Use of Sludge Ash in Stabilising Two Tropical Laterite

Adekemi L. AYODELE, Adedayo O. ADEBISI, Muraino A. KAREEM

Abstract— Soil samples were collected from two different locations in Ile-Ife, southwestern Nigeria. The index properties suc as specific gravity, liquid and plastic limits of the soil samples were determined. The compaction properties (Optimum moisture content, OMC and maximum dry density, MDD) and California bearing ratio, CBR were also determined. Sewage sludge was collected from an oxidation pond and burnt to obtain sewage sludge ash (SSA). The SSA was mixed in varying proportions (0. 2, 4, 8 and 16%) with thesoil samples fro the purpose of stabilization. The Liquid limit (LL), Plasticlimit (PL), OMC, MDD and CBR of each SSA-Soil mix were determined. Chemical analysis revealed that the SSA has a silica composition of about 45% and a low composition (2%) of calcium oxide. There was a reduction in the LL of both soil samples from about 49% to 46% on addition of 2% SSA. The LL later increased at 8% SSA. The highest change (114% increment) was recorded in the plasticity index of the soil samples. The OMC decreased from 19% to 16.75% for sample A at 4% and from 21.75 to 18.16% for sample B at 16% SSA. CBR of the soil samples generally increased with increasing SSA. There was improvement in the strength of the stabilized soil samples although no optimum percentage was obtained.

Index Terms—Atterberg's Limits, Compaction Properties, Sewage Sludge Ash, Soil Satbilisation, Southwestern Nigeria, Tropical Laterite, Waste disposal.

---

1 Introduction

THE crucial role of soil cannot be over emphasized in the construction of Civil Engineering projects. It is sad to note however, that many roads and buildings in Nigeria are in deplorable states thereby hampering the nation's development one way or the other (Owoseni and Atigro, 2014). Although failure in any cases can be caused by various factors, such as: excessive load; poor drainage conditions; construction defects; and poor engineering properties of sub-grade soils among others (Owoseni and Atigro, 2014). The poor engineering properties of soil have a great impact on failures. Owning to this fact, various researches have been carried and are still being carried out by individual, firms and institutions on ways to improve the geotechnical properties of soil (Amu et al., 2011). When the geotechnical properties of soil are improved by one way or another, the soil is said to be stabilised. Soil stabilisation from Geotechnical point of view is defined as the manipulation of the base soil to increase its load bearing capacity, reduce its lateral earth pressure on structures, or resist other stress changes induced by either physical or chemical mechanisms (Alshawabkeh and Sheahan, 2002). Karol (2003) also defined stabilisation as any change that renders the soil adequate for changed strength or permeability (or both) required by field construction.

Soil stabilization is achieved by alteration of the physical, mechanical and chemical properties of soil depending on the type of stabilisation. Mechanical stabilisation alters only the physical and mechanical properties of the soil while chemical stabilisation alters the chemical properties of the soil. Both methods of stabilisation are often used to achieve desired result.

Chemical stabilization is the modification of the soil properties with the addition of stabilisers and admixtures. It also involves the chemical reaction between stabilizer (cementitious material) and soil minerals to achieve the desired effect. Cementitious materials which are usually calcium based such as lime, fly ash e.t.c. are commonly used. There are four clear processes related to calcium-based soil stabilizer: cation exchange, flocculation and agglomeration, cementitious hydration, and pozzolanic reaction.

Sludge are largely inorganic ash residues (Gray and Penessis, 1972). Sludge usually accumulate in water and waste water treatment plants, oxidation ponds with a need to usually dispose off the accumulated sludge. Incineration is used by many plants as a means of sludge disposal. It results in a considerable volume reduction; nevertheless, an ash residue (40 to 60 percent by weight of air dried sludge) remains and must be disposed off (Gray and Penessis, 1972). So a means of putting the sludge or the sludge ash to beneficial use is usually explored.

According to Gray and Penessis (1972), after performing experiments on five different sludge ashes, it was discovered that the specific gravities of ash solids fell within a narrow range from 2.7 to 2.96 except one that with a low value of 2.44. Virtually all of the ashes were composed of predominantly silt-size particles (0.002 to 0.06 mm in diameter). Lin et al. (2005) concluded that the addition of sludge ash reduced the plasticity index (PI) and altered the soil type from mid plasticity to low plasticity, thereby leading to reduced swelling beha-

• *Adekemi L. Ayodele is currently a lecturer in the Department of Civil Engineering, Obafemi Awolowo University, Ile-Ife, Nigeria. E-mail: adekemiayodele@ymail.com*

ISSN 2229-5518

viour of the soil.

Tantawy et al (2012), determined the chemical compositions of sewage sludge ash incinerated at 800^{o}C by X- ray Fluorescence Analysis (XRF) and found that the sewage sludge ash high Al_2O_3, Fe_2O_3 and CaO contents due to the use of alum, ferric salts, and lime in wastewater treatment. This implies that the chemical composition of the sludge ash is a function of what is being treated and the chemicals used for the treatment.

The sludge accumulated in the oxidation pond of the Obafemi Awolowo university, Ile-Ife, Nigeria was recently removed and in a bid to put the removed sludge to beneficial use, the possibility of stabilising two laterite soil with sewage sludge ash was explored. The findings are discussed in this paper.

2 Experimental Methods

Soil samples were collected from two different locations in Ile-Ife, Nigeria. The soil samples were air dried in the laboratory to achieve partial elimination of natural water which may affect the final result of analysis.

Dewatered sewage sludge was collected from the oxidation pond of Obafemi Awolowo University, Ile-Ife, Nigeria. The sludge was also air dried to facilitate burning. Sewage sludge ash (SSA) was obtained by open burning of the sludge. The obtained SSA was then sieved through sieve No. 200 (with aperture size 75μm) and stored in an air tight container. Care was taken to prevent moisture from getting in contact with the SSA which could cause its hardening and loss of some of its properties. The physicochemical such as pH, specific gravity and composition of oxides in the SSA were determined.

Preliminary analysis such as Natural moisture content, specific gravity (ASTM D 854), pH, Atterberg's limits (Liquid Limit, LL and Plastic Limit, PL) (ASTM D 4318) and particle size distribution of the soil samples were determined according to American Society of Testing and Materials (ASTM, 2003). The result was used to classify the soil samples according to the Unified Soil and Classification System (USCS). The Optimum Moisture Content (OMC) and the Maximum Dry Density (MDD) were determined from compaction test (ASTM D 698) carried out on the soil samples. The California Bearing Ratio (CBR) of the soil samples was also determined (ASTM D 1883).

The SSA was then mixed in ratio 2, 4, 8 and 16% with the soil samples. The pH, Atterberg limits, OMC, MDD and the CBR of each mixt were then determined. The results obtained was used to analyse the effect of the SSA on the soil samples.

3 Results and Discussion

3.1 Physicochemical Properties of SSA

The pH and specific gravity of the SSA was obtained to be 3.33 and 2.2, respectively. The pH value of the SSA implies that it is acidic. The specific gravity of the SSA is lower than the specific gravity of most soil which shows that stabilisation of the soil samples with the SSA will be obtained through mechanical/physical means by the SSA filling the pores of the soil samples.

The percentages of some chemical oxides present in the SSA are presented in Table 1. The results show that the SSA contain very low percentages of iron and calcium oxides but a very high percentage of silicon oxide. Due to low calcium content in the SSA, chemical stabilization which usually requires supersaturation of calcium (Glendinning and Rogers, 1996) cannot be achieved when SSA is added to the soil samples. It is also further shown that whatever stabilization effect obtained on addition of SSA to the soil sample will be due to mechanical/physical stabilization.

Table 1: Chemical Analysis of Sewage Sludge Ash

Oxide	Composition (%)
CaO	2.02
MgO	0.089
Fe_2O_3	4.934
SiO_2	45.96

3.2 Preliminary Analysisi Results of the Soil Samples

The results of the preliminary analysis of the soil samples are presented in Table 2. Sample A has a higher natural moisture content than soil sample B. The natural moisture content is however not an intrinsic property of soil since its value is a function of climatic condition (such as temperature, amount, intensity and duration of rainfall), depth of excavation with the relief of the location. The specific gravities of the soil samples are within the usual range for soil samples according to Das (2006). The pH values of the soil samples show that both soil samples are acidic which is typical of laterite soils (Gidigasu, 1976).

The liquid limit (LL) of both soil samples are higher than 35% (the maximum requirement for a soil to be suitable as sub base material). These result also imply that both soil samples are of similar compressibility and swelling characteristics since the LL is closely related to the compressibility of soil. The plastic limit (PL) of both soil samples are high resulting in low plasticity index (PI). Based on these results, sample A is of medium plasticity, while sample B is of low plasticity according to Das (2006).

Both soil samples are classified as ML i.e. low plasticity silt according to USCS. Silt are typically difficult to compact so the addition of fine clay like material like the SSA may prove useful in stabilising the soil samples.

The compaction properties and the California bearing ration (CBR) of the untreated soil samples are also shown in Table 2.

Table 2: Results of Preliminary Analysis of Soil Samples

	SAMPLE A	SAMPLE B
Natural moisture content (%)	18.82	14.42
Specific gravity	2.56	2.52
Liquid limit (%)	49.30	49.00
Plastic limit (%)	33.31	40.00
Plasticity index (%)	12.04	9.00
pH	5.02	4.77
USCS Classification	ML	ML
Soil Colour	Light Brown	Reddish Brown
OMC (%)	19.00	21.75
MDD (g/cm3)	1.72	1.63
CBR	12.01	5.89

3.3 Effect of Sewage Sludge Ash on the Atterberg's Limits of the Soil Samples

The effect of the SSA on the Atterberg's limits of the two soil samples are illustrated in Figures 1 to 3. Figure 1 show that the addition of SSA has effect on the LL of the soil samples but the effect is not uniform between and within the soil samples. In soil sample A, there was 6.5% highest reduction and 1.01% highest increment in LL while in sample B, there was 8.57% highest reduction and 0% highest increment in LL. There was considerable change in the PL of both soil samples as compared to LL. Figure 2 show that there was continual reduction in PL of sample B while the change in PL of sample A was not uniform. In sample A, there was 20.08% highest reduction and 2.64 highest increment in the PL while in sample B, there was highest 25.92% reduction and 0% highest increment in the PL. Figure 3 shows that there was continual increment in the PI of sample B while the change in PI of sample A is not uniform. The highest change was recorded in the PI of the treated soil samples as illustrated in Figure 3. There was 43.52 highest reduction and 35.13 highest increment in the PI of sample A, while there was 0% reduction and highest 114.67 increment in the PI of sample B. The results indicate that the addition of SSA to sample B altered the soil to medium plasticity according to Das (2006) while addition of 2% and 16% SSA to sample A altered the plasticity to low plasticity

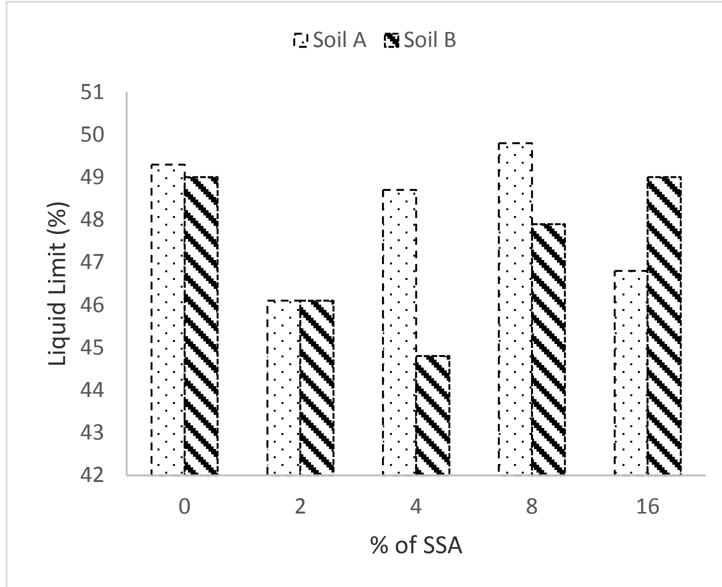

Figure 1: Effect of SSA on the liquid limits of the soil samples

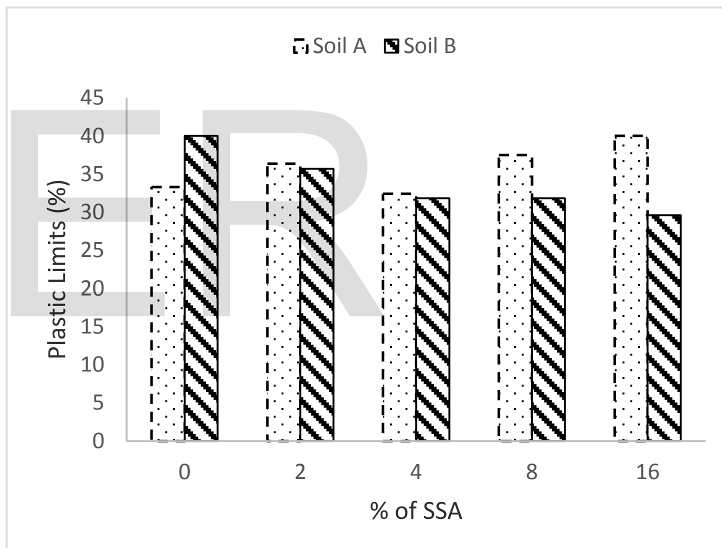

Figure 2: Effect of SSA on the plastic limits of the soil samples

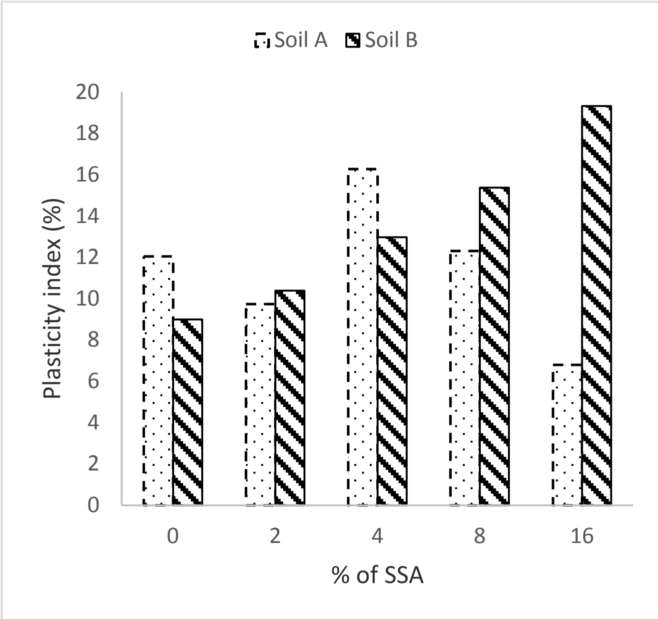

Figure 3: Effect of SSA on the plasticity index of the soil samples

3.3 Effect of Sewage Sludge Ash on the Compaction Properties and CBR of the Soil Samples

Figure 4 shows the changes in the compaction properties of the two soil samples when stabilised with sewage sludge ash (SSA). As the percentage of SSA increased, the optimum moisture content (OMC) of sample B decreased while the maximum dry density increased. The addition of the sewage sludge ash caused reduction in the OMC and increment in MDD due to the fact that the SSA as higher unit weight and also the specific surface area of the sludge is smaller than the soil samples. The MDD was also increased due to the fact that the fine particle of the SSA filled the pores within the soil sample causing it to be more compact and denser.

The changes in the OMC and MDD of sample A in response to the addition of SSA was however not uniform. There was an initial decrease in the OMC and a later increase in the OMC. The fluctuation in the OMC in turn affect the MDD as the MDD increased to a value of 1.79 Mg/m^3 at 4% SSA addition. After this increment there was reduction in the MDD as the SSA content increased.

The effect of SSA on the CBR is similar for the two soil samples as presented in Figure 5. The CBR of both soil samples increased with increasing SSA content. The CBR increased from 12.95% to 19.6% as the ash increases from 2 to 16% for sample A. and also increased from 8.41% to 24.65% as the ash increases from 2% to 16% for sample B. These results indicate that SSA is beneficial in improving the CBR of the soil samples in agreement with Lin et al. (2005).

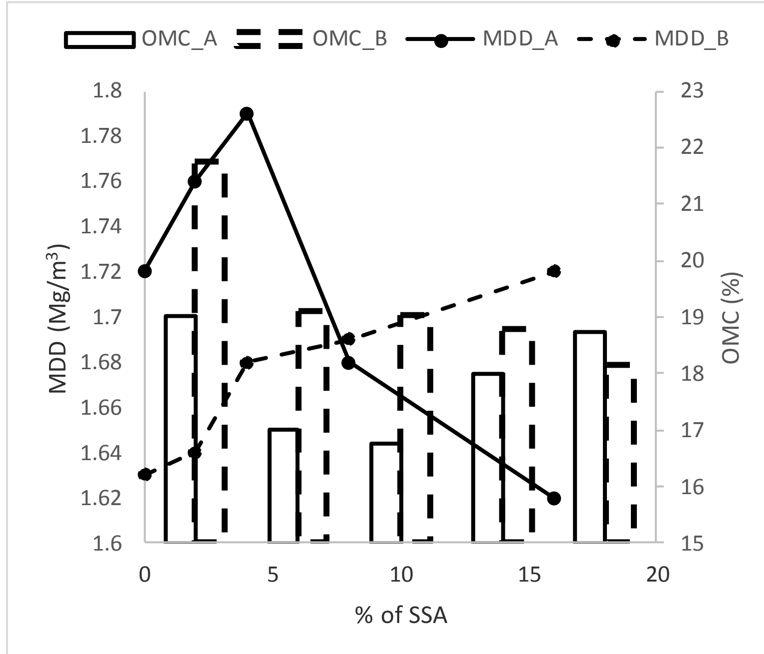

Figure 4: Effect of SSA on the compaction properties of soil samples

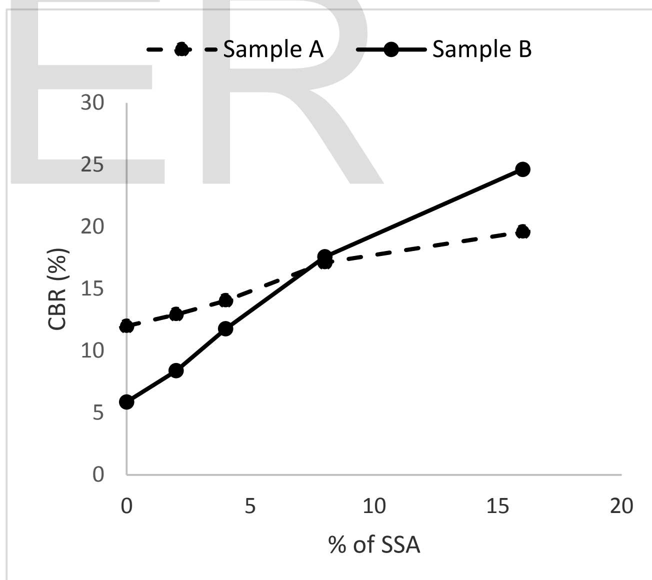

Figure 5: Effect of SSA on the CBR of soil samples

4 Conclusion

Based on the results obtained from the present study, it can be concluded that: the effect of SSA in stabilization is dependent on the soil type and cannot be generalized for all soil types; in order to establish an optimum percentage of SSA, smaller increment of SSA between 0 and 8% should be explored; finally, SSA proved useful in improving the MDD and CBR of the tested soil samples.

References

[1] Owoseni J.O. and Atigro E.O, (2014). 'Use of Agricultural wastes in stabilizing residual tropical soils for road Construction 'European International Journal of Applied Science and Technology Vol. 1, No. 5, pp. 117-136.

[2] Amu, O.O., Ogunniyi, S.A. and Oladeji, O.O., (2011). 'Geotechnical properties of lateritic soil stabilized with sugarcane straw ash', American Journal of Scientific and Industrial Research, 2(2): pp. 323-331.

[3] Alshawabkeh, A. N., and Sheahan, T. C. (2002). Stabilising fine-grained soils by phosphate electrogrouting. *Journal of the Transportation Research Board*(1787), 53-60.

[4] Karol, R. H. (2003): Chemical Grouting and Soil Stabilisation (3rd ed.). Marcel Dekker, Inc. New York.

[5] Gray D.H and Penessis C., (1972). 'Engineering Properties of Sludge Ash' water pollution control journal, vol.44, no. 5, pp. 847-858.

[6] Deng-Fong Lin, Huan-Lin Lu, Darn-Horng Hsiao and Chung-Chang Yang, (2005). 'The Effects of Sludge Ash on the Strength of Soft Subgrade Soil.' Journal of the Chinese Institute of Environmental Engineering, 15(1): 1-10.

[7] Tantawyl A.M., El-Roudi A.M., and Abdelzaher A.M. (2012): Evaluation of the pozolanic activity of sewage sludge ash. www.hindawi.com/journals/isrn/2012/487037/

[8] Glendinning, S., and Rogers, C. D. (1996): Deep stabilisation using lime. In Rogers et al., Deep stabilisation using lime (pp. 127-136). Thomas Telford, London.

[9] Das B. M. (2006): Principles of Geotechnical Engineering, 5th ed. Nelson, Ontario

[10] Gidigasu, M. D. (1976): Lateritic Soil Engineering: Pedogenesis and Engineering Principles. Elsevier Publishing Company, Newyork.