A Comparative Study of Portland Cement, Hydrated Lime and Lateralite as Stabilizing Agents of Quaternary Coastal Plain Sands North of Lagos Metropolis and as Road Construction Material

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Abstract

The Lagos end of the Lagos-Ibadan expressway has been constructed within a wetland terrain of South Western Nigeria. The section was constructed upon a thick deposit of relatively loose, silty and slightly clayey sand technically referred to as the Coastal Plain Sand. The formation is a major sedimentary deposit in Southern Nigeria, and it is a major road construction soil material in the northern environs of the Lagos metropolis that has been massively quarried by many road contactors as borrow materials for several years. Previous and present studies confirm the substandard geotechnical properties of the deposit as road construction material. It requires substantial improvement through stabilization by additives. This study examines the effect of three fluxes, namely Portland cement, Hydrated Lime and newly evolved "**Lateralite''** on the compaction and California Bearing Ratio (CBR) characteristics on several samples of the deposit. Lateralite offered the highest hope of stabilizing the deposit effectively for highway construction on account of its significant anti-shrinkage/swelling control and CBR enhancing effect on treated samples of Coastal Plain Sand deposit.

Keywords: Lateralite, California Bearing Ratio (CBR), Stabilization, Coastal Plain Sand

Introduction

The "Coastal Plain Sands" is a major sedimentary deposit, which extends from the Benin Republic through the northern part of Lagos metropolis to the South Eastern part of Nigeria (Jackson, 1980). The extent of the Coastal Plain Sand is shown in Fig. 1. Coastal Plain Sand has been quarried in several locations as borrow material in the construction of many important roads such as the Lagos – Ibadan expressway and the Sagamu – Ore – Benin highway. Jackson (1980) carried out considerable investigation of the deposits geotechnical properties in specific localities in Lagos and Calabar, and identified the soils as "collapsible" foundation material. Teme (1990) also investigated the deposits' engineering behaviour in the South Eastern part of the Lower Niger Delta of Nigeria and confirmed its "collapsing" nature. In practice, virtually all the important roads and highways constructed over the deposit have failed significantly. Plates 1 and 2 illustrate the occurrence of dangerous pot holes along Lagos-Ibadan Expressway. These large pot holes have a typical cross section of a clayey base course, upon which there is a compacted stone base of about 150mm thick, succeeded on top by very hard asphalt concrete of about 100mm thick. The sharp edges of the succession have constituted very dangerous vehicle tyre busters. Vehicles, which run into them un-aware at high speed are invariably thrown off balance and summersault off track. Unfortunately the illustrated phenomenon is characteristic of several stretches of the expressway.

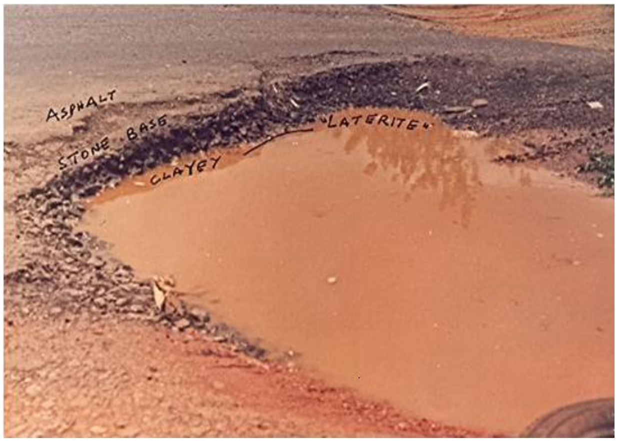

PLATE 1: Large pothole showing clayey lateritic, sub-grade, a stone base & the Asphalt wearing course on Lagos-Ibadan Expressway, Nigeria.

PLATE 2: Dangerous potholes, Lagos-Ibadan Expressway, Nigeria

Fig. 1: Map of Southern Nigeria showing the occurrence of the Coastal Plain Sands (Jackson, 1980)

Field Compaction

Several years of observation by the authors has shown that field compaction with the aid of various heavy rollers is the only form of stabilization stipulated by Consultants, and adopted by Contractors. This form of stabilization is inadequate. Under excessive heavy rollers, the soil grains break down into much finer grains, increasing the silt size content of the compacted soil. Increased silt content constitutes a further destabilizing factor for roads or highways constructed on such soil materials. Most lateritic soils, including the coastal plain sands, do not possess the degree of excellence ascribed to them by Engineers. The lateritic soils possess variable internal structures, geochemical and mineralogical properties, which derive from their geological history, and their respective geotechnical properties are as a direct response to the listed factors. Present studies show that the Coastal Plain Sands possess an "open, skeletal structure", caused by the precipitation of ferric iron oxide and alumina (sesquioxides), which occupy the interstices of medium to fine silica sand grains. Many other mineral grains are also found within the matrix. The sesquioxide precipitates form weak coatings round the silica and mineral nuclei. The bulk of the fines are silt-size, as can be observed in the Grain size distribution curve in Fig. 2. The sand content is usually fine to medium, and clay size particles are minimal. The silt-size particles seem to act as the weak binders when the soils are compacted. Although supervising engineers usually identify the compacted soils as satisfactory, the long term performance of the soils as base or sub-base course materials has shown that they are vulnerable to quick water destabilization at the onset of rainy seasons.

Stabilization

There is abundant literature to show that lateritic soils are known to respond favourably to stabilization by ordinary Portland cement and hydrated lime respectively, (Gidigasu, 1976). In practice however, the two additives have shown little success when used to stabilize fine grained lateritic soils in major road works in Nigeria. Considerable efforts and expenses have been invested on seeking a more effective additive for use in the country. The invention of 'laterilite' may be providing the needed solution. Several samples of the Coastal Plain Sands and other lateritic soils have been experimentally and successfully stabilized against water destabilization, and the treated specimens do not lose their compacted strength when soaked in water for several years.

Lateralite

Lateralite is a new mineral flux evolved experimentally by the first author over a period of about two decades. The mineral flux has been used to stabilize several samples of the Coastal Plain Sands. Lateralite is a mineral compound selected in definite proportions and pulverized to the fineness of cement to induce a pozzolanic effect on sesquioxide –rich lateritic soils in general. The treatment has been amply demonstrated practically. When one measure of the substance is mixed with ten measures of dry soil, and are both mixed with water that is equivalent to the soil's optimum moisture content, the sesquioxide minerals in the soil are noted to form a new precipitate with **lateralite,** When dry, the resulting mixture does not lose its compacted strength and does not respond to water dis-aggregation even when soaked for any length of time.

Engineering index properties of the Coastal Plain Sands

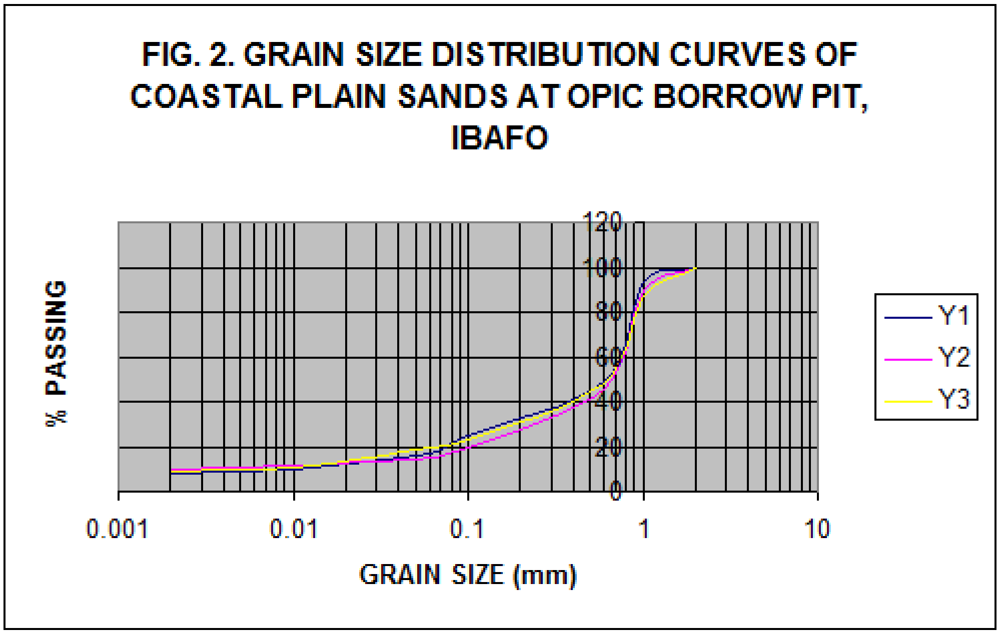

Fig. 2: Grain size distribution curves of coastal plain sands at Opic borrow pit, Ibafo

Table 1: Statistically computed values of engineering index properties of coastal plain sands from "Opic borrow pit" Lagos

Properties	**No of samples**	**Mean values**
Liquid Limit, W^L	20	35%
Plasticity Index, W^p	20	23%
Plastic Limit, W^l	20	12%
Shrinkage Limit	20	8.06%
AASHTO Classification	-	A – 7
Specific Gravity	-	2.66
Percentage fraction passing 0.075mm sieve	-	37.55%

The Stabilized Specimens

The admixture of each of the stabilizing agents to samples of the investigated soil produces an immediate reaction in the presence of water. It was rather difficult to investigate the Atterberg limits of the Mixtures, as a significant level of progressive hardening was noticed while mixing was in progress. Results became very erratic, and the tests were discontinued. Each of the stabilizers induced respective levels of hydration in the prepared specimens at the end of mixing, and by the time that the Compaction test was completed; all the specimens had developed different degrees of hardening.

Compaction

Of special interest in Table 2 are the columns showing the Degree of saturation (%) and Air voids (%). Theoretically, compacted soil specimens should have no air voids at 100% saturation. The compaction test curves shown in Figs.3 and 4 of cement and lime stabilized specimens respectively indicate that there are air voids present, since the compacted specimens were not 100% saturated. The "zero-air-voids" curves are located almost tangentially to the compacted curves.

Table 2: Compaction characteristics of treated specimens

PROPERTIES	VALUES						
	Untreated Soil	Cement Stabilized		Lime Stabilized		Lateralite Stabilized	
	0%	8%	10%	8%	10%	8%	10%
Maximum dry density (kg/m^3)	1922.2	1919.9	1921.3	1911.0	1918.2	1901.2	1913.1
Optimum moisture (m %)	12.89	13.46	13.4	13.3	14.3	13.6	15.4
Degree of saturation (%)	89.33	82.82	76.75	80.29	81.33	83.18	77.8
Air voids (%)	14.67	12.18	11.25	9.71	7.67	13.18	10.8

In contrast, lateralite treated specimens indicate a negative degree of saturation. This means that there is a significant amount of voids present in the treated specimen. This became evident as air bubbles were observed when a dried sample of the compacted soil was immersed in water. However, at the cessation of the bubbling, the immersed sample was not dissipated.

Observations during the study have also shown that treated clayey soils lose their plasticity after setting, but the soil grains remain bound together when dry, though not with a high degree of bonding like in sand/cement mix. Lateralite was found to have some pozzolanic property, although its intensity needs to be investigated. It is believed that as a result of its electrical charge, lateralite has been able to infiltrate into the open skeletal structure of fine-grained lateritic soils, surrounding and binding the larger soil grains even in the presence of water. It is inferred that soils stabilized with lateralite would hardly favour a build-up of pore water pressure when used in construction.

The "Zero-air-voids" curve of lateralite treated soils cut through the compacted curves, indicating negative values (Fig. 5). The reason for this is not yet fully understood, and it is highly essential that a detailed study of the structure of lateralite treated and compacted soil specimens be studied under the petrographic microscope, or with the electron microscope to reveal useful information on the unclear phenomenon. Lateralite treated specimens are expected to possess minimal, and the least air voids compared to those of cement and lime treated soils. It is observed that the grains of lateralite treated specimens are not dissociated when soaked in water for over nine years, and the soaked compacted specimens have also not lost their compacted strength.

Reduction in Maximum Dry Densities (MDD)

It is recognised that additives such as cement and lime do normally decrease the densities of compacted soils (Yoder, 1957; Gidigasu, 1976). The observed is consistent with the results shown in Table 3. The MDD of the untreated soil is higher than those of the stabilized soils. The values obtained from the lateralite-treated soils are the least. This can also be explained by the lighter specific gravity (SG) of lateralite, (2.45). The relative volume of the flux required for the effective stabilization of the soil is higher than those of cement (SG = 3.12) and lime (SG = 2.56) respectively. The buoyancy effect of lateralite on the soil grains is therefore higher than those of cement and lime respectively.

Table 3: Summary of the CBR Test Results.

	UNTREATED SOIL		CEMENT STABILIZED				LIME STABILIZED				LATERALITE STABILIZED			
ADMIXTURE %	0%		8%		10%		8%		10%		8%		10%	
CBR TYPE	S	U	S	U	S	U	S	U	S	U	S	U	S	U
CBR % (*80%)	16.70	35.5	96.93	54.28	129.68	59.11	63.89	52.40	74.22	51.48	64.53	45.30	142.4	51.22
WELL %	4.20	-	2./032	-	1.043	-	2.14	-	0.059	-	0.70		0.00	
MOISTURE CONTENT OF CBR SPECIMENS %	18.9	13.09	15.95	13.21	13.70	12.41	14.83	12.54	14.17	12.43	14.33	13.96	13.03	12.23

NB: S = Soaked; U = Un-soaked

California Bearing Ratio (CBR) Characteristics

The soaked CBR values obtained from unstabilized samples are less than the minimum values recommended by the Nigerian Federal Ministry of Works (i.e. 80%), for base course materials. The soaked CBR values of lime-stabilized soils do not satisfy the Ministry's recommendation either, while values of cement- and lateralite- stabilized soils are satisfactory.

Prolonged Soaking in Water

Long term observation has shown that Nigerian roads are mostly destabilized in wet weather. Sub-base and base course materials are usually compacted clayey lateritic soils, which characteristically absorb water by capillary action; and this softens the compacted soil material, no matter the degree of compaction attained during construction. It is reasonable therefore to investigate all stabilized soils meant to be used as sub-base or base course materials by **prolonged soaking in water to ascertain the possible behaviour of the soil underneath the completed pavement in wet weather**.

Compacted specimens of the soils treated with the respective stabilizing agents at the mixing ratio of 1:10 were selected in equal numbers and subjected to the immersion test. Each specimen was cured for 24 hours under wet condition, and later soaked in a bowl of water for 60 days. Continuous observation throughout the immersion period shows that the hydrated lime stabilized specimens disintegrated completely within the first six days. Cement stabilized specimens remained intact for the first four days after when rapid spalling commenced. By the tenth day, all the specimens had disintegrated. In contrast, all the lateralite stabilized specimens remained un-deformed throughout the immersion period, and up till the time of writing, all the specimens have remained intact, a period of over nine years. The observation period (9 years) practically proved that lateralite treated sub-base or base course lateritic soils are most likely to survive wet weather conditions in flexible pavements if design thicknesses and construction techniques are satisfactory.

Conclusion

The comparative effect of Portland cement, hydrated lime and lateralite as stabilizers of the Coastal Plain Sands in the northern environs of Lagos Metropolis was studied. This study showed that the performance of lateralite as soil-stabilizing agent is more effective than that of cement or hydrated lime. Results of all previous field experiments also indicated that if lateralite is used to stabilize poor quality lateritic soils such as the Coastal Plain Sands in difficult wetland environments, its performance as an adequately thick base course should lead to a positive development towards the construction of stable roads even in such areas. Engineering designs should be modified to take cognisance of the geological environment. It is also essential that the geological characteristics of the soils meant for stabilization with lateralite should be studied to confirm their suitability for lateralite action.

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