GEOTECHNICAL PROPERTIES OF CALABAR SOUTH SUBGRADE SOIL STABILIZED WITH SUGARCANE BAGASSE ASH

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ABSTRACT
In this study, attempts were made to use sugarcane bagasse ash (SCBA) to improve the engineering properties of Calabar South subgrade soil. The soil which was classified as clay with low plasticity under the USC system and A-6 under the AASHTO classification system has a specific gravity of 2.73 with a maximum dry density of 1.74 kg/m³ at an optimum moisture content of 24.5%. The soaked value of the California bearing ratio (CBR) was 6.92%. The soil was stabilized by adding SCBA at 0%, 5%, 10% up to 50% to stabilize the soil. It was observed that SCBA improved the soil’s plasticity by reducing liquid limit, plastic limit, and linear shrinkage. Compaction characteristics showed improvement by 5.2% as MDD increased from 1.74kg/m³ to 1.80kg/m³ at 10% optimal SCBA level with a corresponding reduction in OMC by 4.9%. CBR increased by 46.1% from 6.92% to 11.11% and the unconfined compressive strength (UCS) increased by 25.3% from 103.66KN/m² to 129.85KN/m². Shear strength increased by 25.3% from 58.83KN/m² to 64.93KN/m². The Secant Modulus, a measure of the stiffness of the soil, improved with increased stabilizer content. It was concluded that sugarcane bagasse ash has good potential for stabilizing the soil.

Keywords: Soil stabilization, sugarcane bagasse ash dust, Atterberg Limits, Maximum Dry Density, California Bearing ratio

1.0 INTRODUCTION
Stabilization is the process of combining and mixing elements with soil to improve the engineering properties such as reduction in plasticity and swelling potentials, improvement in dry density, shear strength, and bearing capacity. The method entails blending the soil to obtain the desired gradation which is mechanical stabilization or combining commercially available additives to change the gradation, texture, or plasticity of the soil or function as a binder for cementation in which case, is chemical stabilization. Foundation soils may be stabilized to increase their strength and durability while also reducing erosion and dust production. The main goal is to develop a soil material or system that can withstand design use conditions and the expected life of the engineering project. (Arpan and Rishabh, 2012).

Rimal et al. (2019) observed that stabilizers improve the load-bearing capability of a sub-grade to support pavements and foundations by increasing the shear strength of the soil and/or controlling the shrink-swell potential of the soil. From expansive clays to granular materials, stabilization can be utilized to treat a wide range of sub-grade materials. Higher resistance (R) values, less plasticity, lower permeability, and reduced pavement thickness are some of the benefits of adding these components to the stabilizing process. Geotechnical engineering and construction materials research is focusing on agricultural and industrial wastes that are locally available with disposal challenges. The use of various industrial and agricultural wastes as soil stabilizers has been reported by researchers, (Yadu et al., 2011; Okagbue, 2007; Bethlehem, 2015; Patrick, 2016; Ewa et al., 2016; Fazal et al., 2020).
Researches have been reported on cement kiln dust (CKD) as a chemical stabilizer. CKD increases the treated soils' engineering qualities and improves their performance as a foundation and construction material (Hesham, 2013; Vivek and Rajesh, 2015; Miller and Azad, 2000; Mohamed, 2002). According to Nishantha et al. (2020), CKD or a combination of Fly Ash (FA) and Lime Kiln Dust (LKD) can be used for long-term soil subgrade stabilization of all three soil types tested, whereas FA and LKD can be used as a short-term soil stabilizer in specific soil types (for construction facilitation). Sugarcane Bagasse Ash (SCBA), an agro-waste, has been studied extensively as a soil stabilizer. Utilizing SCBA in soil stabilization will address the environmental challenge associated with bagasse disposal. When soil containing kaolinite clay was stabilized with bagasse ash, the strength and index values improved to some extent, according to Athira and Sini (2019), which agreed with Kharade et al. (2014). Bagasse ash was ineffective as a "stand-alone" stabilizer, according to Osinubi et al. (2009), and should instead be used as an admixture stabilization, as a previous study found that unconfined compressive strength (UCS) values increased with increased lime and bagasse ash treatment of tropical black clay soil (Osinubi, 2006). Md. Atir et al. (2020) found that a mixture of 15 percent Bagasse ash and 4 percent lime was the best way to increase the compaction and strength of black cotton soil.

Rice husk ash (RHA), an agro-industry waste, has been researched as a soil stabilizer due to its pozzolanic properties. (Rahman, 1986), reported improvements in the unconfined compressive strength and the California Bearing ratio of lateritic soil treated with RHA up to 20%. (Alhassan, 2008) reported increased in both soaked and unsoaked CBR values for clay soil, treated with rice husk ash. Notwithstanding, Basha et al., (2005), RHA cannot be utilized as a stand-alone stabilizer in soil stabilization due to its lack of cementitious characteristics. In combination with lime or cement, RHA stabilization of clayey, silty clayey, clayey sandy, silty sandy soils resulted in increased in unconfined compressive strength, (Basha et al., 2005; Muntohar and Hantoro, 2000).

Limestone dust is a by-product of the cutting and polishing of limestone. It can be obtained as a by-product of the limestone crushing process for use as a by-product in the aggregates manufacturing process. The effects of gravel dust and limestone dust on clayey soil geotechnical characteristics were studied by Hassan et al. (2021). According to the findings, the Atterberg limits of clay decreased as the amount of dust particles increased. As the gravel dust content increased, the compaction properties of clay deteriorated. The MDD improved whereas the OMC dropped as the amount of limestone dust increased. Gravel dust, on the other hand, is deficient in calcium oxide.

The subgrade soils of Nigeria's Niger Delta are typically a soft deposit of clay with high plasticity, and they tend to change volume by swelling due to wetting and drying, resulting in foundation failure beneath the pavement construction, Ewa et al., (2016).

Sugarcane Bagasse Ash (SCBA) has not been used as a 'stand-alone' stabilizer for the Calabar South subgrade soil. In this study laboratory results of the use of SCBA as a stabilizing agent to Calabar subgrade soil to improve its engineering properties for construction purposes.

2.0 Material and Test Methods

2.1 Subgrade Soil used

The subgrade soil used for the investigation was collected within the Cross River University of Technology, (CRUTECH), on GPS coordinates of 425512.955E and 544220.535N 32N, in Calabar South Local Government Area. Depth of sampling was between 0.5 - 1m and then air-dried (see Figure 1a-b).
2.1 Stabilizer
Sugarcane Bagasse Ash (SCBA) was used as a stand-alone stabilizer to improve the geotechnical properties of the subgrade. The SCBA was obtained by burning sugarcane bagasse (see Figure 1c) from Mbukpa community located on the following GPS coordinates: N4°56'31.354"E8°18'59.722", in Calabar, Cross River State, Nigeria. Table 1 shows the chemical composition of the stabilizers used for the study.

Figure 1: (a) Sampling of soil (b) Air drying of soil sample (c) burnt sugarcane bagasse ash

Table 1 shows the chemical composition of the stabilizers used for the study.

<table>
<thead>
<tr>
<th>Mineral</th>
<th>% In SCBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al₂O₃</td>
<td>0.35</td>
</tr>
<tr>
<td>SiO₂</td>
<td>1.10</td>
</tr>
<tr>
<td>CaO</td>
<td>54.6</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>0.04</td>
</tr>
<tr>
<td>K₂O</td>
<td>-</td>
</tr>
<tr>
<td>MgO</td>
<td>0.06</td>
</tr>
<tr>
<td>Na₂O</td>
<td>-</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>-</td>
</tr>
<tr>
<td>CaCO₃</td>
<td>96.69</td>
</tr>
<tr>
<td>TiO₂</td>
<td>0.02</td>
</tr>
<tr>
<td>LOI</td>
<td>43.55</td>
</tr>
</tbody>
</table>

2.0 METHODOLOGY
The index properties of the soil were determined following BS1377 (1990). The stabilizer was added to the subgrade soil using the proportions shown in Table 1 to stabilize it. Atterberg Limits, particle size distribution, dry density, the California Bearing Ratio (CBR), secant Modulus, and an unconfined compressive test were all performed on the matrix. Figure 2 shows some of the experimental setups.

The modified proctor compaction test was performed for each mixture matrix in line with ASTM D698-12 (2021). Maximum dry density (MDD) and the related optimum moisture content (OMC) were then evaluated. Each sample was subjected to a 48-hour soak for the CBR test. A 4.5 kg mechanical hammer was used to compact each mixed matrix into the CBR mould. In line with ASTM D1883, compaction was done in three levels, each with 56 blows (2005). Unconfined compression strength was carried out in accordance with AASHTO...
- T 208 (2015), by applying axial stress to a cylindrical soil specimen with no confining pressure and observing the axial strains corresponding to various stress levels.

**Table 2: Mix Proportion**

<table>
<thead>
<tr>
<th>SN</th>
<th>Soil</th>
<th>SCBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>95</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>90</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>85</td>
<td>15</td>
</tr>
<tr>
<td>5</td>
<td>75</td>
<td>25</td>
</tr>
<tr>
<td>6</td>
<td>50</td>
<td>50</td>
</tr>
</tbody>
</table>

Figure 2: (a) USC set up. (b) Atterberg Limit set up, (c) drying oven used

### 3.0 RESULTS AND DISCUSSION

#### 3.1 Index Properties of Soil

Table 3 shows the soil’s index properties, while Figure 3 present the particle size distribution of the soil. The soil was classified as clay with low plasticity by the Casagrande Classification Chart, A-6 under the AASHTO classification, with liquid limits of 38.44 percent and a plasticity index of 15.2 percent. The optimum moisture content of the soil was 24.5 percent, the specific gravity was 2.73, with a maximum dry density of 1.74 kg/m³. The soaked California bearing ratio (CBR) of the soil was 6.92 percent.

**Table 3: Index properties of subgrade soil**

<table>
<thead>
<tr>
<th>Description</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid limit (%)</td>
<td>38.44</td>
</tr>
<tr>
<td>Plastic limit (%)</td>
<td>23.24</td>
</tr>
<tr>
<td>Plasticity index (%)</td>
<td>15.20</td>
</tr>
<tr>
<td>Linear shrinkage (%)</td>
<td>12.33</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>2.73</td>
</tr>
<tr>
<td>Percentage Passing BS Sieve 200 (0.075mm)</td>
<td>65</td>
</tr>
<tr>
<td>AASHTO classification</td>
<td>A- 6</td>
</tr>
<tr>
<td>USGS classification</td>
<td>CL</td>
</tr>
<tr>
<td>Maximum dry density (kg/m³)</td>
<td>1.74</td>
</tr>
<tr>
<td>Optimum moisture content (%)</td>
<td>24.5</td>
</tr>
<tr>
<td>Unconfined Compressive strength (KN/m³)</td>
<td>103.66</td>
</tr>
<tr>
<td>California bearing ratio (soaked) %</td>
<td>6.92</td>
</tr>
</tbody>
</table>
3.1 Atterberg Limits
The influence of SCBA stabilizer on the Atterberg limits properties of the subgrade is shown in Figure 4a. Liquid limit, plastic limit, and plasticity index all decreased with the addition of sugarcane bagasse ash as a stabilizer. These results are in line with Shimola (2018), where the liquid limit decreased with an increase in the dosage of bagasse ash. Linear shrinkage also decreased with the addition of SCBA as indicated in Figure 4b. These effects may be generated by the partial replacement of plastic soil particles with non-plastic bagasse ash, or by flocculation and agglomeration of clay particles caused by cation exchange, (Bethlehem, 2015).

3.2 Compaction characteristics
It can be seen from Figure 5 that maximum dry density (MDD) increased from 1.74 kg/m\(^3\) at 0% SCBA to 1.82 kg/m\(^3\) at 15% SCBA, after which a decline to 1.67 kg/m\(^3\) at 50% SCBA was observed. While OMC decreased from 23.5% at 0% SCBA to 22.3% at 10% SCBA, it then eventually increased to 26.02% at 50% SCBA. The drop in MDD could be due to the partial replacement of relatively heavier soil with light SCBA. It could also be because the soil is covered in bagasse ash, which causes coarse particles with greater spaces to form, lowering the density. The drop in density may be linked to the lower specific gravity of the bagasse ash, which replaces the higher specific gravity soil particles, as the stabilizer concentration increases. The fluctuation of OMC with bagasse ash indicates an increase from
untreated soil with greater bagasse ash to treated soil with lower bagasse ash. This could be due to the bagasse's great affinity for water. With an increase in SCBA content, the pozzolanic reaction of bagasse ash with the soil may be responsible for the increase in water content and decrease in MDD and an increase in OMC (Bethlehem, 2015; Amu, O. O., et al, 2011; Osinubi, et al., 2009).

3.3 California Bearing Ratio
The California Bearing Ratio (CBR) is used to assess the strength of soil subgrades and base courses. There was a remarkable improvement in the CBR of the subgrade as SCBA was added up to 25% as shown in Figure 6a. This could be attributed to the pozzolanic reaction of bagasse ash with dissolvable alumina and silica from the clay in the presence of water, which results in the formation of stable calcium silicate hydrate (CSH) and calcium aluminate hydrates (CAH), both of which generate long-term strength enhancement, (Ojeda-Farias, et al, 2018). As a result, the rise in CBR could be due to cation exchange, which causes flocculation and agglomeration. Kiran and Kiran (2012) reported similar increases in CBR and UCS when bagasse ash was used to treat the soil.

3.4 Unconfined Compressive Strength (UCS)
Figure 6b indicates that compressive strength increased as the quantity of bagasse ash is increased, with the highest strength attained at 10% bagasse ash substitution. As the percentage of bagasse ash increased, the compressive strength dropped. The creation of calcium silicates after the reaction of silica from SCBA with calcium from soil could explain the rise in UCS. The decrease in strength with increasing SCBA could be due to a lack of calcium in the soil to compensate for the excess silica in the additional SCBA (Kumar, et al. 2020). Grain size effect and specific gravity may also contribute to a decrease in strength.
3.5 Shear Strength and Secant Modulus

Both shear strength and secant modulus increased with increasing SCBA to a maximum of 64.93KN/m² and 7834Kpa respectively at 10% SCBA addition. Beyond this threshold, both shear strength and Secant modulus rapidly declined. The cementation effect and pozzolanic reaction generated by the soil and SCBA reaction with available moisture may account for the initial rapid increase in shear strength and Secant Modulus. As a result of the procedure, the link between soil particles will strengthen. While the decrease in shear strength caused by more bagasse ash may be attributable to less calcium in the soil available to react with the alumina and silica in SCBA, as well as the specific gravity of bagasse ash.

4.0 CONCLUSION

1. Sugarcane bagasse ash obtained by burning sugarcane bagasse is abundant in many parts of Cross River State and the utilization of bagasse ash for soil stabilization for construction purposes has not been given adequate attention.

2. Laboratory attempts have been made in this study to improve the geotechnical properties of Calabar South subgrade soil using sugarcane bagasse ash.

3. Liquid limit, plastic limit, and plasticity index all decreased generally as the sugarcane bagasse ash content increased.
4. The maximum dry density (MDD) of the soil increased while OMC reduced with an increase in the SCBA content. An optimal value of 15% was observed to have given the highest improvement to MDD.

5. California bearing ratio (CBR) increased with an increase in the bagasse ash content. 15% SCBA content was found to give maximum CBR value.

6. The unconfined compressive strength (UCS) and the Shear strength of the soil all increased with an increase in SCBA content. The optimal stabilizer content is 10%.

7. The stiffness of the soil being measured by the Secant Modulus experienced improvement with the addition of SCBA. A 10% optimal level of the bagasse ash content gave the highest stiffness value.

REFERENCES


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