Assessment of the Effects of Lime and Cement on Geotechnical Properties of Laterites

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Abstract- Two different samples of soil tested as A-7-5 and A-7-6 were stabilized respectively with lime and cement. The samples were stabilized with the additives in steps of 2% and subjected to laboratory tests such as consistency limits, compaction, California bearing ratio (CBR) and unconfined compressive strength (UCS) until it reached 10% additives by weight of dry soil sample. The Proctor energy type of compaction and soaked method of CBR was adopted for the research while the compressive strength of the soils were measured in an unconfined state at days 1, 7 and 14 respectively. The plasticity index (PI) of the soil samples increase at 2% additives which later reduces with further increase as the additives contents. The soil samples attained their maximum dry densities at 6% cement and lime respectively, with cement being more effective compared to lime and the water content needed to achieve maximum dry density of the soil were higher in cement than in lime. The CBR values of the soil appreciate with increase in the additives content as indicated in the rise from 1.12% at natural to 7.26% at 6% cement content. The UCS of the lime stabilized soil improved better than that of cement stabilized soil with respect to the age of curing.

Keywords- Stabilization, Lime, Cement, Soil, Laterite

1 INTRODUCTION

Laterite is a highly weathered material that is rich in secondary oxides of iron, aluminium or both, with silica sesquioxides ratios (SiO2/FeO + Al2O3) of less than 1.33 (Charman, 1988; Bell, 1993; Olarewaju, 2010 and Madu, 1977). Ola (1983) defined laterites as products of tropical weathering with red, reddish brown, or dark brown colour, with or without nodules or concreting, which are generally found below hardened ferruginous crust or hardpan. Because of the availability of laterites in large quantities from one region to another, it has therefore gained ground as one of the reliable materials used in civil engineering construction as fills or pavement materials. It has been observed that most of the roads constructed in the recent years are failing within few years of their construction, even some before final commissioning. These failures are in most cases caused by poor materials, poor construction techniques and corruption. The construction material used as either subgrade or subbase in these roads is laterite or lateritic soil in most cases.

Findings on most of the available laterites used for construction of roads and as fill materials had shown that many of these soils are deficient either in terms of their grain arrangement, water retention capacity and strength (Mustapha et al., 2014). As a result of these observed deficiencies, researchers had risen to finding lasting solutions that will bridge the deficiencies in the soils used as our construction materials. Aside the ancient materials (cement and lime) used in stabilizing the poor soils encountered on civil engineering works, the use of other waste products which are classified as agricultural and industrial wastes (Ogunribido, 2012) are also being encouraged by researchers. Soils that are not meeting the requirements can either be cut to spoil or treated (stabilized).

The latter had been the hope of engineers in as much the safety and economy aspect of the work is satisfied (Ola, 1975). Anouksak and Direk (2006), Garber & Hoel (2000) and Thagesen (1996) defined stabilization as the process which may include blending soils to achieve a desired gradation or mixing commercially available additives that may alter the gradation, change the strength and durability, or act as a binder to the soil in order to improve its engineering properties and make it more stable.

Researchers (Ola, 1974; Balogun, 1991; Osinubi, 1998; Ogundipe, 2013; and Nnochiri et al., 2017) have attempted to stabilize laterite soil and they have reported that the stabilization of this soil with bitumen, lime or cement is effective. Lime stabilization is one of the oldest, relevant and reliable methods of improving the properties of cohesive soils. Lime in any of its form, either as quicklime, hydrated lime or slurry is a useful agent of soil stabilization. Lime stabilization creates long-lasting changes in soil characteristics. Addition of lime to a moist clay always resulted in cation exchange which is responsible for the early strength development, pozzolanic reaction for late strength development and carbonation (O’Flaherty, 2002).

Portland cement is used widely for stabilizing low-plasticity clays, sandy soils, and granular soils to improve the engineering properties of strength and stiffness. Increasing the cement content increases the quality of the mixture. At low cement contents, the product is generally termed cement-modified soil. A cement-modified soil has improved properties like reduced plasticity or expansive characteristics and reduced frost susceptibility (Maciejewska et al., 2006). This study looks into the effects of the generally acceptable additives (lime and cement) used in the construction industry on the strength indices of samples of laterite from two different existing borrow pits.
2 MATERIALS AND METHODS

2.1 MATERIALS

The materials used for this study are laterites, calcium hydrated lime, cement and water. Samples of laterites used were collected from two different borrow pits at an average depth of 1.0m below the present elevation of the sites. The locations with coordinates 7º36'10"N, 5º18'15"E and 7º41'18"N, 5º15'09"E are tagged as A and B respectively. Location A is situated beside the main gate of the Federal Polytechnic, Ado-Ekiti while location B is directly opposite junction of the Federal Radio Corporation of Nigeria, Ado-Iworoko road all within Ado-Ekiti, Ekiti State, Nigeria. The additives (lime and cement) used were procured from a retail chemical shop in Ado- Ekiti and portable water was used for mixing the samples.

2.2 METHODS

The soil samples were tested in the laboratory in accordance with British Standards Institution (1990a, 1990b) at natural and stabilized states. The following tests were carried out:

(i) specific gravity;
(ii) particle size distribution;
(iii) consistency limits;
(iv) compaction;
(v) California bearing ratio;
(vi) unconfined compressive strength.

3 RESULTS AND DISCUSSION

The samples combinations are described as presented in the Table 1.

3.1 SPECIFIC GRAVITY

The specific gravity values of both soil samples were coincidentally equal to 2.17. The standard range for the specific gravity of soil lies between 2.60 and 2.80 (Wright, 1986). Specific gravity value of 2.17 shows a less dense materials and is an indicator of organic matter in the soil samples.

| SAMPLE CODE | DESCRIPTION |
|-------------|-------------|
| LA          | Sample A and B respectively stabilized with lime          |
| CA          | Sample A and B respectively stabilize with cement         |
| LA1         | Lime stabilized samples cured for 24 hours            |
| CA1         | Cement stabilized samples cured for 24 hours            |
| LA7         | Lime stabilized samples cured for 7 days               |
| CA7         | Cement stabilized samples cured for 7 days              |
| LA14        | Lime stabilized samples cured for 14 days              |
| CA14        | Cement stabilized samples cured for 14 days             |

3.2 PARTICLE SIZE DISTRIBUTION

The percentage of different grains making up the soils are analysed and the gradation curve presented in Figure 1. The grain size analysis shows that the percentage of materials passing 75μm sieve are 76.37% and 64.25% for sample A and B respectively. The percentage of the soil samples passing 75μm sieve are greater than 35%, hence, the samples according to American Association of State Highway and Transportation Officials (AASHTO) (AASHTO, 1986) are grouped as silt-clay materials (A-7.5 and A-7.6 respectively).

According to clause 6201 of Federal Ministry of Works General Specifications for roads and bridges (FMWH, 1997), samples A and B can be deduced to be unsuitable materials for subgrade, base and sub-base layers as the percentage by weight finer than 75μm is greater than 35%. This therefore calls for the soils’ treatment.

Fig. 1: Particle Size Distribution Curve of the Natural Soil Samples

3.3 CONSISTENCY LIMITS

Consistency limits of the soil samples were evaluated by adding lime and cement separately at 2% step by weight of the soil sample until it reached 10%. The effects of the additives on liquid limit (LL) and plasticity index (PI) of soil samples A and B are presented in Figures 2a-d. The value of liquid limit for soil sample A and B at natural state are 68.5% and 49.4% respectively. The LL values of the stabilized samples with lime and cement ranged from 49.4% to 68.5% and 49.4%-70.5% respectively. Plasticity index of samples A and B at natural state were 36.31% and 21.75% respectively while that of the stabilized samples with lime and cement ranges between 21.75%-44.25% and 21.75%-38.56% respectively.

Fig. 2a: Effect of Lime and Cement on Liquid Limits of Sample A.
The Federal Ministry of Works General Specifications for roads and bridges (FMWH, 1997) recommended liquid limit not exceeding 80% and 35% and plasticity index not exceeding 55% and 12% for subgrade and sub-base course respectively. Consistency limits result of the natural sample showed that the samples were only suitable for subgrade layer. However, the soil samples as classified with AASHTO (AASHTO, 1986) indicate that samples A and B are A-7-5 and A-7-6 soils which are rated as ‘poor’ materials for subgrade layer.

3.4 Compaction Test

Compaction characteristics of soil samples A and B were monitored at natural and stabilised states at compactive energy of standard Proctor. The values of maximum dry density (MDD) of sample A and B vary from 1500 to 1653 kg/m³ and 1568 to 1656 kg/m³ respectively while that of the optimum moisture content (OMC) vary from 23.1-26.5% and 20.4-23.7% for samples A and B respectively. The results presented in Figure 3a indicate an increase in MDDs of samples A and B with an increase in the additives content with the peaks observed at 6% additives content, after which the values continued to drop gradually. The reduction in MDDs which was observed at 8 and 10% additives contents indicates that the additives are in excess to improve the soil’s gradation. The effect of cement was more pronounced on the MDD of soil sample A compared to that of the lime, while lime and cement have nearly same effects on that of soil sample B.

The behavioural pattern of the OMC of soil samples A and B stabilized with lime and cement is shown in Figure 3b. It was observed that soil sample A when compared with soil sample B, needed more water to achieve its MDD either when stabilized with lime or with cement. Increase in cement content increased the OMC of soil samples A and B with its peak observed at 6% cement. No definite trend was observed for the OMC of soil samples A and B with its peak observed at 6% cement. No definite trend was observed for the OMC of soil samples A and B stabilized with lime, though the maximum was observed at 10% for both samples. The OMC of cement-soil mixture was observed to be higher than the lime-soil mixtures. This is predicted due hydration between cement and the clay contents of the soils, which clearly indicates that more water is needed to get the soils compacted to their desired dry density with cement than with lime.

Liquid limits of the samples vary slightly with an increase in additive contents, though soil sample A responded very slower than sample B. Plasticity index of the soil samples stabilized with lime increase up to 2% additive after which the values continue to drop, while that of cement increase to 4% before coming down. It was observed that both additives were effective on the plasticity index of the soils but cement is more effective when compare to lime.

![Fig. 2b: Effect of Lime and Cement on Liquid Limits of Sample B.](image)

![Fig. 2c: Effect of Lime and Cement on Plasticity Index of Sample A.](image)

![Fig. 2d: Effect of Lime and Cement on Plasticity Index of Sample B.](image)

![Fig. 3a: Effect of Lime and Cement on MDD of Samples A and B](image)
3.5 CALIFORNIA BEARING RATIO

The CBR values of sample A and B at natural state as presented in Figure 4 are 1.83% and 1.12% respectively. These values were found not meeting the required 5% specified for material to be used as subgrade layer of road pavement stipulated in specification for Nigeria road and bridges (FMWH, 1997). Low values of CBR were confirmed by the high clay/silt contents in the soil as shown in the classification. Increase in additives content increased the CBR values of both samples. Figure 4 shows that the CBR of lime stabilized soil increased for lime content of 2% to 4% with further increase in lime content resulting in gradual decrease in CBR. Increase in cement content on cement stabilized soil increased the CBR value of soil sample A from 2% to 8% cement content and from 2% to 6% cement content for soil sample B with maximum CBR values of 5.2% and 7.26% for sample A and B respectively.

It was observed that cement is more effective on the stabilized soil samples compared to lime. Although, an increase in lime content increases the CBR value of soil sample A, with the maximum CBR value of 2.82% at 4% lime content, the value was observed to be less than the specified 5% CBR value.

3.6 UNCONFINED COMPRESSION STRENGTH

Unconfined compressive strength values of soil samples A and B at 2% to 10% lime and cement compacted at the energy of standard Proctor and cured for fourteen (14) days were obtained. The UCS values are as shown in Figures 5a and 5b for soil sample A and B respectively.

The UCS values of soil samples A and B were found to increase with increase in curing age. The UCS values of soil samples A and B are better when stabilized with lime compared to when stabilized with cement. The UCS values of the natural soil samples A and B cured for 14 days range from 186.45 to 196.74 kN/m² and 210.56 to 222.07 kN/m² respectively. The stabilized soil samples A and B had their maximum UCS values of 430.2 and 402.2 kN/m² at 8% and 6% lime content respectively on the 14-day strength.

4 CONCLUSION

The geotechnical properties of the soils were determined in accordance with British standards BS 1377 and BS 1924 and were classified in accordance with AASHTO to be A-7.5 and A-7.6 (AASHTO, 1986). The soils were stabilized with lime and cement separately in order to assess the effects of the two major stabilizers on them. It was observed that cement stabilized soil samples are of higher strength when compared with that of lime stabilized soils. The additives were found to be at their optimum effects on the soils at an average of 6% of the weight of dry soil sample.

The MDD and UCS of the soil samples were observed not to be meeting the requirements as prescribed by the general specifications. This could be as a result of the compactive energy applied on the soil samples. It is
therefore suggested that the effects of higher compactive energy be observed on the strength of the soil samples.

REFERENCES

American Association of State Highway and Transportation Officials (AASHTO) (1986) Standard Specification for Transportation Materials and Methods of Sampling and Testing (14th ed.). USA: Washington DC.

Anouksak T. & Direk L. (2006) Stabilisation of Reclaimed Asphalt Pavement Using Foamed Asphalt. Proceedings in the Technology and Innovation for Sustainable Development Conference (TISD)

Balogun, L.A. (1991). Effect of sand and salt additives on geotechnical properties of lime stabilized black cotton soil. The Nigerian Engineer, 26(22), 1-4.

Bell F. G. (1993). Engineering geology. Blackwell Scientific Publications, Oxford: 84-86.

British Standards Institution. (1990a). BS 1377: British Standard Methods of Test for Soils for Civil Engineering Purposes. UK: London, British Standards Institution.

British Standard Institution. (1990b). BS 1924: Methods of Tests for Stabilized Soils. British Standards Institution, London.

Charman, I.M. (1988). Laterite in Road Pavements. Special Publication 47, Construction Industry Research and Information Association (CIRIA), London (1988).

Federal Ministry of Works and Housing (FMWH). (1997). General Specifications (Roads and Bridges) –Revised Edition (Volume II), Nigeria, Abuja.

Garber N. J. & Hoel L. A. (2000). Traffic and highway engineering. 2nd ed. Brooks/Cole Publishing Company, London.

Maciejewska, A., Veringa, H., Sanders, J., & Petevo, D.S. (2006). Co-firing of Biomass with Coal Constraints and Role of Biomass. International Journal of Biomass and Constraint, Vol. 79, (34), 786-789.

Madu, R.M. (1977). An investigation into the geotechnical and engineering properties of some laterites of Eastern Nigeria, Engineering Geology 1(2) (pp. 101-125).

Mustapha, A.M., Jibrin, R., Etsuwor, N.M., & Alhassan, M. (2014). Stabilization of A-6 lateritic soil using cold reclaimed asphalt pavement. International Journal of Engineering and Technology, Vol 4(1), 52-57.

Nwokiri, E.S., Emeka, H.O. & Tanimola, M. (2017). Geotechnical characteristics of lateritic soil stabilized with sawdust ash-lime mixtures. The Civil Engineering Journal, 7(1), 66-76. doi: 10.14311/CEJ.2017.01.0007

O’Flaherty, C.A. (2002). Highways: The Location, Design, Construction and Maintenance of Pavements. 4th Edition, Butterworth-Heinemann, Oxford, United Kingdom.

Ogundipe, O.M. (2013). An Investigation into the Use of Lime-Stabilized Clay as Sub grade Material. International Journal of Scientific and Technology Research, 2(10), 1-6.

Ogunrhibido, T. H. T. (2012). Geotechnical Properties of Saw Dust Ash Stabilized Southwestern Nigeria Lateritic Soils. Environmental Research, Engineering and Management, 2(60), 29-33. doi:10.5755/01.erem.60.2.986

Ola, S.A. (1974). Need for estimated cement requirement for stabilizing lateritic soil. Journal of Transport Division, 4(8), 379-388.

Ola, S.A. (1975). Stabilization of Nigerian lateritic soils with cement, bitumen, and lime. Proceedings of the 6th Regional Conference for Africa on Soil Mechanics and Foundation Engineering.