A COMPARATIVE STUDY ON THE EFFECT OF SISAL FIBRE AND WASTE PLASTIC STRIPS IN STRUCTURAL STRENGTH IMPROVEMENT OF TROPICAL BLACK CLAY

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Abstract: A study on the effect of sisal fibre and waste plastic strips on tropical black clay (also called Black cotton soil, BCS) was carried out. Tests piloted on the natural and treated soil consist of California bearing ratio (CBR), Atterberg limits and compaction for different percentages inclusion of sisal fibre (0, 0.5, 1, 1.5 and 2%) and waste plastic strips (0, 0.5, 1, 1.5 and 2%) by dry weight of soil. Results obtained showed that the liquid limit of BCS initially fluctuated between 43.4% and 55.9% at 1% sisal fibre content, then dropped to 49.4% at 2% sisal fibre content. In the case soil treated with waste plastic strips, liquid values increased from 43.4% for the natural soil to a highest value of 58% at 1% waste plastic strips and thereafter decreased to 49.15% at 2% waste plastic strips content. Plastic limit for both BCS-sisal fibre/ waste plastic strips initially decreased from its natural value of 25.78 to 15.55 and 14.77% when treated with sisal fibre and waste plastic strips respectively at 0.5% admixtures content. In the case of plasticity index, values initially increase from its natural value of 17.66% to peak values of 35.39 and 43.23% for sisal fibre and waste plastic strips treated soil respectively, and thereafter decreased. Maximum dry density (MDD) initially increased from 1.55 mg/m^3 at 0%, to 1.60 mg/m^3 at 0.5% and thereafter decreased to 1.53 mg/m^3 at 2% of fibre content. In the case of samples treated with waste plastic strips. The MDD progressively increased as the amount of waste plastic strips increased. OMC show an overall trend of increase for BCS treated with sisal fibre, and a general trend of decrease for soil treated with waste plastic strips. The CBR values initially lessened from their natural value of 13.59% to 4.76% at 1% sisal fibre and subsequently increased to 10.57% at 2% sisal fibre. Similar behaviour was observed for soil modified with waste plastic strips. Based on the results, BCS/waste plastic strips improved the soil more than BCS/sisal fibre treated soil and is recommended at optimal 2% waste plastic strips for geotechnical engineering application such as road payment.

Keywords: black cotton soil, liquid limit, plastic limit, plasticity index, compaction, california bearing ratio, sisal fibre, waste plastic strips

1. INTRODUCTION

Tropical Black clay are clays with potential for swelling or shrinking with varying moisture condition [1, 2]. BCS usually form bases for structural damage, predominantly light structures and pavements, more than any natural catastrophe. BCS are developed by the disintegration of basic igneous rocks wherever seasonal deviation in

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weather occurs. BCS is a type of soil that have a compressibility range of medium to high plastic characteristics and distinguished by the presence of montmorillonite, which undergoes considerable volume change from dry to saturated conditions. When a structure is built on the BCS during the dry season with the foundation in the unstable zone, the partially saturated soil begins to absorb water during the rainy season, causing swelling pressure at the foundation's base. However, this happened as a result of the foundation's limitations on free swelling. BCSs are the key problem soils in Nigeria covering an estimated area of about 104,000 km^2 in North East Nigeria [1-3]. Generally, the formation of expansive soils has been linked to two groups of parent rock constituents. constituents. The parent materials are known to be the first and include volcanic, sedimentary rocks found primarily in South Africa, Israel, and North America, whereas the second parent materials include intricate igneous rocks found primarily in Nigeria, the Southwest United States, and India [1, 4].

Construction of buildings or roads on BCS requires the removal of the soil in the entire area and replacing it with a granular soil of higher bearing capacity. However, replacing BCS in an area is not economical and will lead to an increase in the cost of construction. Therefore, these called for soil stabilization/ modification in order to improve the structural strength of BCS for use in road constructions and other engineering projects. Stabilization is a procedure that assists in achieving the essential qualities in soil layers for construction work, such as enhancing a soil's engineering properties, regulating a soil's shrink-swell properties, and therefore raising the bearing capacity of soil used for structures and pavements use [5]. In another word, it could be the process of enhancing the qualities of frail soil in order to enhance its strength and make it more durable [6]. Lime and cement have long been known as the two primary soil stabilizers, and their prices have risen significantly due to the steep rise in energy costs [7]. It has also been reported in the literature [1, 8] that cement production processes give rise to carbon (IV) oxide (CO_2) in large quantities. Thus, replacing cement with other options such as sisal fibre will tackle the environmental problems caused by carbon (IV) oxide (CO_2).

In recent times, an alternative to these costly materials such as ash obtained from agricultural produce include, rice husk ash, locust bean and plantain peels among others, also industrial wastes such as steel slag, fly ash lack bottom ash both in structural and geotechnical applications have been studied by many researchers [9, 10]. Interestingly, the plastic bottle is mostly used in packaging drinks, especially beverages in which after beneficiated of the content the plastic is discarded. World Economic Forum [11] reported that the quantity of Plastic discarded has risen from 15 to 311 million tons from 1960s to 2014, and anticipated the triple by 2050. In addition, one of the goals of the 2030 Agenda for Sustainable Development is to drastically reduce waste output through recycling, reduction, and reuse, as well as to promote the use of local resources in engineering projects [12]. Although the use of discarded waste bottle strips has a great potential for enhancing soil properties, research on these materials is still in its early stage. This finding leads to an agreement among various authors on the necessity for a more thorough examination of the qualities required in plastic strip for soil augmentation [12].

Furthermore, the use of natural fibers such as sisal fiber as soil reinforcement has been recognized as an effective method of soil stability since the olden days. Several studies on soil reinforcement with fibres have been documented in the literature [13]. A study that combined the characteristics of both stabilization methods and reinforcement appears to be more effective in realizing geotechnical properties [14]. Ehrlich et al., [15] conducted pilot research on the hydro-mechanical behavior of a lateritic soil coated with polyethylene fibers for waste containment. Results from the study revealed a rise in both the hydraulic conductivity and the tensile strength of the fibre modified soil. Improvement of cement-stabilized clay reinforced with glass fibers was conducted by Bo et al. [16]. Glass fiber contents use for soil improvement in the rations of 0, 1, 2, 3, and 4% by weight of the dry soil. Results indicate an enhancement in shear strength parameters of glass fiber reinforced clay soil better than the cement-stabilized clay. The cohesion value of cement-stabilized clay modified with 4% glass fiber content is 2.8 times higher when compared to cement-stabilized clay. The goal of this study is to assess the effects of sisal fiber and waste plastic strip (WPS) on the geotechnical qualities of BCS. The objectives are to compare and evaluate their effects on strengthening structural strength in BCS for road construction, at varying concentration studies.

2. MATERIALS AND METHODS

2.1. Materials

2.1.1. Black cotton soil

The black cotton soil was gotten by the disturbed sampling method from Akko LGA, along Gombe Adamawa Road, with a geographic location of latitude 10.308920° and longitude 11.213692°. The top soil at about 0.5 m was removed so as to get the soil without organic deposits which are contained in the topmost part of the soil. Sample was collected in sacks. Samples used for determination of natural moisture content was collected and tied properly in aired tight bags so as to avoid moisture loss while transporting the soil. The samples were then air-dried then sieved via BS No. 4 (4.76 mm aperture).

2.1.2. Sisal fibre

Sisal Fibre was obtained at a local market in Building Materials, Jos Plateau State, Nigeria. Required sisal fiber was gotten by a process called decortications, as contained in [17]. Decortications involve the process where the leaves of sisal plants are beaten and crushed by a rotary wheel set that has a blunt knives, while the leaves are wash away by water, only fibre remains. A representative sisal plant is given in Figure 1.

2.1.3. Waste plastic strips

The waste plastic strips were obtained by cutting waste plastic bottles (a high-density polypropylene water bottle) into a small thread of about 1cm length. Plastic bottles have been well-thought for this study because of its availability, chemical unreactive nature, low cost, zero water absorption proficiency and no reaction with soil [18]. Typical waste plastic strips are shown in Figure 2.

Fig. 1. Uncut sisal fibre used for the study.

Fig. 2. Waste plastic strips used for the study.

2.1.1.4. Sodium borohydrade

Sodium borohydrade was sourced from a chemical shop in Jos, Plateau State Nigeria.

2.2. Methods

2.2.1. Soil preparation

The preparation process involves sieving the soil through 0.425 mm sieve for Atterberg limits test, while that of compaction, volumetric shrinkage and unconfined compressive strength were sieved through 4.76 mm sieve. The sisal fibre where cut to an average length of about 1cm, then treated with Sodium borohydrade ($NaBH_4$) at 1%/wt as recommended in the literature [19]. Sodium borohydrade was used to remove the cellulose (i.e a biodegradable material that can decay with time) content of the sisal fibre that is responsible for its decaying with time when used for soil improvement. After removing the cellulose, the treated sisal fibre were air dry prior to mixing with the soil for the various tests. No treatement was applied on the waste plastic strips after cutting.

2.2.2. Index properties

Index test were carried for the untreated soil based on the specification outlined in BS 1377 (1990) [20].

2.2.3. Atterberg's limits

Atterberg limits includes liquid limit, plastic limit and the plasticity index of both the natural and modified soil sample. The test was also coordinated according to BS 1377(1990) [20] for the untreated soil and BS 1924 (1990) [21] for the modified soil sample.

Liquid limit, LL

The test was done using air-dried soil passing BS No 40 (425 µm aperture). About 300 g of the sieved sample was place on a glass plate and mixed properly with tap water until it forms a uniform paste. After in-depth mixing with water, small part was collected and put in casangrande apparatus**.** A groove was made at the centre of the cup filled with the soil, with the aid of a grooving tool. The Casangrande device is cranked through the handle to lift the cup and descends until the soil's two halves come into contact with the groove's base. Each turning of the handle makes a rise and fall of the groove (i.e a blow). The number of blows in which that occurs is documented and a small measure of the soil sample from the groove apparatus is then taken and the moisture content determined. The process was then reiterated for the soil samples varied with variable percentages of the sisal fibre (i.e 0, 0.5, 1,1.5 and 2% sisal fibre by dry weight of soil) and the required numbers of blows were obtained and recorded. Similar procedure was followed for samples treated with waste plastic bottles (i.e 0, 0.5, 1,1.5 and 2% waste plastic botsles by dry weight of soil).

Plastic limit, PL
A slice of the soil/soil mixed with the sisal fibre used in carrying out the LL test was collected for the purpose of determining the PL. A small soil/soil mixed with sisal fibre was turned between the palms of the hand up until it become dry adequately forming a thread-like structure of about 3mm thick before it crushes(despite the soil was moderately drier compared to the soil used for LL test). The crushed soil is at that point placed into a moisture content container in order to obtain the moisture content of the crumbled soil sample. The progression is reiterated for all proportions of the sisal fibre (i.e 0, 0.5, 1, 1.5 and 2% sisal fibre by dry weight of soil). Similar procedure was followed for samples treated with waste plastic bottles (i.e 0, 0.5, 1,1.5 and 2% waste plastic bottles by dry weight of soil).

Plasticity index, PL
The soil/soil –sisal fibre plasticity indices (PI) is the mathematical difference between the liquid limit of the natural/various mixes and their resultant plastic limits.

2.2.4. Compaction test
Compaction test was done on the natural and modified soil (i.e. at different percentages of sisal fibre), all agreeing to BS 1377(1990) and BS 1924(1990) respectively by means of the British Standard Light energy.

Maximum dry density, MDD
3000g of soil was used for the compaction of the natural soil and (water was added at 5% at each stage). The sample was compacted into a 1000 cm^3 (of mass ml); in 3 layers of each getting 27 blows by means of a 2.5 kg rammer falling over a height of 300 mm (i.e British Standard Light, BSL energy). The collar is then removed after compaction, frills the compacted soil by means of the upper part of the mould with the aid of straight edge and weighed. Then two small samples were then removed from the mold and sliced through to get a small portion of the soil for moisture determination. The sample was thereafter detached from the mould, then crumble and another 5% of water was further added and the same process as initial was reiterated a until a minimum of five sets of samples were gotten and their respective moisture contents *w* measured. The bulk density was computed from each compacted layers using equation (1).

$$\rho = \frac{m_2 - m_1}{\text{volume of compaction mould}} \tag{1}$$

where m_1 is the weight of empty mould without the coller, m_2 is weight of mould + compacted soil in the mould without the coller.

The dry density was computed using equation (2).

$$\rho_d = \frac{100\rho}{100+w} \tag{2}$$

Dry densities values were gotten from equation (2) and plotted verses their corresponding moisture content. The maximum dry densities (MDD) was deduced as the maximum point on the resultant curves. The same approach was reitreated for the soil reinforced with the sisal fibre/waste plastic strips to achieve their moisture content and dry density from plotted curve.

Optimum moisture content, OMC
The OMC is calculated by graphing dry density against moisture content and obtaining the resultant values of moisture content at MDD.

2.2.5. California` bearing ratio, CBR
For natural and treated soils, a CBR test was done in line with BS [20]. CBR is calculated by combining the plunger's force and the depth of penetration into the specimen using force and penetration relationship. In a 2360

cm^3 mould, 5 kg of soil-sisal fibre/waste plastic strips were mixed at their corresponding OMCs. The 2.5 kg rammer was used to compact three layers, each receiving 62 hits. After compaction, the base plates were detached, and the compacted specimens were placed for testing based on the Nigerian General Specification [22]. The CBR measured load was achieved using penetration of 2.5 mm or 5.0 mm (whichever was greater). The CBR was computed as:

$$\text{California Bearing Ratio} = \frac{\text{Measured}}{\text{Standard}} \text{x } 100 \tag{3}$$

But, standard load = 13.24 kN of 2.5 mm penetration = 19.96 kN of 5.0 mm penetration. Similar process was then reiterated for the soil samples mixed with variable percentages of the sisal fibre and waste plastic bottles.

3. RESULTS AND DISCUSSIONS

3.1. Untreated soil index properties

Primary tests on the natural soil deduced that the soil is greyish black in colour with a comparatively low moisture content of 3.90%. The basic properties of the natural are provided in Table 1 below. The soil was classified by AASHTO (1986) [23] and ASTM, (1992) [24] as A-7-6(25) and CL in that order. The soil has a LL of 45.18%, PL of 25.82% and PI of 19.43%. The soil has a maximum dry density of 1.55 mg/m^3 using British Standard Light and a specific gravity of 2.41. The soil is of low plasticity. Grain size plot of the natural soil is given in Figure 3.

Table 1. Untreated soil index properties.

Properties	Quantities
Passing 75 µm	77.69
Moisture content	3.90
LL %	45.18
PL %	25.82
PI %	19.43
Specific gravity	2.41
MDD mg/m^3	1.55
OMC %	19.0
AASHTO classification	A-7-6(25)
NBRRI classification	Low swell potential
USCS	CL
Colour	Greyish black
Dominant clay mineral	Montmorillonite

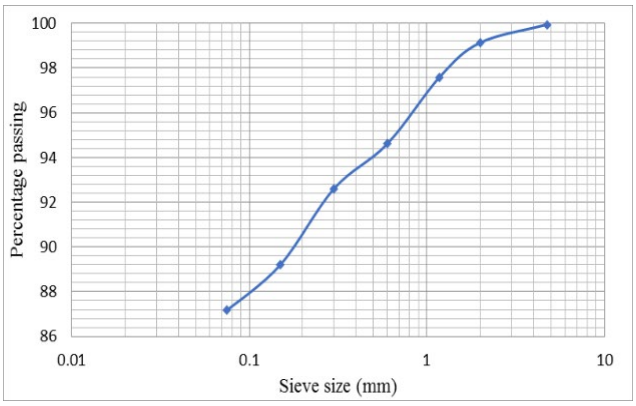

Fig. 3. Grain size plot of the natural soil.

3.2. Influence of of sisal fibre/ waste plastic strips on modified properties of soil

3.2.1. Atterberg's limits

Liquid limit, LL

Plots of LL of BCS with variations in percentages of sisal fibre/waste plastic strips is given in Figure 4 the liquid limit of BCS initially improved from its natural value of 43.4% to the highest value of 55.9% at 1% sisal fibre content (i.e 50.12%.increament), and subsequently declined to the least value of 49.4% at 2% sisal fibre content. Values of 43.4, 50.94, 55.87, 50.31 and 49.36 were recorded at 0, 0.5, 1, 1.5 and 2% sisal fibre in that order. In the casing of soil treated with waste plastic strips, liquid values increased from 43.4% for the natural soil to a top value of 58% at 1% waste plastic strips, and thereafter decreased to 49.15% at 2% waste plastic strips content. The initial increment with rising in the sisal fibre content could be attributed to the absorption capacity of sisal fibre to absorb more water. Similar observation was reported in literature [16, 25-26]. However, treatment of the soil with more than 1% sisal fibre/ waste plastic strips content resulted to a decline in the liquid limit of the modified soil. The possible reason for the reduction could be associated with an increase in stiffness of the soil with higher concentration of the admixtures in the soil. Also improved soil workability with higher sisal fibre/ waste plastic strips content could be the reason for the decline in the liquid limit. Similar observations were made in literatures [16, 18, 27-28].

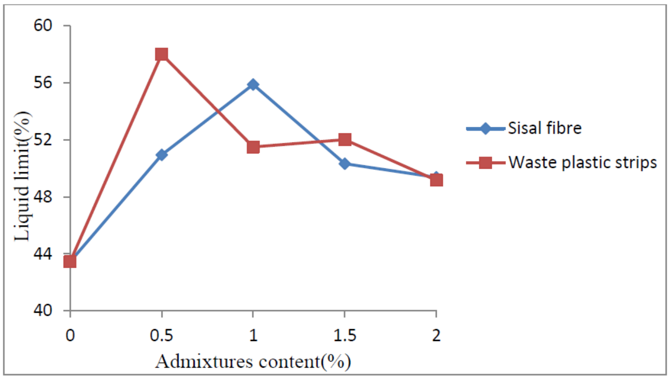

Fig. 4. Liquid limit with percentages of sisal fibre/plastic strips.

Plastic limit, PL

The plot of BCS-sisal fibre/ waste plastic strips mixtures is given in Figure 5. Plastic limit for both BCS-sisal fibre/ waste plastic strips at first decreased from its natural value of 25.78 to 15.55 and 14.77% when treated with sisal fibre and waste plastic strips respectively at 0.5% admixtures content. Beyong 0.5% sisal fibre/ waste plastic strips content, the plastic limit increased up to 2% mixes. Values of 25.8, 15.55, 20.97, 22.95 and 22.38% were recorded at 0, 0.5, 1, 1.5 and 2% sisal fibre in that order. Values of 25.78, 14.77, 16.7, 22.95 and 22.58% were recorded at 0, 0.5, 1, 1.5 and 2% waste plastic strips in that order. Friction forces of resistance established between the soil and the sisal fibre/waste plastic strips that served as a reinforcing material could be responsible for the decline in the plastic limit of the modified soil [16, 26]. Also, an increase in water adsorption capacity of the modified soil with higher sisal fibre may be responsible for the recorded trend.

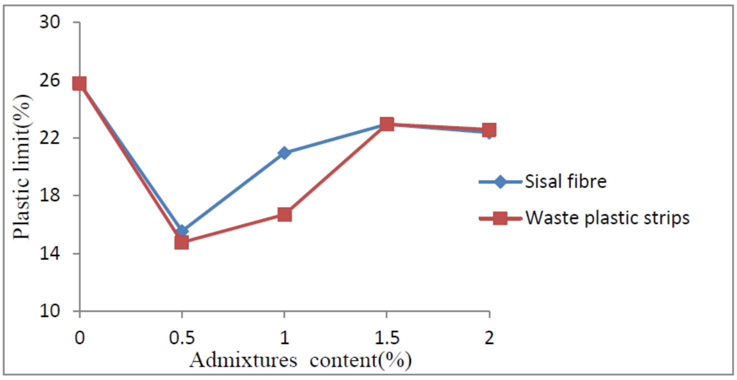

Fig. 5. Variation of plastic limit with respect to percentages of sisal fibre/waste plastic strip.

Plasticity index, PI

Figure 6 presents a plot of the plasticity index of soil mixed with additives in various percentages. Results show that the plasticity index initially increase from its natural value of 17.66 to peak values of 35.39 and 43.23 % for sisal fibre and waste plastic strips treated soil respectively. Plasticity index of 17.66, 35.39, 34.9, 27.36 and 26.9% were recorded at 0, 0.5, 1, 1.5 and 2% sisal fibre in that order. Values of 17.66, 43.23, 34.8, 29.05 and 26.57% were recorded at 0, 0.5, 1, 1.5 and 2% waste plastic strips in that order. The recorded decrease in plasticity index with higher proportion of sisal fibre and waste plastic strips may be presumed to be in line with increase in the frictional resistance between the soil particles by its interaction with the sisal fibre/ waste plastic strips, thus causing a fall in the swelling prospective of the soil. Stephen [29] also reported similar trend when carrying out research on the influence of bagasse ash on the stabilization of soil. Moreover, reduction in the plasticity index with increament in the sisal fibre/waste plastic strips content may be linked to the reduction in the shrinkage behaviour of the modified soil as a result of sisal fibre/waste plastic strips incorporated in to the soil mix [16]. Ibrahim and Fourmont, Diambra et al. [30-31] reported that cement-stabilized soil reinforced with fibers has a significantly higher potential to expand when compared to cement-stabilized soil. Onyelowe et al. [32] stated that high plasticity is an undesirable property in construction materials.

The one – way analysis of variance (ANOVA) test on the liquid limit result is given in Table 2. The result shows that the effects of both sisal fibre and waste plastic strips on BCS were statistically significant. For sisal fibre (F_{CAL}= 589.697 > F_{CRIT} = 5.318) and for waste plastic strips (F_{CAL}= 438.631> F_{CRIT} =5.318). The effect of sisal fibre were more noticeable than that of waste plastic strips.

Table 2. ANOVA for Plasticity properties of BCS mixed with sisal fibre/waste plastic strips.

Property	Source of Variance	Degree of Freedom	F_{CAL}	p-value	F_{CRIT}	Remark
Liquid limit	Sisal fibre	1	589.697	8.82334E-09	5.318	F_{CAL}> F_{crit} SS
	Waste plastic strips	1	438.631	2.83482E-08	5.318	F_{CAL}> F_{crit} SS
Plastic Limit	Sisal fibre	1	141.916	2.26625E-06	5.318	F_{CAL}> F_{crit} SS
	Waste plastic strips	1	86.953	1.42685E-05	5.318	F_{CAL}> F_{crit} SS
Plasticity Index	Sisal fibre	1	71.114	2.98253E-05	5.318	F_{CAL}> F_{crit} SS
	Waste plastic strips	1	46.896	0.000131243	5.318	F_{CAL}> F_{crit} SS

SS- Statistically Significant

The ANOVA test on the plastic limit result is given in Table 2. Result shows that the effects of both sisal fibre and waste plastic strips on BCS were statistically significant. For sisal fibre (F_{CAL}= 141.916> F_{CRIT} =5.318) and for waste plastic strips (F_{CAL}= 86.953> F_{CRIT} =5.318). The effect of sisal fibre were more noticeable than that of waste plastic strips.

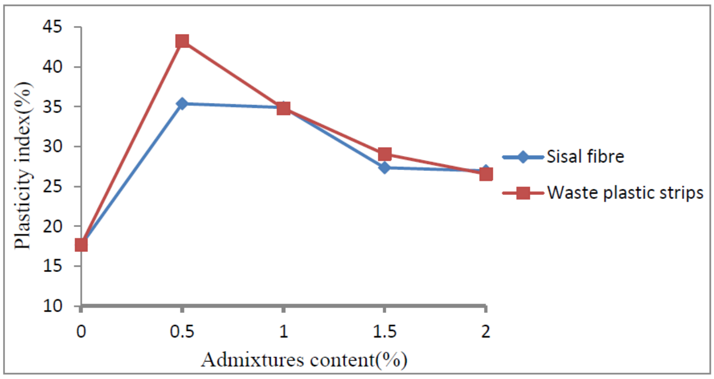

Fig. 6. Plasticity index with respect to percentages of sisal fibre/waste plastic strips.

The ANOVA test on the plasticity index result is given in Table 2. The result shows that the effects of both sisal fibre and waste plastic strips on BCS were statistically significant. For sisal fibre (F_{CAL}= 71.114> F_{CRIT} =5.318) and for waste plastic strips (F_{CAL}= 46.896> F_{CRIT} =5.318). The effect of sisal fibre were more noticeable than that of waste plastic strips.

3.2.2. Compaction characteristics

Maximum dry density

Figure 7 indicates the variation of MDD with varying percentages of sisal fibre/waste plastic strips contents. For soil samples treated with sisal fibre, MDD initially increased from 1.55 mg/m^3 at 0%, to 1.60 mg/m^3 at 0.5% and thereafter decreased to 1.53 mg/m^3 at 2% of fibre content. In the case of samples treated with waste plastic strips, MDD progressively increased as the waste plastic strip content grew. MDD with higher sisal fibre content can be explained by the sisal fibres' low density relative to the soil, which in turn reduces their normal unit weight. [25-26]. The fibre now occupying more space that supposed to be filled with soil, thus creating some voids in the mixture. Also, the reduction may also be due to the fact that the sisal fibre fell to make a good bonding with the soil matrix as the sisal content increase, thus a decrease in the soil density. Similar observation is documented in [33]. The increased waste plastic strips content in MDD might be owing to the higher density of waste plastic strips compared to soil, resulting in an increase in density. Another possible reason for the progressive increase in MDD could due to the fact that the waste plastic strips fills in void spaces within the soil marix thus densifying the soil. Similar observations were made in literatures [18, 31].

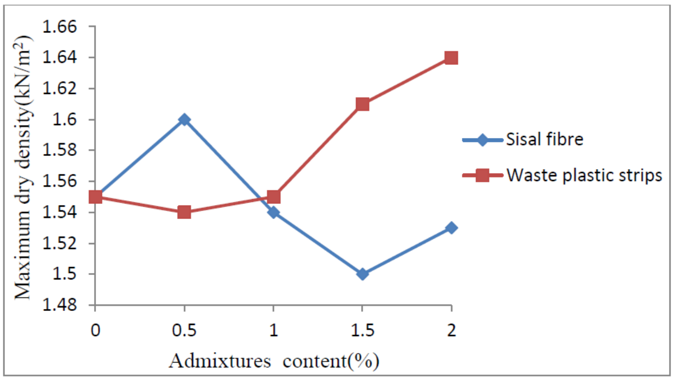

Fig. 7. Variation of MDD with respect to percentages of sisal fibre/waste plastic strip.

Optimum moisture content

The variations OMC of the soil with respect to percentages of sisal fibre and waste plastic strips is shown in Figure 8. The natural soil has an OMC of 19%, while for the modified soil with sisal fibre at 0.5, 1, 1.5 and 2% sisal fibre,recorded an OMC values of 19.5%, 22%, 24.5% and 23% respectively. The results show that there was an increase in the OMC of the modified soil compared to the natural soil. This could be as a result of the absorption of moisture by the fibre during the compaction process. As the fibre content in the soil increased more water was needed to lubricate the soil surface leading to increase in the OMC. This suggests that the fibre, which naturally had a high water absorption capacity, caused the increase in the OMC. Similar statement was reported in literatures [25-26]. In the case of soil modified with waste plastic strips, a general trend of decrease in OMC was documented with increase in waste plastic strips contents. OMC values of 19, 23.9, 21, 17.2 and 15% were recorded at 0, 0.5, 1, 1.5 and 2% waste plastic strips in that order. Similar trend of decrease in OMC was reported in literatures [33-34] (Peddaiah et al., 2016; Hussein et al., 2020).

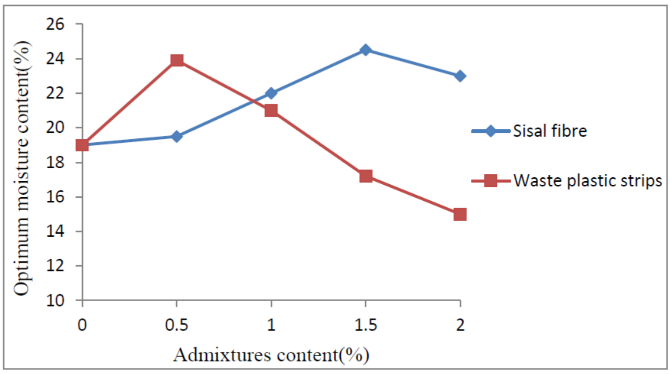

Fig. 8. Variation of OMC with respect to percentages of sisal fibre/waste plastic strip.

The ANOVA test on MDD result is given in Table 3. The result shows that the effects of both sisal fibre and waste plastic strips on BCS were not statistically significant. For sisal fibre (F_{CAL}= 2.362> F_{CRIT} =5.318) and for waste plastic strips (F_{CAL}= 2.664> F_{CRIT} =5.318).

The ANOVA test on OMC result is given in Table 3. The result shows that the effects of both sisal fibre and waste plastic strips on BCS were statistically significant. For sisal fibre (F_{CAL}= 350.711> F_{CRIT} =5.318) and for waste plastic strips (F_{CAL}= 134.107> F_{CRIT} =5.318). The effect of sisal fibre were more noticeable than that of waste plastic strips.

Table 3. ANOVA for compaction characteristic of BCS with sisal fibre mixtures/ waste plastic strips.

Property	Source of Variance	Degree of Freedom	F_{CAL}	p-value	F_{CRIT}	Remark
MDD	Sisal fibre	1	2.362	0.162840939	5.318	$F_{CAL} < F_{cri}$ NS
	Waste plastic strips	1	2.664	0.141268636	5.318	$F_{CAL} < F_{cri}$ NS
OMC	Sisal fibre	1	350.711	6.82577E-08	5.318	$F_{CAL} > F_{crit}$ SS
	Waste plastic strips	1	134.107	2.81046E-06	5.318	$F_{CAL} > F_{crit}$ SS

NS= Not Statistically Significant

3.2.3. California bearing ratio (CBR)

The variations in CBR of separate samples with sisal fibre and waste plastic strip content is provided in Figure 9. The CBR values initially reduced from their natural value of 13.59% to 4.76% at 1% sisal fibre and afterward increased to 10.57% at 2% sisal fibre. Similar behaviour was observed for soil modified with waste plastic strip. CBR values declined from its natural value of 13.59% to 4.25% at 1% waste plastic strip. After then, there was an increase in value to 15.53% and 17.03% at 1% and 2% of the waste plastic strip respectively. The increase in the CBR values for both treatments at 1% up to 2% sisal fibre/waste plastic strips content could be linked to high friction established between the soil and the reinforcing material which led to the transfer of load that is built up in the soil mass to the plastic strip. Furthermore, the increase in CBR could be linked to the fact that soil and sisal fibre/waste plastic strip interactions offer restraint to the penetration plunger; and thus, gradual increase in the CBR values. Similar results were documented in literatures [18, 34 - 36].

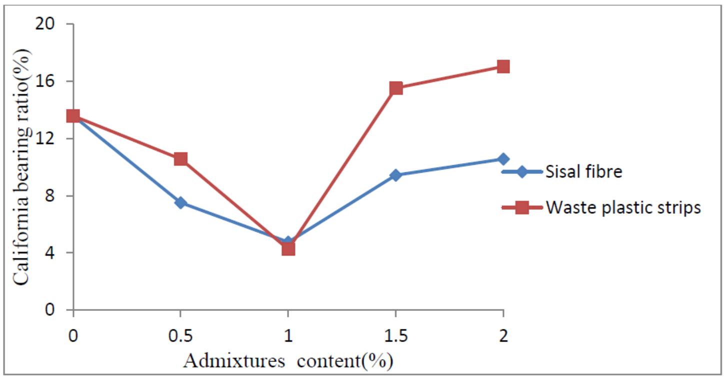

Fig. 9. CBR with respect to percentages of sisal fibre/ waste plastic strips.

The ANOVA test on CBR results is given in Table 4. The result reflects the effects of both sisal fibre and waste plastic strips on BCS were statistically significant. For sisal fibre (F_{CAL}= 28.871> F_{CRIT} =5.318) and for waste plastic strips (F_{CAL}= 23.974> F_{CRIT} =5.318). The effect of sisal fibre were more noticeable than that of waste plastic strips.

Table 4. ANOVA for CBR of BCS with sisal fibre/ waste plastic strips.

Property	Source of Variance	Degree of Freedom	F_{CAL}	p-value	F_{CRIT}	Remark
CBR	Sisal fibre	1	28.871	0.000667045	5.318	$F_{CAL} > F_{crit}$ SS
	Waste plastic strips	1	23.974	0.001199389	5.318	$F_{CAL} > F_{crit}$ SS

4. CONCLUSIONS

Influence of sisal fibre and waste plastic strips on the properties of BCS was studied. From the study, these conclusions were drawn:

- The natural soil was classified as A-7-6(25) and CL using the AASHTO and ASTM classification system. The soil have a LL of 43.4%, PL of 25.82% and PI of 19.43%. The soil has an MDD of 1.55 mg/m^3 using British Standard Light. The soil is of low plasticity.
- The liquid limit of BCS originally climbed from 43.4% to 55.9% at 1% sisal fibre content, then decreased to 49.4% at 2% sisal fibre content. Soil treated with waste plastic strips, liquid values increased from 43.4% for the natural soil to a peak value of 58% at 1% waste plastic strips, and thereafter decreased to 49.15% at 2% waste plastic strips content. Plastic limit for both BCS-sisal fibre/ waste plastic strips initially reduced from its natural value of 25.78 to 15.55 and 14.77% when treated with sisal fibre and waste plastic strips respectively at 0.5% admixtures content. Plasticity index values initially increase from its natural value of 17.66% to peak values of 35.39 and 43.23 % for sisal fibre and waste plastic strips treated soil respectively and thereafter decreased.
- MDD initially increased from 1.55 mg/m^3 at 0%, to 1.60 mg/m^3 at 0.5% and thereafter decreased to 1.53 mg/m^3 at 2% of fibre content. Samples treated with waste plastic strips, The MDD progressively increased with increase in waste plastic strips content.OMC shows a general trend of increased for BCS treated with sisal fibre, and a general trend of decrease for soil treated with waste plastic strips.
- The CBR values initially reduced from its natural value of 13.59% to 4.76% at 1% sisal fibre and afterward increased to 10.57% at 2% sisal fibre. Similar behaviour was observed for soil modified with waste plastic strips.
- Based on the results, BCS/waste plastic strips improved the soil more than BCS/sisal fibre treated soil and is recommended at optimal 2% waste plastic strips for applications such as rural road payment, walk ways.

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