

Geotechnical Properties of Bagasse Ash Stabilized Black Cotton Soil

D. W. Dauda^a, J. Edwin^b, U. N. Wilson^c and M. O. Ibrahim^d

^aDepartment of Civil Engineering, Federal Polytechnic Ede, Osun, Nigeria

^bDepartment of Civil Engineering, Ahmadu Bello University, Zaria, Nigeria

^cDepartment of Civil Engineering, Nigerian Defence Academy, Kaduna, Nigeria

^dDepartment of Mechanical Engineering, Ahmadu Bello University, Zaria, Nigeria

Corresponding Author: idealihotu@gmail.com

ARTICLE INFO

Received: December, 2019

Accepted: March, 2020

Published: July, 2020

Keywords:

Stabilization

Bagasse Ash

Black cotton soil

Geotechnical properties

ABSTRACT

Black Cotton Soil in itself, possesses no suitable engineering property for engineering purposes, hence, the need to stabilize the soil so as to achieve the desired goal of improving the soil's geotechnical properties using Bagasse Ash. This study focused on stabilizing Black Cotton Soil (BCS) with Bagasse Ash (BA) by dry weight, in stepped concentrations of 0, 4, 8, 12 and 16 %. Laboratory tests such as Atterberg limits, Compaction tests making use of British Standard Light (BSL) compaction energy and Consolidation tests were conducted on both the natural and treated soils in conformance to relevant standards. Results of the experiment carried out shows that BCS is Greyish black inorganic clay of medium plasticity. The Atterberg limits exhibited improved index properties, the compaction and the consolidation parameters as well exhibited appreciable changes. The geotechnical properties of the stabilized soil were seen to have optimum results at 8% addition of bagasse ash.

1. INTRODUCTION

The soil mass as a whole is very large, hence, the thought that it can carry any load is not entirely an understatement but this statement in itself is limited to the soil properties because in most cases, soils in their natural state do not possess sufficient geotechnical properties to be used in many civil engineering works. Expansive soils like black cotton soil (BCS) which is obtainable in the North-Eastern area of Nigeria in West Africa, have a high content of the clay mineral 'montmorillonite'. This type of clay mineral makes the soil have a low permeability, a low bearing capacity, and high change in volume and also makes it to behave in a manner such that upon wetting, it swells and upon drying, it shrinks. This alternate swelling and shrinkage causes rigid structures such as buildings, highway pavements, embankments, etc., to seriously crack and fail and with respect to highway pavements, the pavement rises and falls along its own grade because of the soil underneath, thus making the road pavement to wobble and crack which later leads to its total disintegration and washing away. As a result, the soil is rendered unfit for construction of embankments and other engineering structures (Osinubi *et al.*, 2009; Eberemu, 2008; Das, 1998; Bowles, 1979).

Therefore, because of this nature and properties of BCS, options of improving the properties of the soil have been developed by various researchers worldwide though there are factors that are normally considered in the use of such options which include availability, cost, accessibility, location and workability. Nevertheless, there are materials that have been used to improve the properties of BCS such

as cement and lime, pozzolanic admixtures like bagasse ash (BA), saw dust ash, locust bean waste ash, rice husk ash, groundnut shell ash, etc., by various means and one of such means is by stabilization method. Stabilization is a technique aimed at increasing or maintaining the stability of soil mass or otherwise increasing its engineering properties (Moses, 2008). Cheaper but efficient materials are thus needed for soil modifications especially for poor soils. As a basis, since the bagasse (matted-cellulose fibre residue from sugar cane which has undergone some processes in a Sugar mill) ash is cheap, its use will be economically viable (Ola, 1974).

Most researches have been based on the combination of bagasse ash and other chemicals or cementitious materials to stabilize black cotton soil but this study seeks to find out the geotechnical properties of bagasse ash stabilized black-cotton soil and the percentage of bagasse-ash required to produce maximum results.

2. METHODOLOGY

2.1 Materials

Black cotton soil

The BCS sample was obtained from Deba local government area in Gombe State. The soil was excavated from a depth of not below 0.5m so as to avoid organic materials that would be incorporated into the sample being collected as a disturbed sample. A portion of the sample was packaged in sealed plastic bags in order to maintain the soil's moisture content at the time of collection, for test in the laboratory. The obtained soil sample was dried and pulverized into smaller particles passing through BS No. 4 sieve before laboratory tests were conducted.

Bagasse ash

The bagasse needed for this research was obtained from Zaria city, Zaria local government area of Kaduna state. The bagasse was dried and burnt into ash in open air under atmospheric conditions, sealed up and taken to the laboratory. The ash was first sieved locally to remove coarse particles and then sieved using sieve No. 200 (75 μ m aperture) and stored in an air tight container to prevent hydration during its storage.

2.2 Methods

Atterberg Limits

The Atterberg limits which include the determination of liquid and plastic limits, and plasticity index, were carried out in conformity to Test 1(A), BS 1377 Part 2 (1990) standard.

Compaction Test

The compaction test was conducted on the BCS treated with 0, 4, 8, 12 and 16 % bagasse ash, using British Standard Light (BSL) compaction energy effort. Each sample was compacted in a British Standard mould with a 2.5kg rammer left to fall freely from a height of 300mm. The samples were compacted uniformly in three layers, with each of the layer given 27 blows. At the end of the compaction, the top of the mould was trimmed to form a levelled edge so as to remove the excess projected soil. The mould with the soil sample were weighed. The compacted soil was then extracted from the mould and a representative soil sample was taken from the top and bottom of the mould for determination of moisture content.

Consolidation Test

The Consolidation tests were conducted in conformance with the procedure specified by BS 1733; part 5 (1990). Loading pressures of 50.0, 100.0, 200.0, 400.0, and 800.0 kN/m² and unloading pressures of 800.0, 400.0, 200.0, 100.0, and 50.0 kN/m² were used.

3. RESULTS AND DISCUSSION

Properties of Materials

The natural soil was classified as an A-7-5 (39) soil and CH group based on AASHTO classification system standard, (1986) and in the Unified Soil Classification System – USCS (ASTM, 2000). Also using the Nigerian General Specifications (1997), it is a Greyish black soil with inorganic clay of medium plasticity. The soil has a liquid limit of 59 %, plastic limit of 28.31 %, plasticity index of 30.69 %, specific gravity of 2.38 with 85.9 % of the soil passing through No. 200 BS Sieve. The natural black cotton soil's properties are summarized in Table 1, while its particle size distribution is shown in Figure 1.

Table 1: Properties of the natural black cotton soil

Property	Quantity
Natural Moisture Content %	16.8
% Passing No.200 BS Sieve	85.9
Liquid Limit, %	59
Plastic Limit, %	28.31
Plasticity Index, %	30.69
Specific Gravity	2.38
AASHTO	A-7-5
Group Index	39
USCS	CH
Maximum Dry Density, Mg/m ³	1.38
Optimum Moisture content, %	25.73
Colour	Greyish Black

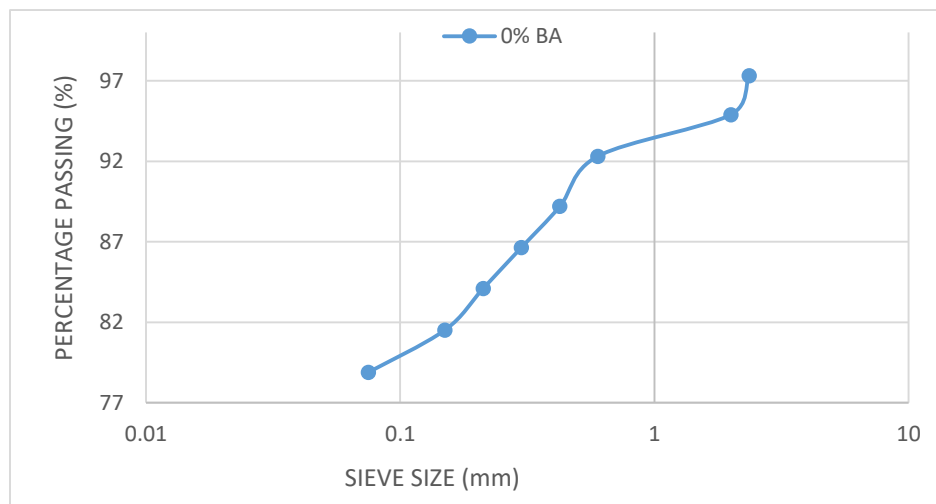


Figure 1: Particle Size Distribution Curve for the Natural Black Cotton Soil

Specific Gravity

The variation of the specific gravity of treated black cotton soil with different bagasse ash content is seen in Figure 2. The incorporation of bagasse ash into the natural soil resulted in the specific gravity decreasing from 2.38 for the natural soil to 2.15 at 16% bagasse ash content. This implies that the density of the minerals that makes up the individual soil particles is low. Specific gravity of a higher value gives more strength for roads and foundations (Surendra and Sanjeev, 2017).

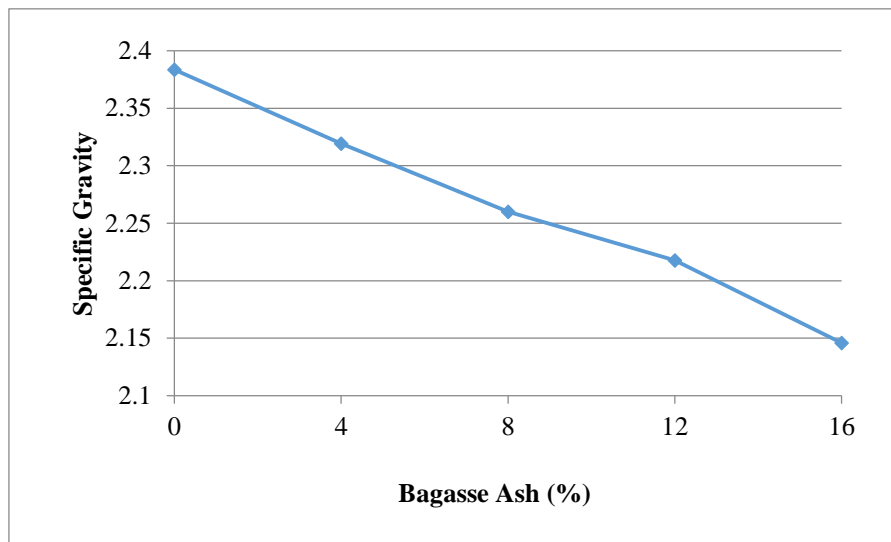


Figure 2: Variation of specific gravity with BA content

Atterberg Limits

The liquid limit of the soil-bagasse ash mixture increased with increasing bagasse ash content (0 – 16 %), from 59 % to 69.5 %. The possible explanation of this increase could be that as the content of bagasse ash increased, it supported flocculation and aggregation of the clay particles. As a result of the agglomeration of the clay particles, the effective grain size increased, hence, the agglomeration transformed clayey soil to silt, increasing the liquid limit of the soil due to the lowered surface area. The general increase in liquid limit at all soil-bagasse ash combination can also be attributed to the fact that the bagasse ash experienced pozzolanic reaction with the lime in the soil forming compounds possessing cementitious properties with soil particles, thus requiring additional water for hydration. The plastic limit of the soil-bagasse ash mixture decreased with increasing bagasse ash content (0 – 16%), from 28.31% to 20.17%. This was due to the effect bagasse ash had on the modified soil. The plasticity index of the soil-bagasse ash mixture increased with increasing bagasse ash content (0 – 16%), from 30.69% to 49.33%. This could be due to the increase in the fine fraction which absorbed more water and became more plastic. The variation of liquid limit, plastic limit and plasticity index of black cotton soil with bagasse ash contents are seen in Figure 3 – 5 respectively.

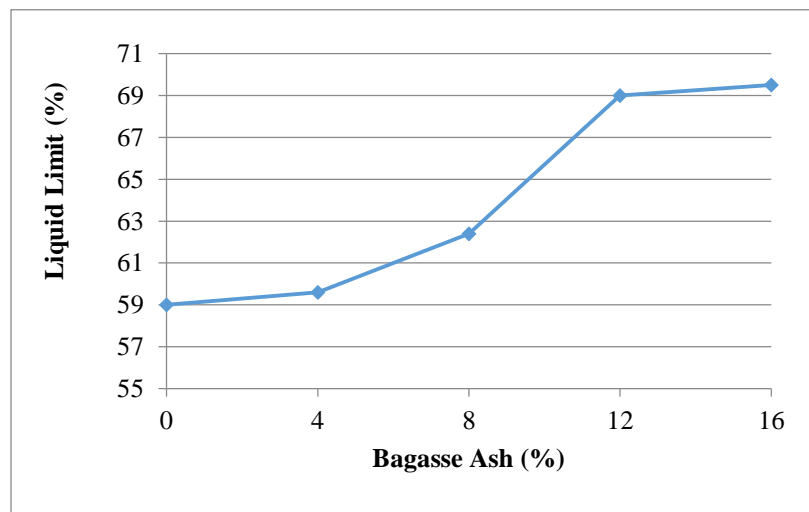


Figure 3: Variation of liquid limit of BCS with BA content

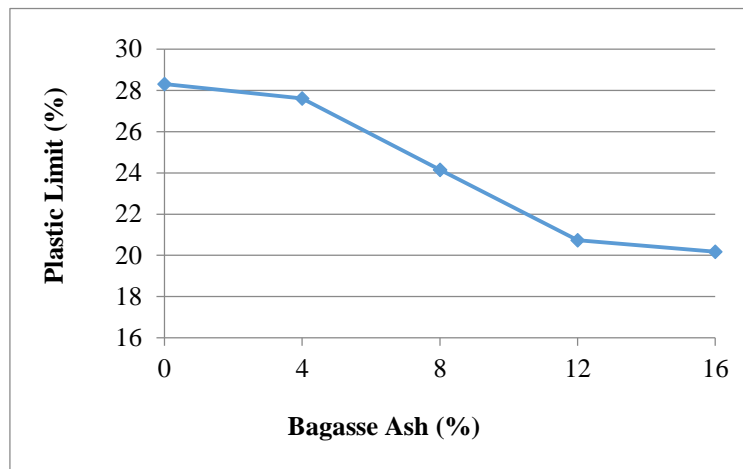


Figure 4: Variation of plastic limit of BCS with BA content

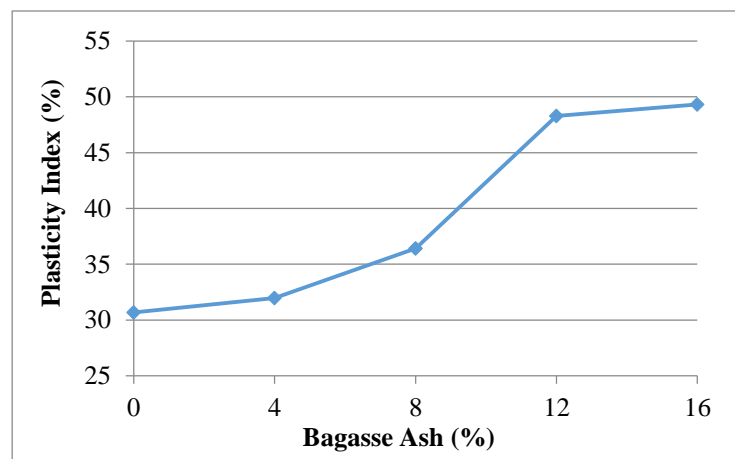


Figure 5: Variation of plasticity index of BCS with BA content

Compaction characteristics

The maximum dry density (MDD) and optimum moisture content (OMC) of the treated soil with varied bagasse ash contents are shown in Figures 6 and 7 respectively. The results indicate a decrease in the MDD and an increase in the OMC with increasing bagasse ash content. The decrease in the MDD from 1.38 Mg/m³ for the natural soil to 1.31 Mg/m³ for soil treated with 16 % bagasse ash can be ascribed to the bagasse ash particles having a specific gravity of 2.15 relatively lower compared to that of the soil it is replacing; and the increase in the OMC from 25.73 % for the natural soil to 30 % for 16 % bagasse ash treatment of soil is as a result of more water needed for the hydration of bagasse ash. This agrees with Osinubi (1995) and Eberemu *et al.* (2015).

Properties of Consolidation

The consolidation properties of the treated soil were observed by estimating the following: the coefficient of volume compressibility, coefficient of consolidation, void ratio and the pre-consolidation pressure. At all levels of treatment of BCS with BA, the coefficient of volume compressibility including the coefficient of consolidation as a whole, declined with increasing consolidation pressure. The Coefficient of Volume Compressibility decreased with increasing Pressure. The initial load increment causing the soil to reach very large compression by expelling voids could be a reason for the decrease, and so with further increase in the loading pressure, a little amount only of compression is then achieved. This is related to what was obtained by Eberemu *et al* (2013), when he researched on the compressibility of compacted black cotton

soil treated with rice husk ash. With respect to bagasse ash content, the coefficient of volume compressibility decreased from 0 to 4 %, increased upon 8 % addition and finally decreased from 8 to 16 %. This could be probably due to the pozzolanic nature and reaction taking place, as agreed with Eberemu (2011). The variation of the coefficient of volume compressibility with pressure is seen in Figure 8.

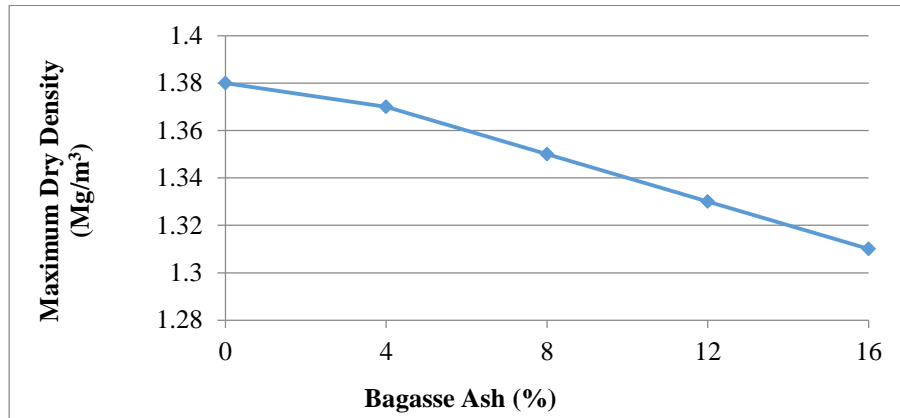


Figure 6: Variation of MDD with BA content

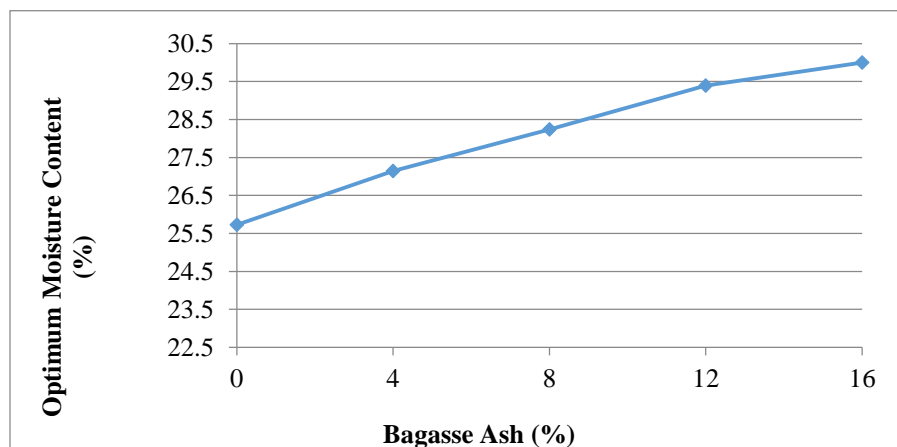


Figure 7: Variation of OMC with BA content

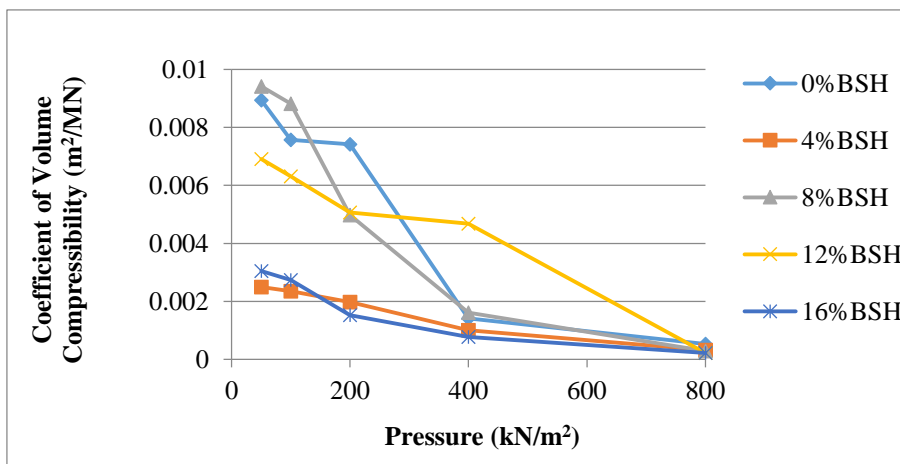


Figure 8: Variation of Coefficient of Volume Compressibility with Pressure

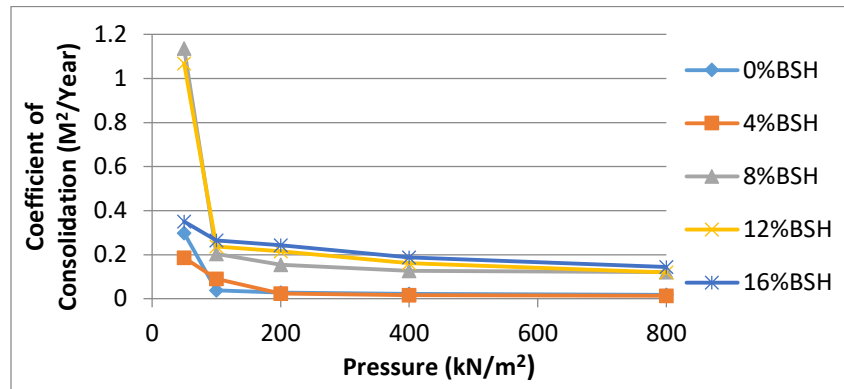


Figure 9: Variation of Coefficient of Consolidation with Pressure

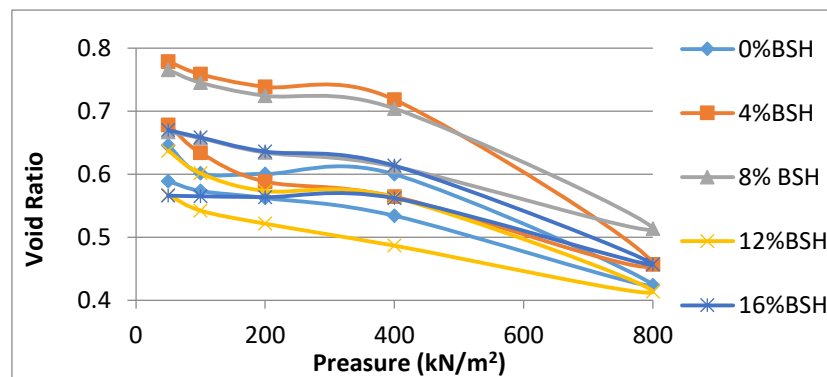


Figure 10: Variation of Void Ratio with Pressure at different BA content

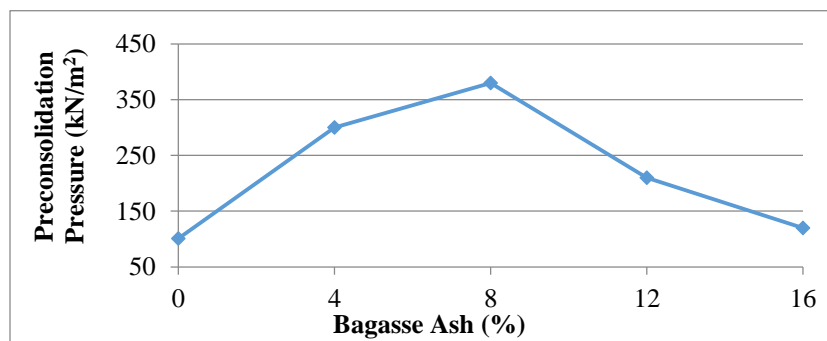


Figure 11: Variation of Pre-consolidation Pressure with BA content

Coefficient of Consolidation decreased with increasing Pressure and increased with increment in bagasse ash content. The variation of coefficient of consolidating, with pressure is seen in Figure 9. Figure 10 shows the variation of the void ratio with pressure at different bagasse ash content. The results depicts a similar pattern as that of natural clay. There was decrease in void ratio as pressure increased in the loading stage from 50 kN/m² to 800 kN/m² and it increased as pressure was reduced in the unloading stage. And this occurred for all the levels of soil treatment with BA. Eberemu *et al.* (2013) attributes this variation to be as a result of the soil particles adjusting themselves to fill up any present void when pressure is applied and during pressure release, causing a slight readjustment. Also, with respect to the bagasse ash treatment, there was an increasing and decreasing pattern of the void ratio curve, with no clear trend. These results depict that the black cotton soil's particle state as a result of the optimum moisture content, affects the void ratio adversely. The pre-consolidation pressure as seen in Figure 11, increased with increasing bagasse ash content from 0 to 8% and upon further increment of bagasse ash, it decreased down to 16 % owing to the

fact that the soil is able to withstand increase in pressure. Hence, it can be noted that the stabilizing of black cotton soil with up to 8% bagasse ash treatment can be used for optimal performance.

4. CONCLUSION

The black cotton soil is A-7-5 (39) and CH based on AASHTO classification and Unified Soil Classification System (USCS) respectively. From the results of the tests conducted on the natural and treated Black Cotton Soil with Bagasse Ash in stepped concentrations of 0, 4, 8, 12 and 16 %, the behavior of bagasse ash on the Atterberg limits of the Black cotton soil showed improved properties and as well, the compaction characteristics of the treated soil were improved at all concentrations of bagasse ash treatment. The Consolidation characteristics of the treated BCS with BA shows that 8% of BA treatment is the concentration to achieve best results. Hence, it can be concluded based on this research, that the treatment of Black cotton soil with Bagasse ash at 8% concentration will improve the Geotechnical properties of the compacted black cotton soil thereby making it suitable for engineering works and construction. It will furthermore reduce the environmental issues and problems that accompany waste disposal of Bagasse ash.

References

- AASHTO. Standard Specifications for Transport Materials and Methods of Sampling and Testing. 14th Edition, American Association of State Highway and Transport Officials (AASHTO), Washington, D.C, 1986.
- ASTM D2487-00, Standard Classification of Soils for Engineering Purposes (Unified Soil Classification System), ASTM International, West Conshohocken, PA, 2000, www.astm.org
- ASTM D4546-96, Standard Test Methods for One-Dimensional Swell or Settlement Potential of Cohesive Soils, ASTM International, West Conshohocken, PA, 1996, www.astm.org
- Bowels, J. E. (1979). Physical and Geotechnical Properties of Soil. 4th Edition, Publish Division of International Thomas publishing London.
- B.S. 1377(1990). Method of Testing Soil for Civil Engineering Purposes. British Standards, London.
- Das, B. M. (1998). Principles of Geotechnical Engineering. 4th Edition, PWS Publish Division of International Thomas publishing London.
- Eberemu A. O. (2008). Evaluation of Bagasse Ash Treated Lateritic Soil as a Suitable Material for Waste Landfill Barrier. Unpublished Ph. D. dissertation, Department of Civil Engineering, Ahmadu Bello University, Zaria.
- Eberemu, A. O. and Sada, H. (2013). Compressibility Characteristics of Compacted Black Cotton Soil treated with Rice Husk Ash. *Nigerian Journal of Technology*, 32(3): 507 – 521.
- Eberemu, A. O., Omajali, D. I. and Abdulhamid, Z. (2015). Effect of Compactive Effort and Curing Period on the Compressibility Characteristics of Tropical Black Clay Treated with Rice Husk Ash. *Geotechnical and Geological Engineering, an International Journal*, 33(6): 313-322
- Moses, G. (2008). Stabilization of Black Cotton Soil with Ordinary Portland Cement Using Bagasse Ash as Admixture. *IRJI Journal of Research in Engineering*, 5(3): 107-115.
- Nigerian General Specification (1997). Road and Bridge Works. Federal Ministry of Works, Abuja, Nigeria.
- Ola, S. A. (1974). Need for Estimated Cement Requirement for Stabilization of Laterite Soils. *Journal of Transportation Engineering. Division of ASCE*, 100(2): 379 – 388.
- Osinubi, K. J. (1995). Lime modification of black cotton soil. *Spectrum Journal*, Kaduna, 2(1 and 2): 112 – 122.
- Osinubi, K. J., Bafyau, V. and Eberemu, A. O. (2009). Bagasse Ash Stabilization of Lateritic Soil. In: Yanful E. K. (eds) *Appropriate Technologies for Environmental Protection in the Developing World*. Springer, Dordrecht. pp 271-278
- Surendra R. and Sanjeev K. B. (2017). Role of Geotechnical Properties of Soil on Civil Engineering Structures. *Resources and Environment*, 7(4): 103-109.