slight drops in the UCS values beyond 6% SPW content, which was due to the result of more SPW occupying the soil matrix, also the results indicate that SPW admixture has long time strength improving capability (Akinmade, 2008, Mercy *et al.*, 2013, Dhatrak and Konmare, 2015). The UCS value obtained fall short of $1710kN/m^2$ specified by TRRL (1977) as criterion for adequate stabilization using Ordinary Portland Cement but met the requirement for sub base of 687 kN/m^2 as recommended by Ingles and Metcalf 1972.

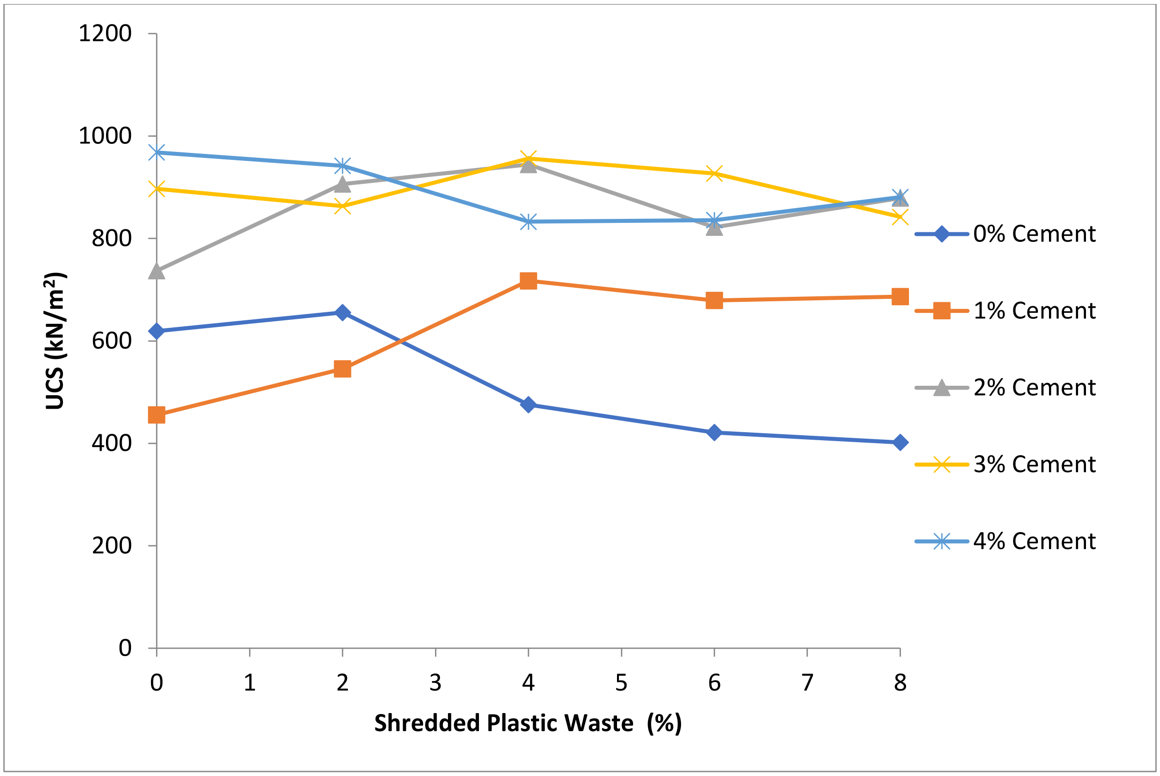

Fig. 6: Variation of UCS (28 Day Curing) of Soil – Cement Dust Mixture with SPW Content

4.0 CONCLUSION

Based on the results of the study it can be concluded that:

i. The lateritic soil falls under A-7-6 (12) classification for AASHTO (1986) and ML according to Unified Soil Classification System (ASTM, 1992)

ii. The natural soil has low moisture content of 16.4%. It has a liquid limit of 47%, plastic limit of 27.3% and plasticity index of 19.7%. The linear shrinkage was 6.4%, specific gravity of 2.63. All these values indicated that the soil is highly plastic with about 64% of the soil particles passing the BS. No 200 sieve.

iii. The MDD decreased with higher additive blend. The MDD values recorded a peak value of 1.44 Mg/m^3 at 4% Cement/8% SPW treatment. Consequently, the OMC, on the other hand, increased with higher SPW contents. The optimum moisture content values at the natural states increased from 20.2 to 21% at 3% Cement/4% SPW.

iv. The UCS increased to a peak value of 950.09kN/m^2 at 7 days curing with addition of 2% Cement and 8%SPW treatment thus meeting the requirement for sub-base construction.

v. It is therefore recommended that an optimum treatment of 2% Cement and 8%SPW with lateritic soil is recommended for use as a sub-base material when compacted with British Standard light energy (BSL).

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