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Efficiency of Costus Lateriflorus Bagasse Fiber and Cement Composite as Soil Stabilizer for Road Pavement

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Abstract **Original Research Article**

This study investigated the effect of costus lateriflorus bagasse fiber and cement composites on extensive soil compaction. Laterite and clay samples from Ubeta-Ula-Ubie Road at Ahoada West LGA in Rivers, Nigeria were prepared and analyzed for changes in maximum dry density (MDD), Optimum moisture content (OMC), consistency limits, and California bearing ratio (CBR) and unconfined compressive strength (UCS), maximum dry density (MDD), liquid limit (LL), and plasticity index (PI) of laterite and stabilized clay decreased with increasing proportion of bass fiber composites, while optimum moisture content (OMC), plastic limit (PL), and unconfined compressive strength (UCS) increases with the proportion of bagasse fiber. This study found that proper ratio of bagasse fiber content in soil stabilization will improve soil properties suitable for paving and road construction. Bagasse fiber has a relatively better performance in lateritic soil than in clay with the optimum ratio of cement composition of 0.75% and 7.5%.

Keywords: Stabilization, Soil, Cement, Costus lateriflorus Bagasse Fibre, Properties.

1. INTRODUCTION

Expansive soils are soils that exhibit changes in volume in response to changes in water content. The soil swells with increasing water content and shrinks with decreasing water content. Expansive soil is a global problem that presents several challenges for civil engineers. They are considered a potential natural hazard that can cause significant damage to structures if not handled properly. Large areas of land cause more damage to structures, especially light buildings and walkways, than any other natural hazard, including earthquakes and floods (Holtz, 1956).

Expansive clay is common; their presence is not climate specific, although they are very common in arid to semi-arid climates and are problematic for engineering structures due to their tendency to rise during the rainy season and shrink during the dry season. Although the scale and extent of this soil problem have not been studied expansively, expansive soils are known to be widespread in Ethiopia (Asnake, 2015).

There are several roads in Ethiopia whose premature decay was caused by massive alterations in the vast clay; The Modjo-Ejerie-Areti and Addis-Jimma roads can be examples of such errors (Awoke, 2013; Asnake, 2015; Nikodimos-Bekelle 2017). Therefore, this land is not suitable for building infrastructure because it has a high risk of sedimentation. Therefore, it becomes a challenging task for the construction industry to design and construct structures on such soft soils.

To improve the structural properties of such soils, various methods are practiced. Stabilization, injection, replacement and exchange, pre-loading, rock columns and dynamic compaction and reinforcement with geosynthetics. Replacement methods can be a possible solution for organic soils, replacing organic soils with granular soils such as sand and gravel or preloading at sufficient depth to improve technical properties, but with increasing global energy demand and increasing local demand. It becomes materially expensive to remove and replace inferior soil. Chemical stabilization is a cost-effective alternative where stabilizers such as cement, lime, fly ash and other binders rapidly stabilize organic soils through chemical reactions.

Stabilization is a technique that was introduced many years ago with the main goal of making soiling according to the needs of a particular engineering project. The stabilized material can be used as an improved subgrade or roof layer or substrate for highway or summer paving. It is the modification of one or more soil properties by mechanical or chemical means to make a better soil material with the desired technical properties. Soil can be stabilized to increase strength and durability or to prevent erosion and dust formation (Usha and Rani, 2016).

The purpose of stabilizing flexible overburden placed on weak and problematic soils is to achieve the desired properties of the underlying soil layer, namely high compressive and shear strength, resistance to all weather and load conditions, ease and durability of compaction, ease of Low drainage and vulnerability. to changes in volume and freezing action. Because soils vary widely, the relationship between texture, density, moisture content and strength of the coating material is complex (Usha and Rani, 2016). It is known that cement and lime are mainly used to improve the geotechnical properties of clays (Usha and Rani, 2016). However, cement and lime are expensive in developing countries, so it is very important to modify the properties of locally available soils so that they can be used in road construction, and to make best use of locally available materials that remain after wood burns, such as B. burning wood in home fireplaces or industrial power stations.

Various studies have been carried out to improve the expansive properties of black cotton soil by using additives such as wood ash. Ash is produced from burning of waste materials, and it can be done locally in fireplaces or industrial power plants. It is usually disposed of as garbage and dumped outside the home or landfill, increasing the volume of the landfill. Wood ash experiments have shown that wood ash has alkaline properties, which clearly defines its potential as a source of feedstock for the production of acids and various other soil enhancers. Therefore, as an alternative solution, ash from agricultural wastes can be used as potential soil stabilizer through chemical reactions (Ek.Serafimova, 2011).

Okagbue (2011) showed that ash processed from wood certainly fulfills several of these requirements, like reduced ductility, reduced swelling, increased stability and a significant increase in strength, but could not meet the benefits of a continuous increase in strength over time. This study shows that although wood ash offers most of the beneficial effects of lime in construction, it is unlikely to be a substitute for lime in soil stabilization. However, in this study, cement and wood ash were used in an expansive soil-cement-wood ash mixture to evaluate the potential of the wood ash and cement mixture to stabilize expansive clays and to assess whether the cement-wood ash mixture could replace some of the cement fractions, which have a positive effect on process costs.

2. MATERIALS AND METHODS

2.1 Materials

The materials used are stated and briefly explained under the following subheadings.

2.1.1 Soil

The soils used for the study were collected from Ula-Ubie-Ubieta road in Ubie Districts of Ekpeye, Ahoada-West Local Government of Rivers State, beside the failed sections of the road at 1.5 m depth. The location lies on the recent coastal plain of the North-Western of Rivers state of Niger Delta.

2.1.2 Costus lateriflorus Bagasse

The Costus lateriflorus bagasse is a wide plant, medicinally used in the local areas, and it mostly found in the bushes. The plant was collected from Oyigba Town bush, in Ubie Clan of Ahoada-West, Rivers State, Nigeria.

2.1.3 Cement

The cement used was Portland Cemenet, purchased in the open market at Mile 3 market road, Port Harcourt, Rivers State.

2.2 Method

Tests conducted were maximum dry density, moisture content determination, consistency limits, California bearing ratio (CBR) and unconfined compressive strength (UCS.

2.2.1 Moisture – Density (Compaction) Test

This laboratory test is performed to determine the relationship between the moisture content and the dry density of a soil for a specified compactive effort.

2.2.2 Moisture Content Determination

The natural moisture content of the soil as obtained from the site was determined in accordance with BS 1377 (1990) Part 2. The sample as freshly collected was crumbled and placed loosely in the containers and the containers with the samples were weighed together to the nearest 0.01g.

2.2.3 Consistency Limits

The liquid limit (LL) is arbitrarily defined as the water content, in percent, at which a part of soil in a standard cup and cut by a groove of standard dimensions will flow together at the base of the groove for a distance of 13 mm (1/2in.) when subjected to 25 shocks from the cup being dropped 10 mm in a standard liquid limit apparatus operated at a rate of two shocks per second.

2.2.4 California Bearing Ratio (CBR) Test

The California Bearing Ratio (CBR) test was developed by the California Division of Highways as a method of relegating and evaluating soil- subgrade and base course materials for flexible pavements.

2.2.5 Unconfined Compression (UC) Test

The unconfined compressive strength is taken as the maximum load attained per unit area, or the load per unit area at 15% axial strain, whichever occurs first during the performance of a test. The primary purpose of this test is to determine the unconfined compressive strength, which is then used to calculate the unconsolidated undrained shear strength of the clay under unconfined conditions.

3. RESULTS AND DISCUSSION

Laboratory analysis on maximum dry density (MDD), optimum moisture content (OMC), consistency limits, California bearing ratio (CBR) and unconfined compressive strength (UCS) of stabilized Laterite and clay soils collected along Ubeta-Ula-Ubie road in Ahoada West LGA of Rivers State, Nigeria are presented and discussed in this section.

3.1 Maximum dry density

The results of maximum dry density (MDD) of lateritic and clay soils stabilized with fixed composition of cement at 7.5% and Costus lateriflorus bagasse fibre at composition ranging from 0.25% – 1.0% are shown in Table 1, while Figure 1 shows the profile of MDD for stabilized clay and Laterite soils.

Table 1: Effect of bagasse fibre and cement composite on MDD

Fibre content (%)	MDD (kN/m^3)	
	Laterite soil	Clay soil
0	1.96	1.73
0.25	1.87	1.671
0.5	1.82	1.622
0.75	1.78	1.572
1.0	1.65	1.534

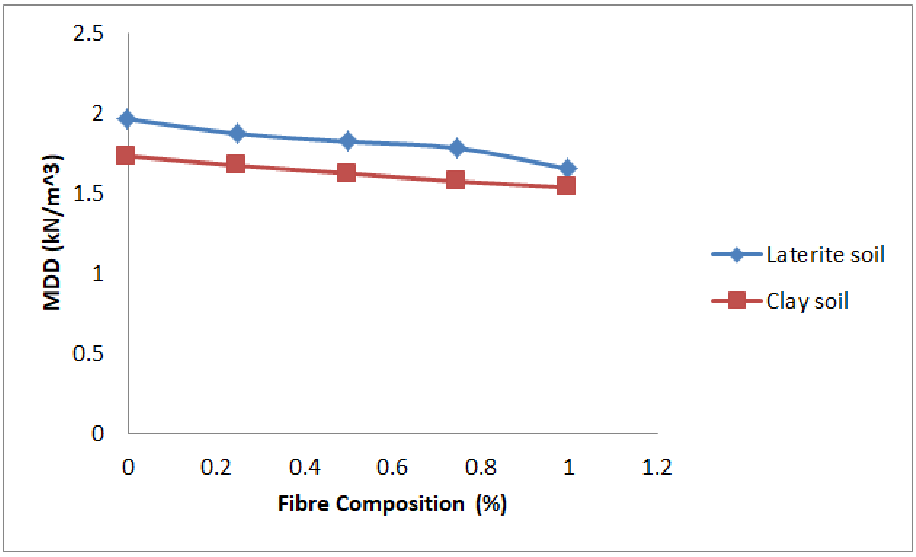

Figure 1: Plot of MDD versus bagasse fibre in cement stabilized soil

Figure 1 showed the profiles of maximum dry density (MDD) of laboratory compaction tests of Laterite and clay soils from Ubeta-Ula-Ubie road stabilized with 7.5% cement and varying proportions of bagasse fibre from 0 – 1.0%. Results showed that MDD decreased with increase in bagasse fibre proportion in both soil types. Comparatively, MDD in Laterite soil was higher than in clay soil sample. The MDD of 0% stabilized lateritic and clay soils was obtained as 1.96 kN/m^3 and 1.73 kN/m^3 respectively, but decreased to 1.650 and 1.534kN/m^3 for lateritic soil clay soils, respectively as bagasse fibre proportion increased to 1.0% at fixed cement proportion of 7.5%. The MDD values recorded in this study were below the value (1.84kN/m^3) reported in deltaic soil located Ahoada and other parts of Rivers State by Omotosho and Eze-Uzomaka (2008). Though, the soil was stabilized with only cement between 2% and 15% proportion. However, the trends in maximum dry density was in conformity with soils stabilized with various proportions of different species of bagasse fibre (Akobo *et al*., 2018; Charles *et al*., 2018; Ngekpe *et al*., 2018; Nwikina *et al*., 2018).

3.2 Optimum moisture content

The results of optimum moisture content (OMC) for the lateritic and clay soils stabilized with fixed composition of cement at 7.5% and Costus lateriflorus bagasse fibre at composition ranging from 0.25% – 1.0% are shown in Table 2. Also, the profiles of OMC for the stabilized soils are shown in Figure 2.

Table 2: Effect of bagasse fibre and cement composite on OMC

Fibre content (%)	OMC (%)	
	Laterite soil	Clay soil
0	11.59	15.44
0.25	11.88	15.53
0.5	11.96	15.71
0.75	12.28	15.92
1	12.82	16.16

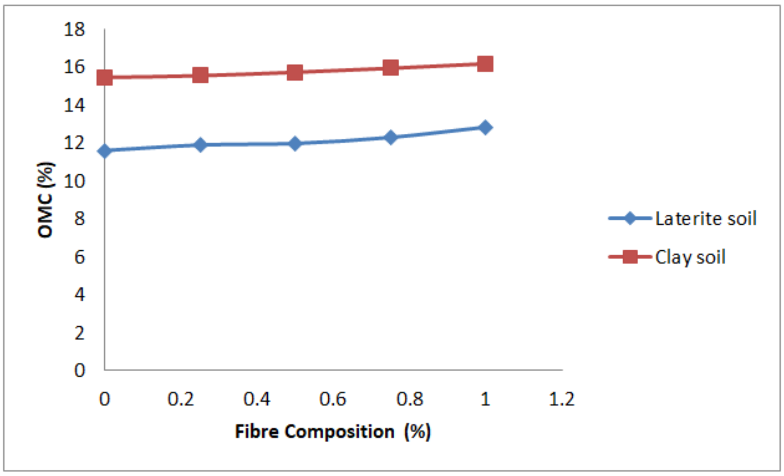

Figure 2: Plot of OMC versus bagasse fibre in cement stabilized soil

Figure 2 showed the profiles of optimum moisture content (OMC) of compaction test on laterite and clay soils from Ubeta-Ula-Ubie road stabilized with cement at 7.5% and varying proportions of bagasse fibre from 0 – 1.0%. The results showed that OMC increased with increase in percentage of bagasse fibre content in both soils. Clay soil recorded higher percentage of OMC compared to lateritic oil. The OMC of 0% stabilized lateritic and clay soils was obtained as 11.59% and 15.44%, respectively, but increased to 12.82% for lateritic soil and 16.16% for clay soil, as the bagasse fibre proportion was increased to 1.0% at fixed cement proportion of 7.5%. The values of OMC recorded were within the ranges reported in some previous works using composite of cement and bagasse fibre (Okonkwo *et al*., 2016; Akobo *et al*., 2018; Charles *et al*., 2018; Ngekpe *et al*., 2018; Nwikina *et al*., 2018). The OMC values obtained in this work were within the ranges recorded for mechanical stabilization of clay soil using waste foundry sand and river sand which also increased with increasing percentage of stabilization material (Omotosho and Eze-Uzomaka, 2008; Essien and Charles, 2016; Bhardwaj and Sharma, 2020). The optimum moisture content reported by Sas and Głuchowski (2013) for 0% stabilized sandy-silty clay was 10.7%, but increased to 11.41% when 6% cement was added.

3.3 Consistency limits

The results of consistency limits **(**liquid limit (LL), plastic limit (PL) and plasticity index (PI)) of the stabilized with fixed composition of cement at 7.5% and Costus lateriflorus bagasse fibre at composition ranging from 0.25% – 1.0% are shown in Table 3, while the profiles are shown in Figure 3.

Table 3: Effect of bagasse fibre and cement composite on consistency limits

Fibre content (%)	Consistency limits (%)					
	Lateritic soil-LL	Lateritic soil-PL	Lateritic soil-PI	Clay soil-LL	Clay soil-PL	Clay soil-PI
0	35.81	16.84	18.97	56.29	22.43	33.86
0.25	36.51	16.93	19.58	54.57	23.85	30.72
0.5	35.66	17.31	18.35	52.94	24.78	28.16
0.75	33.83	17.86	15.97	52.15	26.42	25.73
1	30.36	18.91	11.45	48.64	27.76	20.88

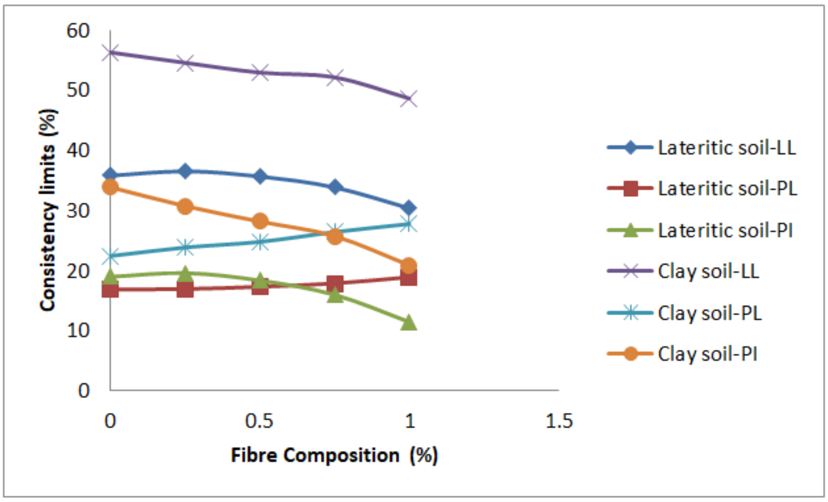

Figure 3: Plot of consistency limits versus bagasse fibre in cement stabilized soil

Figure 3 showed profiles of liquid limit (LL), plastic limit (PL) and plasticity index (PI) of lateritic and clay soils from Ubeta-Ula-Ubie road stabilized with 7.5% cement and 0 to 1.0% bagasse fibre. The results showed that LL in laterite and clay soils gradually decreases as the percentage of bagasse fibre was increased. Clay soil recorded higher percentage of LL compared to lateritic soil. The LL of 0% stabilized lateritic and clay soils were 35.81% and 56.29% respectively, but decreased to 30.36% for lateritic soil and 48.64% for clay soil as the bagasse fibre proportion was increased to 1.0% at fixed cement proportion of 7.5%.

Unlike liquid limit, the plastic limit (PL) in lateritic and clay soils increased consistently as the bagasse fibre proportion was increased. Again, clay soil recorded higher percentage in PL compared to lateritic soil. The PL of 0% stabilized lateritic and clay soils were obtained as 16.84% and 22.43% respectively, but increased to 18.91% for lateritic soil and 27.76% for clay soil as the bagasse fibre proportion was increased to 1.0% at fixed cement proportion of 7.5%.

Also, the plasticity index (PI) of Laterite and clay soils decreased as bagasse fibre was increased in the stabilized sample. Again, clay soil recorded a higher percentage in PI compared to lateritic soil. The PI percentage of 0% stabilized laterite and clay soil samples were obtained as 18.97% and 33.86% respectively, but decreased to 11.45% for lateritic soil and 20.88% for clay soil, as the bagasse fibre proportion was increased to 1.0% at fixed cement proportion of 7.5%. The behaviour of consistency limit of the soils was synonymous to reports from other studies on composite stabilization soil for pavement or road construction (Akobo *et al*., 2018; Charles *et al*., 2018; Ngekpe *et al*., 2018; Nwikina *et al*., 2018). The decrease in plasticity index was attributed to impact of stabilizer on soil (Jain *et al*., 2015; Kale *et al*., 2019; Bhardwaj and Sharma, 2020).

3.4 California bearing ratio (CBR)

The California bearing ratio (CBR) for unsoaked and soaked stabilized laterite and clay soils stabilized with fixed composition of cement at 7.5% and Costus lateriflorus bagasse fibre at composition ranging from 0.25% – 1.0% are shown in Table 4, while the profiles are shown in Figure 4.

Table 4: Effect of bagasse fibre and cement composite on CBR

Fibre content (%)	**CBR (%)**			
	Laterite soil unsoaked	Laterite soil soaked	Clay soil unsoaked	Clay soil soaked
0	9.25	8.55	8.67	7.28
0.25	13.25	11.91	11.73	10.25
0.5	15.35	12.71	12.83	11.85
0.75	17.15	15.33	15.13	14.98
1	14.75	13.51	13.23	12.55

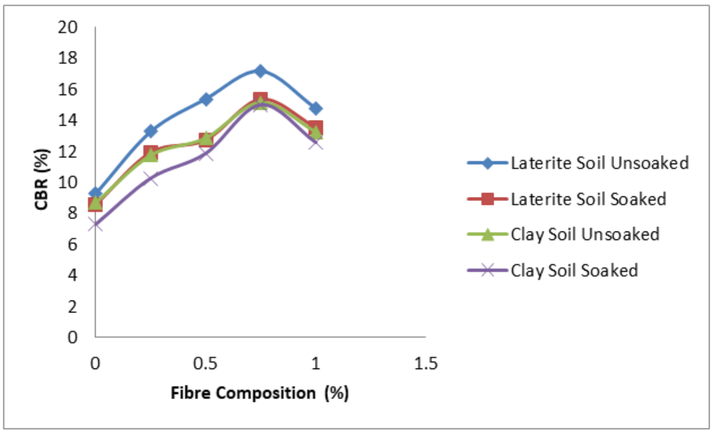

Figure 4: Plot of CBR versus bagasse fibre in cement stabilized soil

Figure 4 shows the profiles of CBR for unsoaked and soaked Laterite and clay soils stabilized with 7.5% cement and varying proportions of bagasse fibre from 0 – 1.0%. The CBR for unsoaked and soaked stabilized Laterite and clay soil increased with increase in bagasse fibre content to a maximum value at 7.5% bagasse fibre. From the recorded results, CBR for unsoaked 0% stabilized laterite and clay soil samples were obtained as 9.25% and 8.55%, while CBR for soaked 0% stabilized laterite and clay soil samples were recorded as 8.67% and 7.28%, respectively. The maximum CBR value was recorded at 0.75% bagasse fiber with fixed cement proportion of 7.5%. At this maximum value, the CBR was recorded as 17.15% for unsoaked Laterite soil, 15.13% for unsoaked clay soil, 15.33% for soaked Laterite soil and 14.98% for soaked clay soil. There was decrease in CBR beyond 0.75% proportion of bagasse fibre in the stabilized soils.

California Bearing Ratio (CBR) test is an important parameter for empirical estimation of soil bearing capacity under soaked and dry conditions (Tse and Ogunyemi, 2016). Thus, increase in CBR is an indication that the composite material is capable of improving the properties of soil for earthworks. Also, the results showed that the CBR of the soaked soils was lower compared to the unsoaked soil samples, implying that soaking reduces the strength of the soils. This observation agreed with other studies on CBR of stabilized soil (Okonkwo *et al*., 2016; Akobo *et al*., 2018; Charles *et al*., 2018; Ngekpe *et al*., 2018; Nwikina *et al*., 2018). However, the stabilized Laterite soil performed better than clay soil in terms of CBR.

3.5 Unconfined compressive strength of stabilized soil

The unconfined compressive strength (UCS) of Laterite and clay soils stabilized fixed composition of cement at 7.5% and Costus lateriflorus bagasse fibre at composition ranging from 0.25% – 1.0%, and cured for 28 days are shown in Table 5.

Table 5: Effect of bagasse fibre and cement composite on unconfined compressive strength

Fibre content (%)	UCS (kPa)	
	Laterite Soil	Clay soil
0	187.18	74.57
0.25	200.13	78.55
0.5	221.76	81.74
0.75	246.53	88.82
1	281.6	94.54

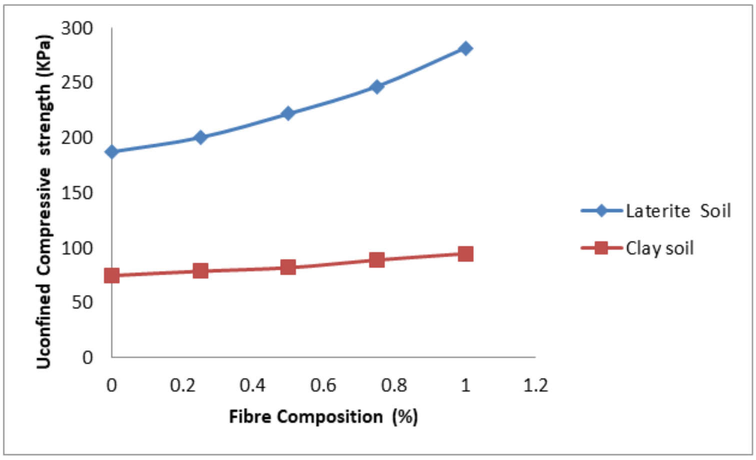

Figure 5: Plot of unconfined compressive strength versus bagasse fibre in cement stabilized soil

The profiles of unconfined compressive strength (UCS) of Laterite and clay soil samples stabilized with 7.5% cement and varying proportions of bagasse fibre from 0 – 1.0% are shown in Figure 5. From the profiles, UCS increased with increasing percentage of stabilized material. The test results presented in Table 5 showed that unconfined compressive strength of 0% stabilized Laterite and clay soil samples was 187.18kPa and 74.57kPa, but increased to 281.60kPa and 94.54kPa for lateritic soil and clay soil, respectively when bagasse fibre proportion increased to 1.0% at fixed cement proportion of 7.5%. The unconfined compressive strength in Laterite soil was far higher than those recorded in and clay soil at the corresponding percentage of bagasse fibre content in the stabilized soil.

The increase in UCS of soils due to addition of bagasse fibre and cement composite have also been reported in previous studies (Okonkwo *et al*., 2016; Akobo *et al*., 2018; Charles *et al*., 2018; Ngekpe *et al*., 2018; Nwikina *et al*., 2018). The increase in UCS value on addition of stabilizing materials was due to the transition of smaller size particles into large size particles, leading to more compact structure and densification (Kumar *et al*., 2016; Bhardwaj and Sharma, 2020).

4. CONCLUSION

Addition of cement and pulverized bagasse fibre composite in soil as stabilization material shows some appreciable changes in properties of soil after stabilization. Thus, maximum dry density (MDD), liquid limit (LL) and plasticity index (PI) of the stabilized Laterite and clay soils from Ubeta-Ula-Ubie road decreased with increasing percentage of Costus lateriflorus bagasse fibre at constant cement proportion, while optimum moisture content (OMC), plastic limit (PL) and unconfined compressive strength (UCS) increased.

The percentage of OMC and consistency limits of the clay soil were higher than the stabilized Laterite soil, while MDD, CBR and USC of Lateritic soil were higher compared to the clay soil sample. Based on results of the California Bearing Ratio (CBR) for unsoaked and soaked stabilized Laterite and clay soil, it is recommended that 0.75% bagasse fibre would be appropriate to obtaining good compaction of soil for road construction purpose.

REFERENCES

- Asnake, A. (2015). Assessment of road pavement Failure along Addis Ababa-Modjo Trunk Road. Addis Ababa, School of Graduate Studies, Addis Ababa University, Addis Ababa, Ethiopia.
- Awoke, S. J. (2014). Further investigation of road failures constructed on expansive soils of central ethiopia addis ababa-jimma road as a case study, School of Graduate Studies, Addis Ababa University, Addis Ababa, Ethiopia.
- Bhardwaj, A., & Sharma, R. K. (2020). Effect of industrial wastes and lime on strength characteristics of clayey soil, *Journal of Engineering, Design and Technology*, https://www.dx.doi10.1108/jedt-12-2019-0350 [15th December, 2021].
- Dong, Q., Huang, V., & Huang, B. (2013). Laboratory evaluation of utilizing waste heavy clay and foundry sand blends as construction materials, *Journal of Materials in Civil Engineering*, 26(9), 40-65.
- Ek.Serafimova, M. M. (2011). Study on the characteristics of waste wood ash, *Journal of Chemical Technology and Metallurgy*, 43, 31-34.
- Eltwati, A. S., Tarhuni, F., & Elkaseh, A. (2020). Engineering properties of clayey soil stabilized with waste granite dust, *Journal of Critical Reviews*, 7(16), 794-802.
- Holtz, W. A. (1956). Engineering Properties of Expansive Clays, *American Society of Civil Engineers*, 121, 641-677.
- Jain, T., Yadav, G., Chandra, B., & Solanki, C. H. (2015). Comparative study of effect of waste material on black cotton soils in Surat region – a review, *Indian Geotechnical Conference*-2015, Pune, 12.
- Jawad, I. B., Taha, M. R., Majeed, Z. H., & Khan, T. A. (2014). Soil stabilization using lime: advantages, disadvantages and proposing a potential alternative, *Research Journal of Applied Sciences, Engineering and Technology*, 8(4), 510-520.
- Kale, R. Y., Wawage, R., & Kale, G. (2019). Effect of foundry waste on expansive soil (black cotton soil), *International Journal for Scientific Research and Development*, 7(2), 1800-1804.
- Kumar, A., Kumari, S., & Sharma, R. K. (2016). Influence of use of additives on engineering properties of clayey soil, *Proceedings of National conference: Civil Engineering Conference-Innovation for Sustainability* (*CEC-2016*).
- Mgangira, M. B., & Jones, G. A. (2006). Laboratory assessment of the influence of the proportion of waste foundry sand on the geotechnical engineering properties of clayey soils, *Journal of the South African Institution of Civil Engineering*, 48(1), 2-7.
- Nikodimos-Bekelle, B. C. (2017). Investigation of causes of sever asphalt damage on road pavement in Addis Ababa-Jimma Trunk Road, *International Journal of Scientific & Engineering Research*, 7, 827-834.
- Okagbue, C. O. (2007). Stabilization of Clay Using Wood ash. ascelibrary.org. Retrieved from ASCE.
- Okonkwo, U. N., Agunwamba, J. C., & Iro, U. I. (2016). Geometric models for lateritic soil stabilized with cement and bagasse ash, *Nigerian Journal of Technology*, 35(4), 769-777.
- Tse, A. C., & Ogunyemi, A. O. (2016). Geotechnical and chemical evaluation of tropical red soils in a deltaic environment: implications for road construction, *Journal of Geography and Geology*, 8(3), 42-51.
- Usha, M., & Rani, J. J. (2016). Analysis of strength characteristics of black cotton soil using wood ash as stabilizer. 56-65.