

LIME STABILISATION OF THE CHICOCO MUD OF THE NIGER DELTA

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ABSTRACT

Chicoco mud is a very soft and extremely compressible organic marine mud found extensively and to considerable depths within the saline tidal flat or mangrove swamp of the Niger delta region in southern Nigeria. Natural chicoco mud is highly compressible barely able to support an average human weight but air-dried chicoco has been used successfully by the natives for shore protection, etc. especially if placed above water. In this study, varying percentages (ranging from 1% to 9%) of industrial and locally produced (from periwinkle shells) slaked-lime were used to stabilise chicoco. It was observed that neutralisation of acidic "air-dried" chicoco by basic lime inhibited the expected ion-exchange reaction and its attendant improvement in mechanical properties. As a result and as lime (industrial or locally-produced) content increases, maximum dry density (MDD) decreases, optimum moisture content (OMC) decreases while unsoaked CBR maximises within low lime content of about 4%. Also, significant improvement in all three parameters (MDD, OMC and CBR) was recorded with slight water addition. However and with maximum unsoaked CBR of only 12.5%, lime-stabilised chicoco can only produce subgrade materials in roadworks, i.e. not unsuitable for sub-base and base-course materials.

KEYWORDS: Chicoco mud, Niger delta, Lime, Periwinkle, Stabilisation

INTRODUCTION

Chicoco mud is the local name given to a darkish brown to pitch-black organic marine mud that superficially covers over 90% of the saline tidal flat (or mangrove swamp) zone or about 4 % of the entire Niger delta region of southern Nigeria. The saline mangrove swamp zone as delineated by Akpokodje(1987) is a permanently submerged or water logged flat lowland plain criss-crossed by numerous tidal creeks, rivers and rivulets and sandwiched between the coastal sandy beaches and the freshwater backswamps of the Niger delta. Chicoco mud comprises at least 50% organic matter (mostly peat derived from partially or completely decomposed rootlets, wood fibres, etc.) while sand, silt and clay constitute the remaining proportion in the ratio 7 : 28 : 2 respectively - NEDECO(1966), Akpokodje(1987), Omotosho et al(2003) George(1989).

In its natural state, chicoco mud is very soft and extremely compressible with varying proportions of partially or completely decomposed organic matter or humus including rootlets, wood fibres, etc. The humus exists mostly as humic acid or macro-molecular ion groups including R-OH and R-COOH ions which are contained, circulating or trapped within the normally large volume of water existing between the soil particles pulling them apart and resulting into low density, high compressibility and other inferior mechanical properties commonly associated with organic soils.

As a result, chicoco mud possesses highly inferior engineering characteristics including natural moisture content and void ratio in excess of 150%, liquid limit in excess of 70%, organic content between 50% and 90% and SPT N-value generally less than unity (NEDECO, 1966; Enoch George Associates, 1990; Omotosho, et al, 2003). And with an average allowable bearing pressure far below 20 kPa, natural chicoco is hardly able to support an average human weight. These inferior engineering properties have rendered natural chicoco highly undesirable and in fact written off for complete replacement by most investigators. However, its considerable thickness over and above the coastal plain sand of the Benin geomorphologic formation (Short and Stauble, 1967) most especially around the northern periphery of the saline mangrove swamp makes complete replacement economically unviable.

But despite all these, chicoco mud is not as useless as it appears or behaves naturally and may with improvement prove a viable engineering material. For instance, air-dried chicoco mud has been used extensively by the natives for landscaping, shore and slope protection, reclamation, etc. most especially if placed above water level. Also, studies by Omotosho et al(2003) has shown that chicoco mud could find a better use as heat-treated structural materials like bricks, etc. In fact when fired at a temperature of about 300°C achievable locally even with firewood, chicoco bricks were observed to exhibit low water absorption capacity (WA) and average cube strength in excess of 2.0N/mm² which compares favourably with the most common and/or popular sandcrete blocks in the Nigerian building industry.

Increased engineering activities through petroleum exploitation within the Niger delta is placing enormous pressure on the less than 10% habitable land available in the tidal flat zone hence the necessity to increase the engineering desirability of chicoco mud through stabilization.

Lime is an-age old soil chemical stabiliser which works through ion-exchange or isomorphous substitution mechanism. Influence of lime stabilisation on some Nigerian soils have been studied in the past. For instance, Ola(1977) observed that lime stabilisation of lateritic soils could produce materials suitable only for road sub-base. Also, Ola(1983) observed a positive influence of lime addition on cement-stabilised black-cotton soils as shown below in Table 1 which is self-explanatory.

Hebib and Farrell (2003) also reported successful stabilisation of two Irish peaty soils with some combinations of stabilisers including lime.

This paper therefore presents the result of stabilizing chicoco mud with lime and its influence on the soil's natural (hitherto undesirable) characteristics.

MATERIALS

Chicoco

The chicoco mud used in this study was obtained from around Bakana, about 10 knots south east of Port Harcourt in

Table 1. Maximum swell using CBR test (after Ola, 1983)

	0% cement	4% cement	8% cement
0% lime	3	1.06	1.50
3% lime	0.11	0.20	0.23
6% lime	0.06	0.13	0.20
9% lime	0.06	0.10	0.11

Table 1. Summary of test results

Lime content (%)	Industrial slaked lime			Periwinkle shell slaked lime			Industrial lime with saltwater		
	MDD (kg/m ³)	OMC (%)	CBR (%)	MDD (kg/m ³)	OMC (%)	CBR (%)	MDD (kg/m ³)	OMC (%)	CBR (%)
0	1290	30	2.7	1290	30	2.7	1457	19.7	3.2
1	1154	33.4	9	1150	32.4	9	1370	21.2	10.5
4	1100	36.2	8.4	1120	33.6	10	1290	25.4	12.5
7	1086	37.2	8.5	1190	29.2	8	1220	30.2	9.5
9	1103	35.96	11	1140	27.7	10.5	1270	25	8.0

southern Nigeria. The soil was dark brown in colour and highly spongy or fibrous. The sample was air-dried over a long time period probably necessitated by the highly hygroscopic salts predominant in natural chicoco and its saline water environment. Air-dried sample was then subjected to standard preliminary or classification tests including natural moisture content, gradation, Atterberg limits, standard proctor compaction, etc. all in accordance with BS 1377 of 1990. Table 2 summarises the result of these preliminary tests.

Table 2: Summary of classification tests on chicoco mud

1	Natural moisture content (%)	157	
2	Fines (% passing No. 200 sieve)	41.7	
3	Atterberg Limits (air-dried)	Liquid limit, LL (%)	63.8
		Plastic limit, PL (%)	40.4
		Plasticity index, PI (%)	23.4
4	Proctor compaction	MDD (kg/m ³)	1290
		OMC (%)	30
5	Classification	AASHTO	< A - 7
		Unified	OH

Lime

Two types of slaked-lime were used in this study. The first was the industrially produced, beige-coloured powdery substance used extensively in water prospecting, treatment, e.g. Sample of this was obtained from the open chemical market in Port Harcourt.

The second type was locally produced by burning or firing periwinkle shells and grinding (after cooling) to fine powder. Periwinkle is a slimy, extremely slow-creeping univalve mollusc with a soft flabby flesh inside a small conically-shaped shell averagely about 10mm diameter by 25mm long. These are found extensively within the mangrove swamp of the Niger delta – the natural habitat of chicoco mud. While the fleshy mollusc is a common rich and cheap source of protein for the natives, the shells have been a voluminous solid waste quite tedious or cumbersome to dispose off. These shells have been and are also being used by the natives as concreting coarse aggregates but their high rate of disintegration or deterioration has always adversely affected the strength and durability of structures constructed with them. The slaked lime powder

obtained from periwinkle shells were found to be brighter coloured than the industrially produced one.

EXPERIMENTAL METHODS

1% industrial slaked-lime (by weight of air-dried soil) was thoroughly mixed with air-dried chicoco mud and standard Proctor compaction test carried out on the mixture using

laboratory distilled water. The resulting maximum dry density (MDD) and optimum moisture content (OMC) were then used to compact another specimen for CBR test. This procedure was thereafter repeated for 4%, 7% and 9% slaked lime contents.

The same procedure was also repeated for locally-produced slaked-lime from periwinkle shells also using distilled water throughout.

To study the influence – if any – of salt addition on lime-stabilised chicoco mud in accordance with Balogun(1991), saline water obtained from the sampling location was later used (instead of distilled water) but only for industrial-lime stabilisation.

RESULTS AND DISCUSSIONS

Table 2 summarises the results of stabilising the chicoco mud sample with both the industrial and the locally produced slaked-lime.

And Fig. 1 plots the maximum dry density (MDD) against the lime contents for all the three test types.

From this figure, it can be observed that generally and within experimental errors, the maximum dry density (MDD) decreases with increasing lime content in all three cases. Lime stabilisation is known to work through ion-exchange principle whereby exchangeable ions in soil are substituted by the Ca⁺⁺ ions from lime which shrinks the ionic double layer, reduces inter-particle spacing hence increase in density. But lime is also basic and the air-dried chicoco mud acidic (Omotosho et al, 2003) hence acid neutralisation takes place thereby liberating additional free water which tend to pull soil grains apart hence the decreasing density observed. But for the saltwater addition, the MDD values are higher as manifested by significant upward shift of the curve. This may be because the saltwater introduces additional exchangeable ions which catalyses isomorphous substitution whereby inter-particle distances are relatively reduced and density slightly improved. This infact conforms with Balogun(1991) which observed considerable improvement in engineering properties (plasticity, free-swell, compressive cube strength, etc.) upon controlled

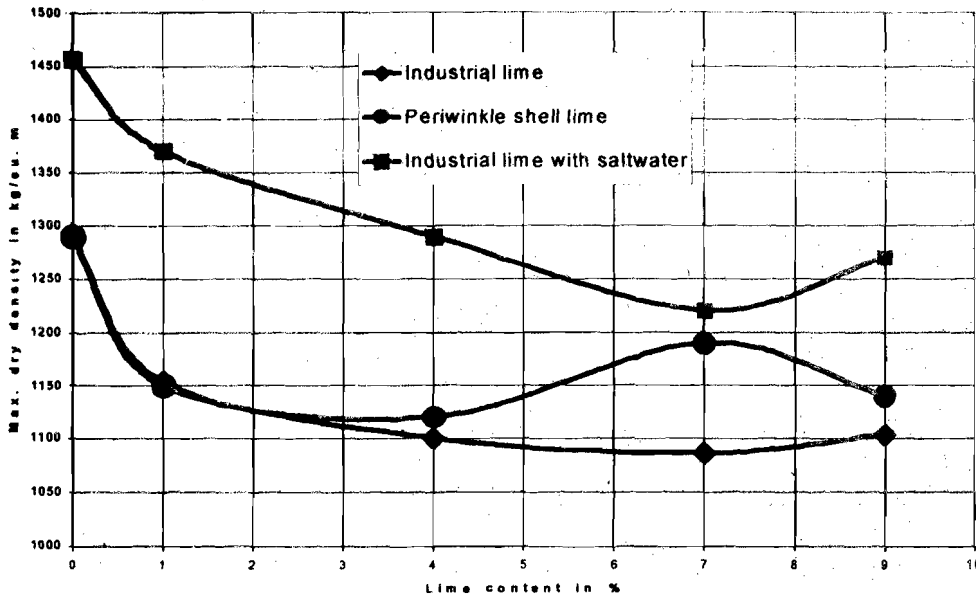


Fig. 1. Maximum dry density (MDD) and lime content

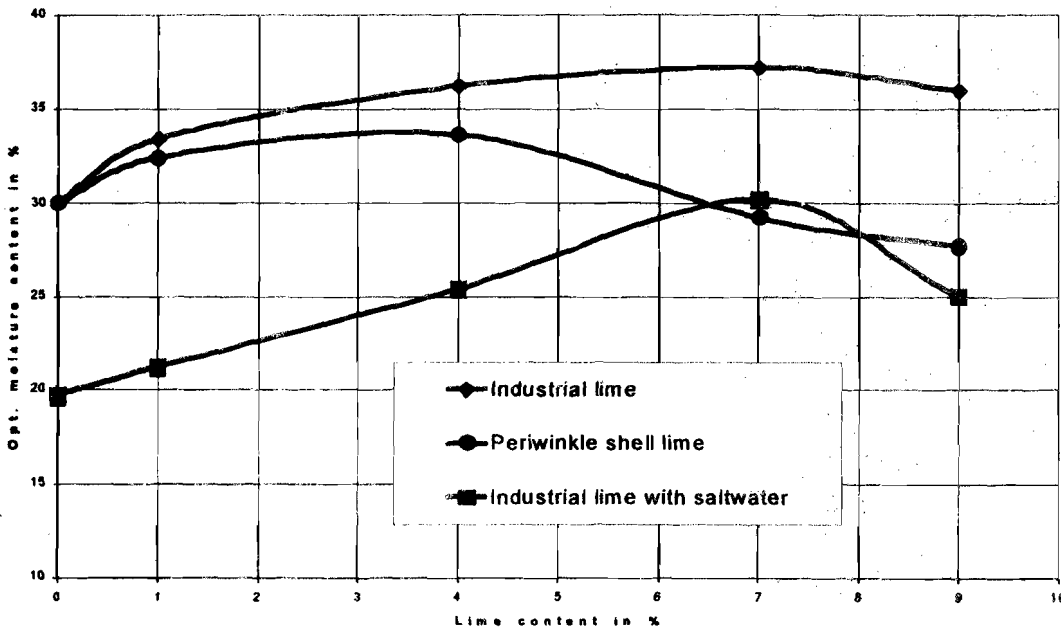


Fig. 2. Optimum moisture content (OMC) and lime content

addition of common salt to a lime-stabilised black-cotton (active) soil.

Also from this figure, the MDD values for both industrial and locally produced slaked-lime almost coincide except for a slight kink at higher lime content. This may be related to the age or time of manufacture of the lime. The industrial lime was imported hence must have been produced ahead of the periwinkle lime which was produced insitu.

Shown in Fig.2 is the plot of the optimum moisture content (OMC) against lime content for all three tests.

From this figure, it can be observed that optimum moisture content (OMC) increases with lime content, maximises and thereafter decreases continually. This follows from the explanation for Fig. 2. As lime content increases, the amount of water liberated increases hence the increasing OMC. At

higher lime content however, all the acidity in the soil may have been fully neutralised hence reduction in proportion of additional water liberated and consequently decrease in OMC. Also, OMC for saltwater addition is lower because as already discussed above, the saltwater minimises the amount of free water liberated through acid neutralisation hence the observed reduction.

Fig. 3: is a plot of unsoaked California bearing ratio (CBR) against lime content for all three tests.

From this figure, CBR increases with increasing lime content, maximises still within lower lime content and thereafter decreases. This may be because at lower lime contents, quantity of water liberated through acid neutralisation is low hence ion-exchange or isomorphous substitution is more effective hence increase in CBR. However, this is at variance with the trend observed with density. Thus it can be concluded

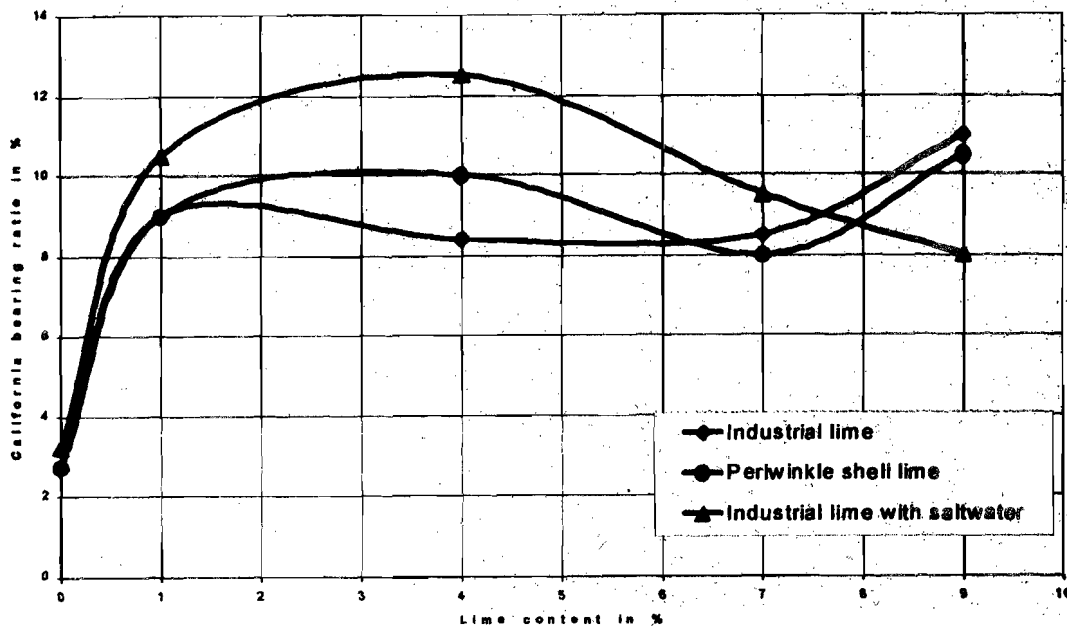


Fig. 3. California bearing ratio (CBR) and lime content

that (a) strength development in lime-stabilised chicoco mud is dependent on apparent cohesion developed over time in the mixture matrix and not the density, and (b) density is not a reliable indicator for evaluating the influence of lime stabilisation on all soils generally and chicoco particularly. This actually agrees with previous observations by Leroueil and Vaughan (1990) and Consoli et al (1998) whereby the shear strength of even natural soils were attributed to soil structure rather than density. Also, at higher lime content, the water liberated is higher and this softens the soil hence reduction in strength and/or CBR. That the periwinkle shell lime exhibited higher CBR than the industrial lime may still be a result of age-related potency.

Also, saltwater exhibited better improvement in CBR than distilled water which makes it more effective both technically and economically in lime stabilisation of chicoco mud. It should be noted that saltwater is readily available within the saline mangrove swamp home of chicoco mud as against fresh water which has to be specially produced through very deep boreholes.

The maximum observed CBR of about 12.5% (though this may improve even if marginally over time) falls short of producing material requirements for sub-base (30% minimum soaked CBR) and base-course (80% minimum soaked CBR) in roadworks. However, the resulting composite material meets the subgrade requirement of between 4% and 5% soaked CBR. This actually puts a serious limitation on the usefulness of this composite material. It is hoped that combination of lime with cement may boost this.

CONCLUSIONS

From the foregoing, the following conclusions can be drawn:-

- slaked-lime stabilisation of chicoco mud reasonably improves its natural strength characteristics by about 363% but only good enough for use as subgrade materials in road structure;
- strength development or improvement in lime-stabilised chicoco mud can be attributed to the time-

related apparent cohesion developed within the mixture matrix and not density; thus density may not be a very reliable indicator for evaluating the influence of lime stabilisation on chicoco mud in particular and most soils in general;

- saltwater addition gave better strength improvement – an economic advantage considering the abundance of such water within chicoco mud's natural habitat; and
- since air-dried chicoco mud has been shown by Omotosho et al (2003) to be highly acidic and supporting no growth, use of chicoco mud dredge spoils for earthworks will be environmental friendly.

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