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**Stabilization of Lateritic Silty Clays with Common Stabilizing Agents**
**George R. Otoko**

 Civil Engineering Department, Rivers State University of Science and Technology, Port  
Harcourt

[otokosoils@yahoo.com](mailto:otokosoils@yahoo.com)
**Abstract**

Local common stabilizing agents such as ordinary Portland cement, fly ash and lime were used to stabilize a lateritic silty clay for improved strength and plasticity behaviour of the clay. Various percentage cement content, lime content and fly ash content were studied. Specimens were cured for 7 days; and thereafter unconfined compressive strength (UCS) determined.

Test results show that about 8% of Portland cement gave UCS of about 29kg/cm<sup>3</sup> which is satisfactory for road use under Nigerian climatic conditions. 8% lime content gave the 7 days peak strength, while the 7 days strength of fly ash contents were significantly more than that without fly ash for fly ash content exceeding 1.5%.

**Keywords:** Lateritic Silty Clays, Stabilizing Agents.

**Introduction**

Previous work on the geological study of laterites in Nigeria dwells mainly on their distribution, classification, depth extent, general nature and formation (Pugh and King 1952, du Preez 1956, Pullan 1967, Burks and Durotoye 1972, Faniran 1970, 1972, 1974 and 1978, Adekoya et al 1978). Although much work has also been done on the geotechnical study of laterites and lateritic soils (Ola 1978, 1980a, 1980b, Alao 1983 and Otoko 2014) most especially in connection with foundation problems, little attention is paid to stabilizing laterites with various stabilizing agents.

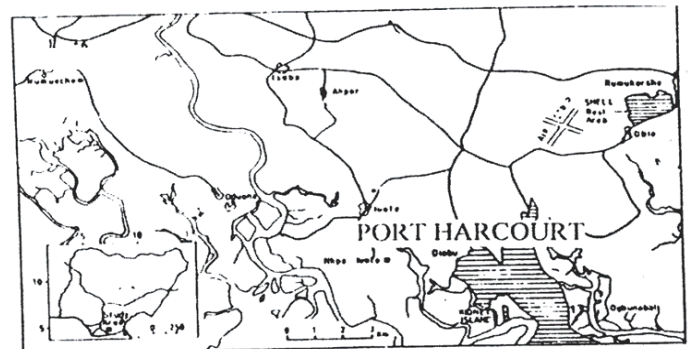
Otoko (1985, 1987, 1988a, 1988b, 1997, 2000) has shown that the soils design engineer requires the strength of the field compacted soil for analysis in the design of roads and embankments. The soils design engineer must select or estimate the expected soil strength over the service life of the project soil. Economy in present day practice usually dictates that this strength behaviour of the field compacted soil be inferred from behavioural characteristics developed in the laboratory.

A number of stabilization methods are available by which the durability, strength and deformation resistance of a soil may be increased. The lime-cement mixing methods are being used to improve the properties of the soil since ancient times. The object of this paper is the stabilization of a lateritic soil using ordinary Portland cement, lime and fly ash.

Fly ash is used as a pozzolana/ stabilizing agent as well as from the angle of industrial waste management.

**Experimental Procedure**

The soil used for testing was obtained from Port Harcourt Local Government Area of Rivers State (see fig 1).



**Fig. 1 Map of the Niger Delta of Nigeria showing the location of Port Harcourt**

Classification test results are summarized in table 1, as are the optimums for the various compaction curves produced for the soil.

**Table 1- Geotechnical Properties Of Soil.**

Properties	Values
Colour	Red
Specific Gravity	2.70
Liquid Limit	35.7%
Plastic Limit	18.4%
Plasticity Index	17.3%
Maximum Dry Unit Weight	18.6kN/m <sup>3</sup>
OMC	15.2%
Clay %	26.5
Silt %	43.4
Sand %	30.1
Classification	CI

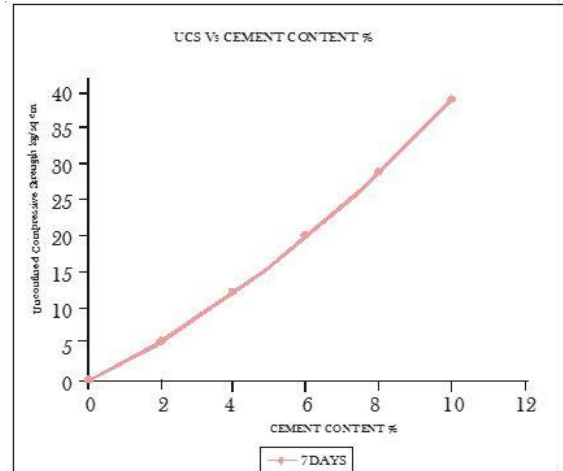
Ordinary Portland cement, lime and fly ash were used as soil stabilizers. Cement and lime were procured in Port Harcourt, while fly ash was procured in Oji River Power Station, the only source of fly ash in the country (Ngwu 1984).

### Cement Stabilization

The cementing action in cement stabilization is believed to be the result of chemical reaction of cement with the silicious soil during hydration. About 45% tri-calcium silicate (C<sub>3</sub>S) and 27% di-calcium silicate (C<sub>2</sub>S) contained in ordinary Portland cement (OPC) hydrates in the presence of soil to form gels or mono and di-calcium silicate hydrate (CHS and C<sub>2</sub>HS). Free time (CH) is liberated in the hydration reaction. The insoluble calcium silicate gel crystallizes very slowly into an interlocking matrix.

In the study, a mix design to select a cement content to give the required strength or durability gain was determined by laboratory trial mixes. There are several methods. The British method is based on compressive strength of specimens cured for 7 days. The cement content corresponding to a strength of 17.5kg/cm<sup>2</sup> is taken as design cement adequate for highway base courses with light to medium traffic. Higher strength of 28 to 35kg/cm<sup>2</sup> may be achieved. Cement content corresponding to compressive strength of 25 to 30kg/cm<sup>3</sup> should normally be satisfactory for tropical climates.

Soil was generally prepared with various properties of Portland cement from 2% to 10%, cured for 7days and thereafter UCS test performed on them for strength determination. Fig 2 shows the variation of unconfined compressive strength with cement content.



**Fig. 2 Variation of Unconfined compressive strength with cement content**

It is clear from fig 2 that UCS increases with increases in cement content, with less than 10% cement, most of the soil improvement applications can be achieved, as it corresponds to UCS of about 35kg/cm<sup>3</sup>. Laterites are used for road fills in Nigeria and most tropical climates. Cement content of 7 to 8% is quite satisfactory as this corresponds to UCS of about 25 to 30kg/cm<sup>3</sup>.

### Lime Stabilization

Lime may be used as a soil modifier, or binder or both. It reduces the plasticity index of the soil and makes the soil more workable and easy to be pulverized, having less affinity with water. These are all desirable for stabilization work. There can also be pozzolanic action in fine grained soils, resulting to added strength. Lime reacts with the clay minerals of the soil to form a tough water insoluble gel or calcium silicate, which cements the soil particles like for OPC; the difference being that with the later, the calcium silicate gel is formed from hydration of anhydrous calcium silicate, whereas with lime. the gel is formed only after attack on silica from the clay minerals of the soil. While lime stabilization is dependent on soil type, cement stabilization is not. For lime stabilization silica is progressively removed. Calcium Aluminate and Alumina are formed residually.

When lime stabilization is used to upgrade heavy clay soils to sub-base material quality or to upgrade plastic gravel to base course quality, the mix design criteria include UCS of 17.5kg/cm<sup>2</sup> at 7days. Lime content of 2% to 12% were used in the present study and UCS determined after 7days curing. The atterberg limits were also determined and plotted in fig 3.

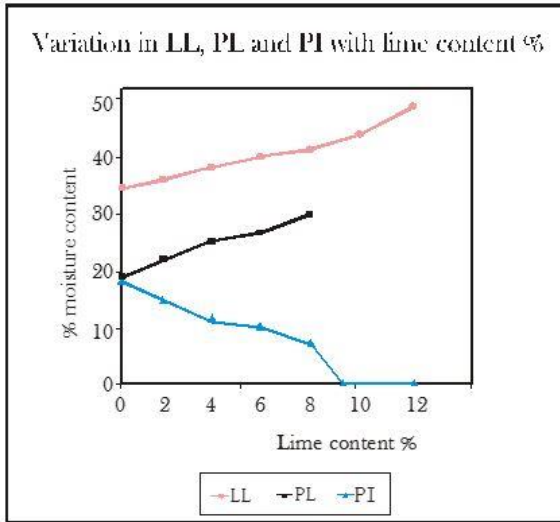


Fig. 3 Variation of LL, PL & PI with lime contents

It is clear from fig 3 that lime content is directly proportional to liquid and plastic limits, and inversely proportional to plasticity index. However, beyond 8% lime content, Nil plasticity was observed in specimens. Fig 4 shows a variation of UCS with lime content and shows that maximum strength was gained at 8% lime content.

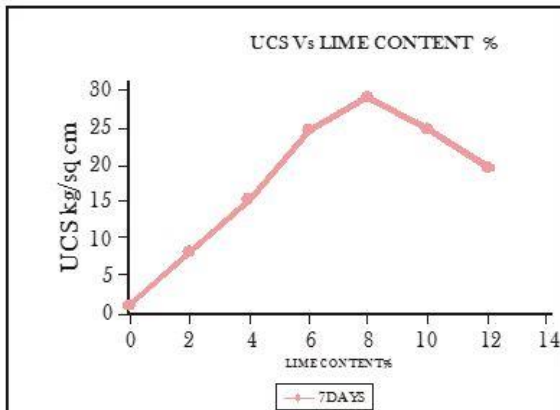


Fig 4. Variation of UCS with lime content

### Stabilization with Fly Ash

As a result of pozzolanic crystallization, permeability of a well compacted fly ash is relatively low and decreases with time. This is one of the reasons that fly ash is suitable for seepage cutoffs.

Specimens were prepared with fly ash content varying from 2% to 10%; and UCS determined after 7days curing. Results obtained is plotted in fig 5. From fig 5, it is clear that the strength developed with fly ash is more than double that of specimen without fly ash for fly ash content exceeding 1.5%, while the seven days strength is more or less the same as from 2.5 to 10% fly ash content. Therefore, in Nigeria where

fly ash is waste product at Oji Power Station, it can be safely used in construction of embankments and roads.

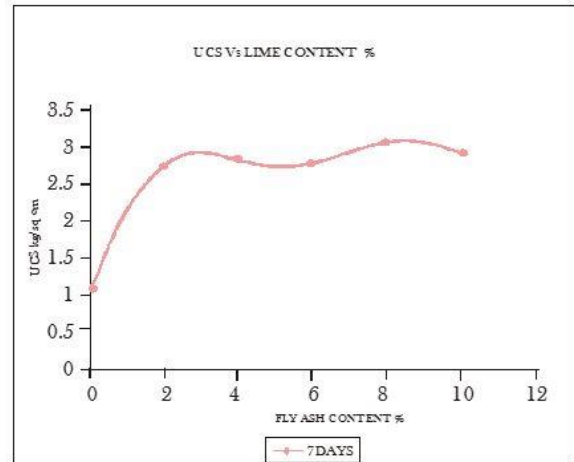


Fig. 5 Variation in UCS with fly ash contents

### Conclusion

From this study, it can be concluded that the tropical detritic lateritic soils can be successfully satisfactorily stabilized with cement and lime, although soil-cement has a problem of subsequent cracking; while lime causes changes in plasticity which has an added advantage in handling and enhancing soil workability. It is therefore suggested that a mixture of lime and cement be used or pretreatment of soil with lime before use of cement or if at all possible, use of lime only. Test results show that 7days strength of fly ash stabilized soil was significantly more than the unstabilized soil. Therefore, fly ash can also be used to stabilize the soil.

### References

- [1] Adekoya, J.A, Irokanulo, B.G., & Ladipo, K (1978). Report on the investigation for bauxite at Works Hills near Oju, Benue State. Unpublished Report Geol. Surv. Nigeria
- [2] Alao, S. A. (1983). Geology and engineering properties of laterites from Ilorin, Nigeria. Eng. Geol. 19: 111-118.
- [3] Burke, K. & Durotoye, B. (1972). The Quaternary in Nigeria. In Dessauvage, T. F. J. & Whiteman, A. J. (Eds) African Geology Ibadan, 1970. Geol. Dept. University of Ibadan, Nigeria.
- [4] Dupreex, J. W. (1956). Origin, classification and distribution of Nigerian laterites. Proc. 3<sup>rd</sup> int. W. Afri. Confr. Ibadan.
- [5] Faniran, A. (1970). Landform examples from Nigeria. No.2. The deep weathering

- (duricrust) profile. Nigerian geographical Journal 13: 87- 88.
- [6] **Faniran, A.** (1972) Depth and pattern of weathering in the Nigerian Precambrian basement complex rocks areas: A preliminary report. In: Dessauvage, T. F. J. & Whiteman, A. J. (Eds.), African Geology, Geol. Dept. University of Ibadan, Nigeria.
- [7] **Faniran, A.** (1974). The depth, profile and significance of deep weathering in Nigeria. *Journal Tropic geogr.*, 38: 19 – 30.
- [8] **Faniran, A.** (1978). Deep weathering duricrust and soils in humid tropics. *Savanna* 7 (1): 1 – 55.
- [9] **Ngwu, F. N.** (1984) Nigeria Coal Corporation Production of Ore Coals. Sunday, February 5, Weekly star, Nigeria.
- [10] **Ola. S. A.** (1978). the geology and geotechnical properties of the black cotton soils of northern eastern Nigeria., eng. *Geol.* 12:375-391.
- [11] **Ola, S. A.** (1980a). Permeability of three compacted tropical soils. *Q. J. Eng. Geol. London.*, 13: 87 – 95.
- [12] **Ola. S. A.** (1980b). Some foundation design problems in the Sokoto area of North-Western Nigeria. *Proc. of the 7<sup>th</sup> regional Conference for Africa on soil Mech. And foundation Eng.* Accra p 267 – 275.
- [13] **Otoko, G. R.** (1985) A study of the strength of compacted fills based on embankment failures. M.Sc. Thesis, University of London.
- [14] **Otoko, G. R.** (1987). A study of five embankment slope failures. *Proc. sixth. Regional Conference for African on soil Mech. and Foundation Engineering, Lagos.* Pp. 363 – 370.
- [15] **Otoko, G. R.** (1988a). The analysis of slope stability - A state of the arts review. *Proc. of the International Conference on Soil Movements and their control, Nsukka,* pp. 136 – 153.
- [16] **Otoko, G. R.** (1988b). The suitability of 'Chikoko' mud as fill for embankments. *Proc. of the 2<sup>nd</sup> National conf. on Technological Dev. and Nigeria Industries, Ilorin, Nigeria.*
- [17] **Otoko, G. R.** (1997). Stability of foundation and slopes in deltaic clays of the Niger Delta, Nigeria. Ph.D Thesis. University of Science and Technology, Port Harcourt, Nigeria.
- [18] **Otoko, G. R.** (2000). Stability of Road Cuts and Embankments in the Yenegoa area of the Niger Delta, NSE Technical Transactions, Lagos (Inpress). Vol. 35, No. 4.
- [19] **Otoko, G.R** (2014). Strength Characteristics Of Compacted Tropical Deltaic Lateritic Fills. *European International Journal of Science and Technology.* Vol 3. No 1. pp 1-9.
- [20] **Pugh, J. C & King, I.** (1952). Outline of geomorphology of Nigeria. *S. Afr. Geogr. Jour.* 34: 30-37.
- [21] **Pullan, R. A** (1967). A morphological classification of lateritic iron-stones and ferruginized rocks in Northern Nigeria. *Nigerian Jour Sc.* 1:161-173