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Comparison of *Costus dewevrei De Wild. and T. Durand* Admixture with Lime and Cement in Soil Stabilization

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Abstract **Original Research Article**

The study investigated the use of cement and lime as composite mixture with *Costus dewevrei De Wild. & T. Durand* as for soil stabilization aimed at improving the properties of expansive soils used for road pavement. The maximum dry density (MDD), optimum moisture content (OMC), consistency limits, California bearing ratio (CBR) and unconfined compressive strength (UCS) of the soil were subjected test to ascertain the performances of the cement and lime with bagasse composite. The results showed that the composite materials improved the soil properties, but the maximum dry density (MDD), optimum moisture content (OMC), liquid limit (LL), plasticity index (PI), California bearing ratio (CBR) and unconfined compressive strength (UCS) of the expansive soil stabilized with cement and bagasse ash composite were greater than the soil samples stabilized with lime and bagasse ash composite. Meanwhile, the value of plastic limit (PL) obtained from the soil sample stabilized with lime and bagasse ash was higher than the value recorded in the soil sample stabilized with cement and bagasse ash. The optimum values UCS and CBR were recorded at 8% combined proportion of bagasse ash with cement and lime. Therefore, the improvement recorded in the soil properties proved that the combined effect of bagasse ash obtained from *Costus dewevrei De Wild. & T. Durand* and cement or lime, is effective and can be applied as stabilization material to reduce shrinkage and swelling of expansive soil that often lead to road pavement failure.

Keywords: soils, road pavement, cement and lime, *Costus dewevrei De Wild. and T. Durand*.

1. INTRODUCTION

In areas where expansive soil forms the bulk of the soil alignment, pavement construction tends to be relatively expensive. This is due to the additional costs required to repair such a foundation. Soil that is not suitable for road construction can be corrected through a process called stabilization. Stabilization improves poor soil properties. Soil stabilization is the modification or maintenance of one or more soil properties to improve the technical properties and performance of the soil. Stabilization in a broad sense includes various methods used to modify soil properties to improve its technical performance. Soil stabilization also refers to the process of adding special soils, cementitious materials, or other chemicals to natural soils to improve one or more of its properties. Stabilization can be achieved by mechanically mixing the native soil and stabilizing agent.

Achieving a homogeneous mixture or by adding a stabilizer to an undisturbed soil deposit and achieving interaction by allowing it to penetrate voids in the soil (Habiba, 2017). It is the addition of additives to the soil to improve its technical characteristics. The most common stabilization method is the use of lime and cement. Due to the various negative effects of using cement, research has been carried out to identify more environmentally friendly and cost-effective additives that can be used as partial substitutes.

Cement stabilization occurs during the compaction process. As cement fills the spaces between soil particles, the fraction of soil voids decreases. When water is then added to the floor, the cement reacts with the water and hardens, increasing the unit weight of the floor. As cement hardens, the shear strength and load bearing capacity also increase (EuroSoilStab, 2002). This cementing effect is similar to that of lime with soil. The effect of cement on clay minerals is to reduce the liquid limit, plasticity index and potential volume changes, as well as increase the shrinkage limit and shear strength (Croft, 1967). Mixing cement and soil with a certain particle size distribution is necessary to ensure good contact between soil and cement particles and thus effective stabilization of soil cement.

Melese (2018) conducted a comparative review of soil stabilization using a combination of bagasse ash with lime and another combination of molasses with cement. It was concluded that the soil treated with the combination of cement and molasses gave a significant increase in strength and reduced the expansion properties of the expansive soil significantly more than the individual treatments with cement alone or molasses alone. The combination of cement and molasses is effective in inhibiting linear shrinkage and eliminating shrinkage cracks that occur on cement floors alone. Soil treated with 4% bagasse ash and 12% cement gave a CBR of 27.3% and 123%, respectively. Soil treated with 4% cement + 4% molasses and 12% cement + 4% molasses gave CBR of 63.5% and 127.5%, respectively. The 4% molasses cement + 4% cement test meets all regulatory requirements for soil stabilization. Stabilization with molasses and cement outperformed bagasse ash and lime stabilization in most of the tests performed.

Allan (2019) also investigated the performance of expansive soils modified with cement and molasses. The study was conducted on extensive clay samples from Jalan Lomori Mor, Nakapiripiriti District, with the addition of cement alone and a combination of cement and molasses at a concentration of 13% cement, 8% cement + 4% molasses, 6% cement + 8% molasses and 4% cement. + 4% molasses, each based on the dry weight of the soil. They concluded that adding cement to the soil sample resulted in a significant increase in strength and eliminated the swelling properties of the original soil. The application of molasses to the soil-cement mixture increases the reaction of the soil-cement with water, resulting in a larger grain size and increased soil strength. The addition of 4% molasses to 4% cement increased the 12.03% CBR of natural soils by 21.80% and reduced the PI of 51.5% of natural soils to 19.2%. Because of this; Soil stabilized with a combination of 4% molasses and 4% cement meets all specifications requirements as it also provides the lowest estimated cost compared to other molasses-cement combinations. In this study, the performance of cement and lime as composite mixture with bagasse ash obtained from *Costus dewevrei De Wild. & T.Durand* was investigated as potential admixture for improvement of expansive soil properties during stabilization.

2. MATERIALS AND METHODS

2.1 Soil Collection and Preparation

Soil samples were collected between 0.5 and 1.0m depth at different locations along Igwuruta road in Ikwerre Local Government Area of Rivers State. Lumps formed in the soil were crushed to reduce the size. The soil was washed severally to remove contaminants, dirt and other organic matters. Thereafter, the soil was sieved using 2.36mm sieve size.

2.2 Bagasse ash Preparation

Costus dewevrei De Wild. & T.Durand was collected from the bush and transported to the laboratory for further processing. The collected *Costus dewevrei De Wild. & T.Durand* was cut into pieces. The preparation was done according to the method described by Okonkwo *et al.*, (2016). Thus, the bagasse was calcined in an oven at 800ºC for about 2 hours, and then allowed to cool. The cooled calcined bagasse was milled using milling machine to fine powdered ash and then sieved with 75 microns sieve size.

2.3 Cement and Lime

Cement and lime were purchased in Mile 3 market, Port Harcourt, Rivers State.

2.4 Mix Preparation

The sieved bagasse ash was divided into portions and weighed at different weight from 8g to 24g. Similarly, different weights of lime and cement were obtained from 12 to 36g. The measured weights of bagasse ash, lime and cement were mixed to make a total proportion of the stabilizing materials in the soil samples at bagasse to binder (cement or lime) ratio of 2:3 (40% bagasse ash and 60% cement or lime). The corresponding total combined composite weight percents in the soil are 4, 6, 8, 10 and 12%. The detail of the mix design is shown in Table 1.

Table 1: Mix design of soil stabilization

Total mix (%)	Group I Mix: 60% cement and 40% Bagasse ash
0	500g natural soil + 0g cement + 0g bagasse ash
4	500g natural soil + 12g cement + 8g bagasse ash
6	500g natural soil + 18g cement + 12g bagasse ash
8	500g natural soil + 24g cement + 16g bagasse ash
10	500g natural soil + 30g cement + 20g bagasse ash
12	500g natural soil + 36g cement + 24g bagasse ash
	Group II Mix: 60% Lime and 40% Bagasse ash
0	500g natural soil + 0g lime + 0g bagasse ash
4	500g natural soil + 12g lime + 8g bagasse ash
6	500g natural soil + 18g lime + 12g bagasse ash
8	500g natural soil + 24g lime + 16g bagasse ash

10	500g natural soil + 30g lime+ 20g bagasse ash
12	500g natural soil + 36g lime + 24g bagasse ash

2.5 Tests Procedures

The experimental procedure for each laboratory test is conducted according to Standards for soil stabilization and analysis.

2.5.1 Optimum Moisture Content and Maximum Dry Density

The maximum dry density (MDD) and optimum moisture content (OMC) of the soil were determined from the natural moisture content and dry density analysis. Thus, the natural moisture content of the soil as obtained from the site was determined in accordance with AASHTO T99 (AASHTO, 1999). The sample as freshly collected was crumbled and placed loosely in the containers and were weighed together to the nearest 0.01g. A representative sample of natural soil as well as the composite soil samples was weighed and dried in the oven at temperature of 105±5°C for about 12 hours. The weight before and after drying was recorded. The moisture content is calculated as:

$$MC = \frac{w_o - w_d}{w_o} \times 100\% \qquad (1)$$

where: $MC =$ Moisture content (%), $w_o =$ weight of soil or composite soil samples before drying (g) and $w_d =$ weight dried soil or composite soil samples (g).

The dry weight obtained from the determination of moisture content was used to determine the dry density of the natural and composite soils. Each weighed dried soil sample was put into a density bottle. The bottle with soil content was dropped gently in a graduated cylinder filled with water. The volume of water displaced was recorded. The dry density is then calculated as the ratio of dry weight to the volume of water displaced.

$$\text{Dry density}\,(\text{g/cm}^3) = \frac{\text{Dry weight of sample}}{\text{Volume of sample displaced}} \qquad (2)$$

The values of dry density obtained were plotted against the natural moisture content. From this plot, the values of MDD and OMC of the soil were evaluated for each of the mix design.

2.5.2 Consistency Limits

The consistency limits of the soil at the various stabilizing mix proportions were carried out. They include liquid limit (LL), plastic limit (PL) and plasticity index (PI). The liquid limit is arbitrarily defined as the percentage of water content in soil that makes a soil start to behave like a liquid. About 120 grams of the filtered and air-dried sample will be collected from the filtered portion of the soil obtained. Distilled water was mixed with soil to form a homogeneous paste. The homogeneous portion of the paste is poured into Casagrande utensil cup and distributed in portions with a few taps of spatula. It is cut to a depth of 1 cm, and excess soil was returned to the disk. The bottom of the cup was divided by the diameter of the passing cutter through the nearest center line to make a sharp groove. The cup was then released at a crank speed of two revolutions per second until the two halves of the grinding cake are connected to each other a length of approximately (12mm) solely by flow. The number of strokes required to approximately (12mm) close the groove is recorded. A representative portion of the soil was removed from the beaker to determine the moisture content. The test was repeated three times for cleaning between 27 and 52 at different humidity levels.

The plastic limit test determines the lowest moisture content at which the soil becomes plastic. The initial drying and sieving procedure for liquid limit was followed for PL test. The PL test was determined by remolding repeatedly a small ball of the soil and manually rolling it out into a 1/8 in thread. The moisture content at which the thread crumbled before being completely rolled out was recorded and taken as plastic limit.

The plasticity index was determined by subtracting the value of PL from LL. Thus, PI is the difference between the liquid limit and plasticity limit. Thus, PI = LL – PL.

2.5.3 California Bearing Ratio (CBR) Test

The California Bearing Ratio (CBR) test was carried out according to AASHTO T99 for natural soils and mixtures of soil and composite materials (AASHTO, 1999). The CBR test was carried out on samples compacted at the optimum moisture content using the standard compaction test. Soil samples that have been compacted by the CBR matrix are immersed in a water bath for 7 days to obtain the submerged CBR value. In a cubic centimetre matrix, 5.0kg of soil, bagsse ash and lime was mixed at optimal moisture content. The sample was compacted in three layers with 56 tampering blows of 2.5kg. The CBR is obtained as a ratio of the force required to effect a given depth of penetration from a standard penetrator piston into a soil sample compacted at a known moisture content and density, up to the standard load required to achieve the same penetration depth in standard gravel sample. Mathematically, CBR is computed as:

$$CBR = \frac{\text{Test object load}}{\text{Standard gravel load}} \times 100\% \qquad (3)$$

2.5.4 Unconfined Compressive Strength

The unconfined compressive strength (UCS) 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.

3. RESULTS AND DISCUSSION

The results of the engineering properties obtained for maximum dry density (MDD), optimum moisture content (OMC), consistency limits, California bearing ratio (CBR) and unconfined compressive strength (UCS) of stabilized soil are discussed in this section.

3.2 Maximum Dry Density

The maximum dry density (MDD) of soil stabilized with the composite of cement and lime with bagasse ash has been analyzed.

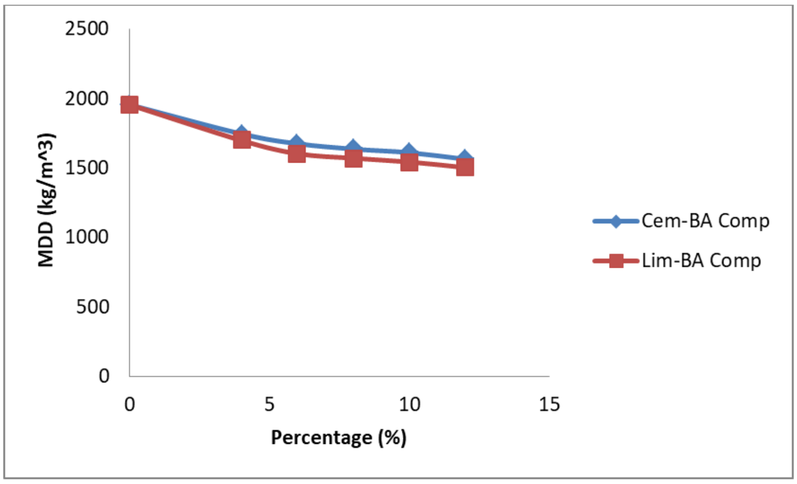

Figure 1: Plot of MDD versus bagasse in cement stabilized soil

Figure 1 showed the profiles of maximum dry density (MDD) at different percentage of cement-bagasse ash mix and lime-bagasse ash mix in the stabilized soil. MDD decreased with increasing proportion of the composite mixtures. Comparatively, MDD of the soil stabilized with cement-bagasse composite is slightly higher than the soil stabilized with lime- bagasse composite. The MDD of the 0% stabilized was obtained as 1956kg/m^3 and decreased to 1564kgm^3 and 1504kg/m^3 in soil stabilized with cement-bagasse and lime-bagasse composite, respectively at 12% proportion. The range of MDD values recorded in this study is similar to some reported studies on soil stabilization, particularly in the Niger Delta region (Omotosho and Eze-Uzomaka, 2008; Akobo *et al.*, 2018; Charles *et al.*, 2018; Ngekpe *et al.*, 2018; Nwikina *et al.*, 2018).

3.2 Optimum moisture content

The optimum moisture content (OMC) of soil stabilized with the composite of cement and lime with bagasse ash has been analyzed.

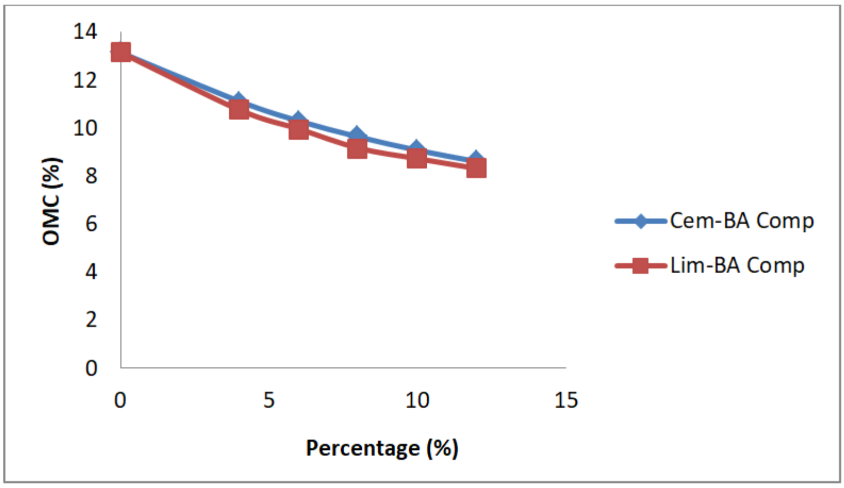

Figure 2: OMC versus stabilized soil composites

Figure 2 showed the profiles optimum moisture content (OMC) at different percentage of cement-bagasse ash mix and lime-bagasse ash mix in the stabilized soil. OMC decreased with increasing proportion of the composite mixtures. Comparatively, OMC of the soil stabilized with cement-bagasse composite is slightly higher than the soil stabilized with lime-bagasse composite. The OMC of the 0% stabilized was obtained as 12.79%, but decreased to 8.38% and 8.10% for soil stabilized with cement-bagasse and lime-bagasse composite, respectively at 12% proportion. Again, the range of OMC recorded in this study is within the range of values observed by some previous researchers for chemical or mechanical stabilization (Omotosho and Eze-Uzomaka, 2008; Essien and Charles, 2016; Okonkwo *et al.*, 2016; Akobo *et al.*, 2018; Charles *et al.*, 2018; Ngekpe *et al.*, 2018; Nwikina *et al.*, 2018; Bhardwaj and Sharma, 2020).

3.3 Consistency limits

The results of consistency limits **(**liquid limit (LL), plastic limit (PL) and plasticity index (PI)) of the stabilized composites of cement and lime with bagasse ash represented in Figures 3 to 5.

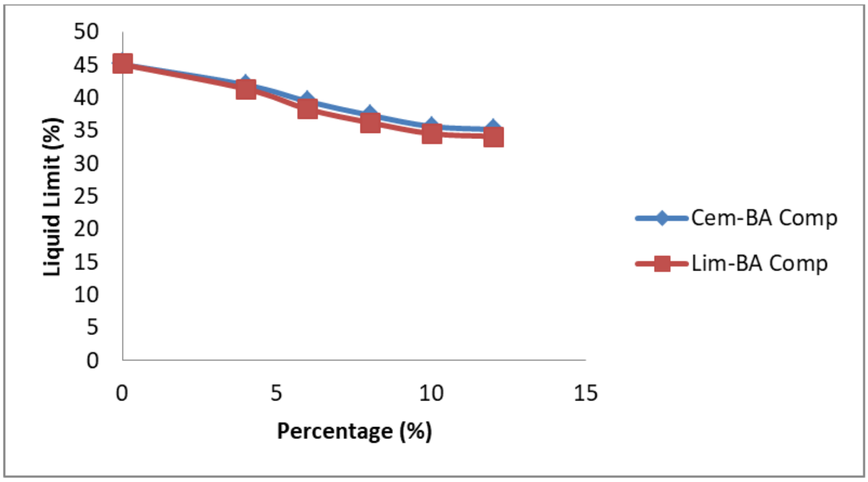

Figure 3: Liquid limit versus stabilized soil composites

Figure 3 showed the profiles of liquid limit (LL) at different percentage of cement-bagasse ash mix and lime- bagasse ash mix in the stabilized soil. The results showed that LL decreased with increasing proportion of the composite mixtures. Comparatively, the LL of the soil stabilized with cement-bagasse composite is slightly higher than the soil stabilized with lime-bagasse composite. The LL of the 0% stabilized was obtained as 43.88%, but decreased to 34.25% and 33.21% in soil stabilized with cement-bagasse and lime-bagasse composite, respectively at 12% proportion.

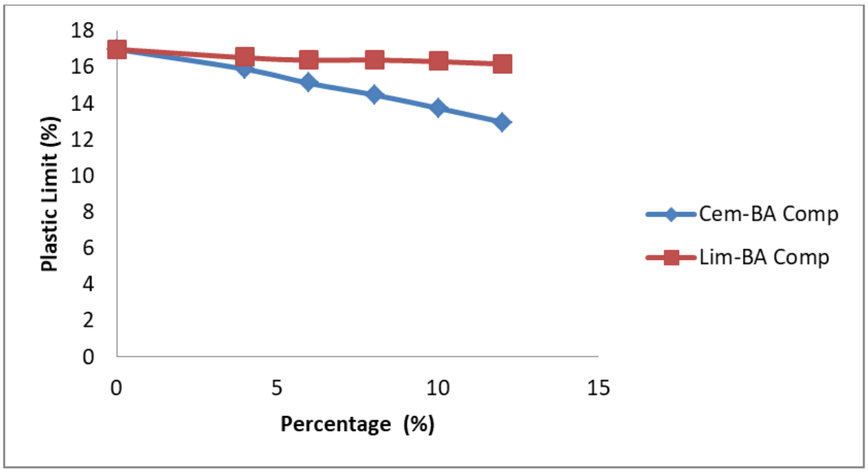

Figure 4: Plastic limit versus stabilized soil composites

Figure 4 showed the profiles of plastic limit (PL) of cement and lime stabilized soil at different weight percent of bagasse ash. The results showed that PL decreased with increasing proportion of the composite mixtures. Comparatively, the PL of the soil stabilized with cement-bagasse composite decreased higher than the soil stabilized with lime-bagasse composite. The PL of the 0% stabilized soil was obtained as 17%, and decreased to 12.98% and 16.19% in soil stabilized with cement-bagasse and lime-bagasse composite at 12% proportion, respectively.

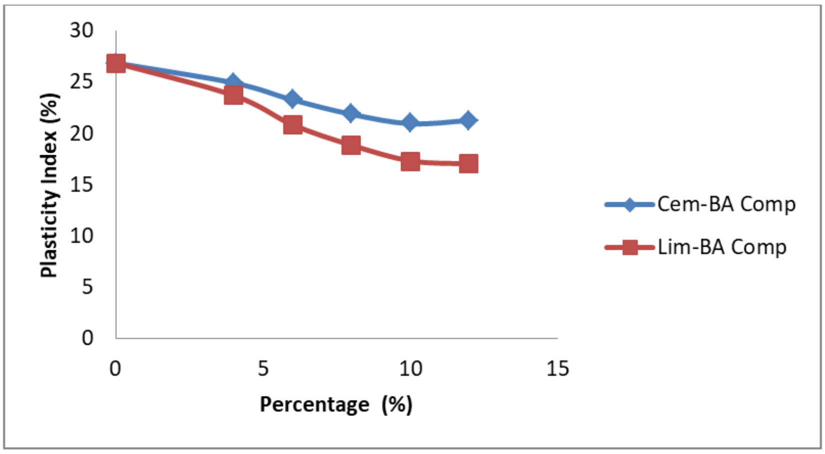

Figure 5: Plasticity index versus stabilized soil composites

Figure 5 showed the profiles of plasticity index (PI) at different percentage of cement-bagasse ash mix and lime- bagasse ash mix in the stabilized soil. The results showed that PI decreased with increasing proportion of the composite mixtures. However, at 12% of the composite mixture for cement and bagasse ash composite, the PI value increased slightly above the value recorded at 10%, but comparatively, the soil stabilized with cement-bagasse composite has higher value of PI than the soil stabilized with lime-bagasse composite. The PI for 0% stabilized soil was obtained as 26.88%, and decreased to lowest value of 20.95% and 17.02% in soil stabilized with cement-bagasse and lime-bagasse composite at 10% and 12% proportion, respectively. Generally, the trends in the consistency limits is similar to those obtained in other previous studies (Akobo *et al.,* 2018; Charles *et al.,* 2018; Ngekpe *et al.*, 2018; Nwikina *et al.*, 2018) which used bagasse ash or fibre from plant-based materials like the *Costus beckii maas* used in this study.

3.4 California Bearing Ratio

The California Bearing Ratio test is significant for practical evaluation of soil bearing capacity under soaked and dry conditions (Tse and Ogunyemi, 2016).

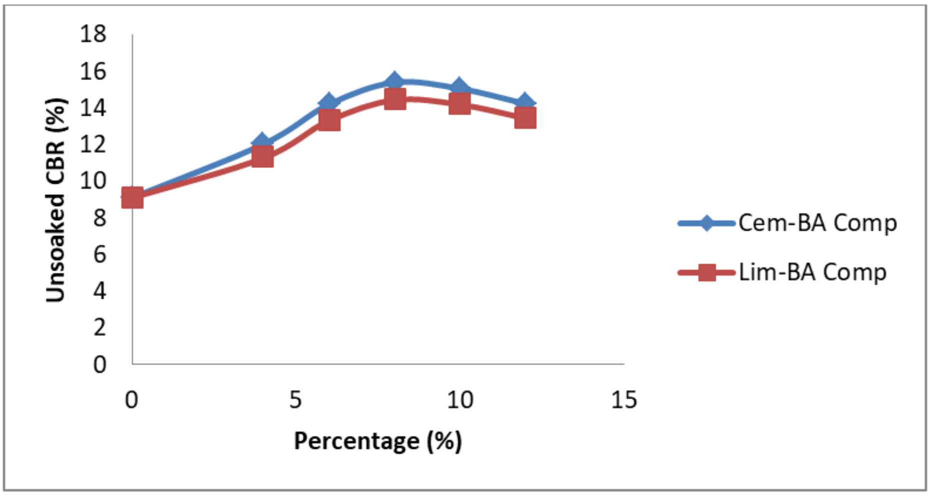

Figure 6: Plot of CBR for unsoaked sample versus stabilized soil composites

Figure 6 showed the profiles of CBR for unsoaked stabilized soil at different percentage of cement-bagasse ash mix and lime-bagasse ash mix in the stabilized soil. The CBR of unsoaked stabilized soil increased with increasing percentage of the composite mixture and attained a maximum value at 8%. Thereafter, there was a decline in CBR. From the results, the CBR of the unsoaked non-stabilized soil sample was as 9.11%. The maximum CBR for the unsoaked soil sample, which was recorded at 8%, is 15.40% for soil stabilized with cement-bagasse composite mixture and 14.44% for lime-bagasse composite mixture. However, the value of CBR at 12% composite mixture was 14.23% for soil stabilized with cement-bagasse composite and 13.44% for lime-bagasse composite.

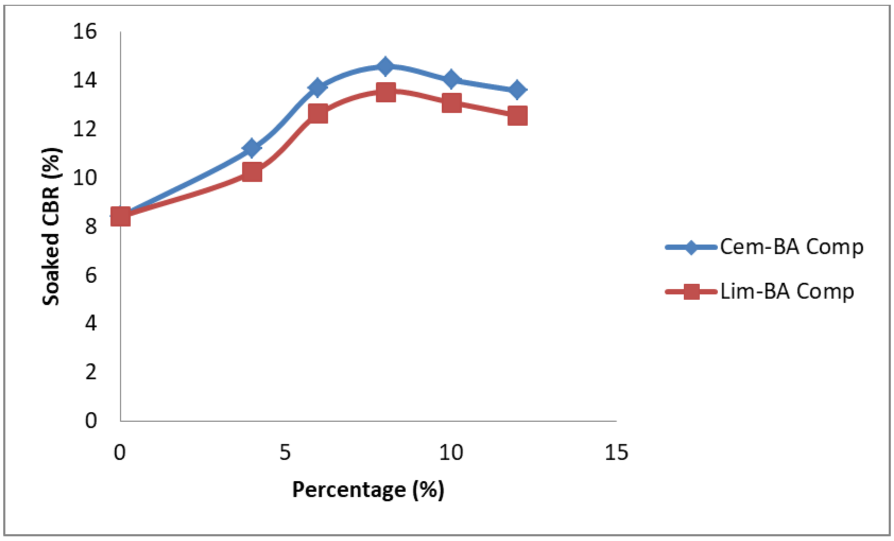

Figure 7: Plot of CBR for soaked sample versus stabilized soil composites

Figure 7 showed the profiles of CBR for soaked stabilized soil at different percentage of cement-bagasse ash mix and lime-bagasse ash mix in the stabilized soil. Like the unsoaked soil samples, the CBR of soaked stabilized soil increased with increasing percentage of the composite mixture and attained a maximum value at 8% before declining thereafter. From the results, the CBR of the soaked non-stabilized soil sample was as 8.41%. The maximum CBR for the soaked soil sample was recorded at 8%. Thus, the optimum value of CBR is 14.58% for soil stabilized with cement- bagasse composite mixture and 13.56% for lime-bagasse composite mixture. The CBR value recorded at 12% composite mixture was 13.59% for soil stabilized with cement-bagasse composite and 12.57% for lime-bagasse composite.

Studies have proven that increase in CBR for mechanical or chemical stabilization is an indication that the expansive soil has been amended, and that the material used for the stabilization has the capacity to improve the properties of the soil (Omotosho and Eze-Uzomaka, 2008; Okonkwo *et al.*, 2016). Thereby, application of such soil for road construction and other soil-bearing load will stand the test of time by suppressing the swelling and shrinkage characteristics of the soil. Further, this study shows that the CBR of the unsoaked soil sample is higher than the soaked soil sample, which is an implication that soil with high water content reduces the strength of soil compared to dry soil. This observation is in agreement with observations by previous researchers (Okonkwo *et al.*, 2016; Akobo *et al.*, 2018; Charles *et al.*, 2018; Ngekpe *et al.*, 2018; Nwikina *et al.*, 2018). Based on the CBR results, the soil stabilized with cement and bagasse ash performed better than soil stabilized with lime and bagasse ash.

3.5 Unconfined compressive strength of stabilized soil

Unconfined compressive strength (UCS) is an important property used in the determination of the performance of a stabilizing material such as cement, lime or any other material.

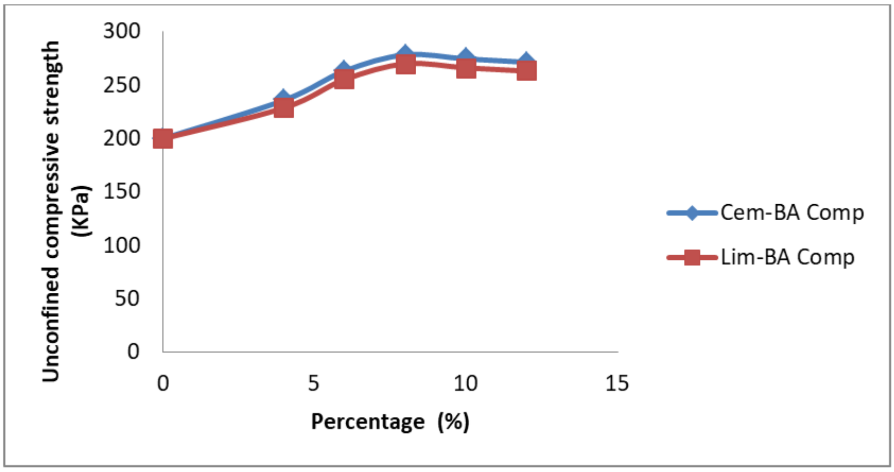

Figure 8: Plot of unconfined compressive strength versus soil composites

Figure 8 showed the profiles of unconfined compressive strength (UCS) at different percentage of cement- bagasse ash mix and lime-bagasse ash mix in the stabilized soil. The profiles showed that the UCS of the stabilized soil increased with increasing percentage of the composite mixtures. Like CBR, UCS of the stabilized soil increased with increasing percentage of the composite mixture and attained a maximum value at 8% before declining afterwards. From the result in Table 2, the UCS of the non-stabilized soil sample was as 199.87MPa. However, the maximum UCS was recorded at 8% with values obtained as 278.45MPa for soil stabilized with cement-bagasse composite mixture and 269.99MPa for lime-bagasse composite mixture. The UCS value recorded at 10% composite mixture was 274.59MPa for soil stabilized with cement-bagasse composite and 266.623MPa for lime-bagasse composite, but at 12%, the UCS value reduced slightly further to 271.48MPa for soil stabilized with cement-bagasse composite and 263.18MPa for lime- bagasse composite. Comparatively, the UCS of the soil stabilized with cement-bagasse composite is higher than the soil stabilized with soil stabilized with lime-bagasse composite. The strength improvement of the soil due to the addition of bagasse ash in cement and lime has equally been reported in previous studies (Kumar *et al.*, 2016; Okonkwo *et al.*, 2016; Akobo *et al.*, 2018; Charles *et al.*, 2018; Ngekpe *et al.*, 2018; Nwikina *et al.*, 2018; Bhardwaj and Sharma, 2020).

4. CONCLUSION

Inclusion of bagasse ash in cement and lime as composite material for soil stabilization improve the properties of swelling and shrinking soil. The soil maximum dry density, optimum moisture content and consistency limits of the expansive soil were reduced by the composite of cement-bagasse and lime-bagasse, which positively increased the California bearing ratio and unconfined compressive strength of the soil. The optimum performance of the cement- bagasse composite and lime-bagasse composite was recorded at 8% proportion. Comparatively, the soil stabilized with cement-bagasse composite performed better than the soil stabilized with soil stabilized with lime-bagasse composite. In spite of the disparity in performance, both lime and cement are suitable combination materials with bagasse ash from *Costus dewevrei De Wild. & T.Durand*. Therefore, stabilization of expansive soil can be combined with agricultural waste and cement or lime.

REFERENCES

- AASHTO (1999). Standard method of test for moisture-density relations of soils using a 2.5-kg (5.5-lb) Rammer and a 305-mm (12-in.) drop, AASHTO T 99.
- Akobo, I. Z. S., Iroaganachi, P. N., & Charles, K. (2018). Comparative strength evaluation of cementious stabilizing agents blended with pulverized bagasse fibre for stabilization of expansive lateritic soils, *Global Scientific Journal*, 6(12), 239-255.
- Allan, M., & Makomiku, C. (2019). A study on the performance of expansive subgrade soils modified with cement and molasses. Makerere University, Department of Civil and Environmental Engineering, Kampala.
- Bhardwaj, A., & Sharma, R. K. (2020). Effect of industrial wastes and cement on strength characteristics of clayey soil, *Journal of Engineering, Design and Technology*, https://www.dx.doi10.1108/jedt-12-2019-0350 [15th December, 2021].
- Charles, K., Nwikina, B. B., & Wokoma, T. T. T. (2018). Potential of cement, lime -costaceae lacerus bagasse fibre in lateritic soils swell–shrink control and strength variance determinations, *Global Scientific Journal*, 6(12), 273-290.
- Croft, J. (1967, June). The influence of soil mineralogical composition on cement stabilization. *Geotechique*, 17(2), 83-118.
- Essien, U., & Charles, K. (2016). Comparative stabilization and model prediction of geotechnical parameters of ebekpo residual soils, Akwa Ibom State, Nigeria, *Journal of Scientific and Engineering Research*, 3(1), 129-137.
- EuroSoilStab. (2002). Developement of Design and Construction Methods to Stabilize Soft Organic Soils; Design Guide for Soft Soil Stabilization. UK: IHS BRE Press. From https://www.brebookshop.com 29
- Habiba, A. (2017).A Review on Different Types Soil Stabilization Techniques. *International Journal of Transportation Engineering and Technology*, 3(2), 19-24.
- 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*).
- Melese, B. (2018). Review on soil stabilization using bagasse ash with lime and molasses with cement. Addis Ababa Science and Technology University, Addis Ababa.
- Ngekpe, B. E., Charles, K., & Ode, T. (2018). Evaluation of cement, lime and bagasse fibre ash waste admixture on swell –shrink control of road embankment materials, *Global Scientific Journal*, 6(12), 220-238.
- Nwikina B. B., Charles, K., & Amakiri–Whyte, B. (2018). Modification of expansive lateritic soils of highway subgrade with blended composite materials and performance characteristics, *Global Scientific Journal*, 6(12), 256-272.
- 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.

- Omotosho, O., & Eze-Uzomaka, O. J. (2008). Optimal stabilization of deltaic Laterite, *Journal of the South African Institution of Civil Engineering*, 50(2), 10–17.
- 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.