SAND-LATERITE MIXTURES FOR ROAD CONSTRUCTION
(A Laboratory Investigation)

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ABSTRACT

Soil mixtures have been used extensively in developed countries to construct great lengths of road when other materials like cement and lime were not either available, developed or widely used. Developing countries with low per capita income, low cement and lime production, can use the same technique today. Laterite being readily available in many places can be mixed with sand to improve its strength, stability and other properties for this purpose.

The paper sets out to investigate the improvements in the relevant properties of six samples of laterites when they are mixed with sand. The six samples are representative of the types of laterites occurring over the eastern parts of Nigeria. In practice, the mode of construction in which sand is used as a stabiliser instead of cement or lime could be used to minimise costs in the construction of roads carrying medium density traffic and in the surfacing of "unimproved roads".

The results obtained show that for all types of laterites tested, the addition of sand to laterites has beneficial effects in reducing the liquid limit, the optimum moisture content, the plasticity index, the linear shrinkage and in increasing the maximum dry density and the California Bearing Ratio. There is an optimum sand percentage for maximising most of the parameters measured. This optimum sand percentage is different for each type of laterite and is also dependent on the level of compaction given to the mixture. Comparison of the results obtained with some specifications shows that the improvements obtained are such as would make the sand-laterite mixtures satisfy most specifications for the types of roads mentioned.

INTRODUCTION

The purpose of this paper is to summarize the results of a study concerned with the improvements or otherwise that may be obtained when laterites from the eastern parts of Nigeria are stabilised with ordinary river sand. Laboratory tests have been carried out on the stabilisation of laterites from South East Asia (1) but for reasons given later, their results are not expected to apply to laterites of the type under consideration. Furthermore, in the test mentioned, only one sample of laterite was assessed.

The problem of financing some meaningful road development in the developing countries of the world is immense, due to high cost of materials and construction. The problem has been examined elsewhere (2) and it has been shown that most of these countries cannot afford the extensive use of the traditional stabilising materials like cement and lime. Such countries produce a minimum of these materials and the foreign exchange requirements militate against the wide importation of the materials. Often in many of these places and on rural roads, the level of traffic is such that a stage construction using mechanical stabilisation will suffice for bases and for surfacing.

A great amount of effort has been directed to the study of laterites (3-5) and a large volume of literature has emanated. This delineates the importance attached to this type of soil as a structural material as well as the differences in the results obtained. Despite this large volume of literature, there is little agreement on anything about laterites-not even on what a laterite is. The situation has arisen because enough attention was not paid in the past to the origin of the laterites, the geological and soil climatic conditions under which they were formed etc and the effects of these factors on the resulting laterites. This gave rise to a stereo-type expectation of their behaviour and properties. Despite these disagreements and variability in properties arising out of their history and genesis most engineers particularly in West Africa, agree that laterites are good materials for road and air-field construction. They are often used unmodified for bases for roads carrying light traffic hence it is thought that a little improvement might make them acceptable as bases for medium trafficked roads.

The occurrence of laterites and lateritic soils is wide-spread in Africa and they occur widely in the western, Midwestern, eastern, Benue Plateau and other parts of Nigeria. In most of these areas, sands and sandy soils can be found and consequently can be used as a component in the sand-soil mixture where such mixtures are found suitable. In America, this method of stabilisation was used extensively in the early thirties and forties. (6) In many tropical countries, more than three quarters of the total road mileage consists of earth or unimproved roads (7) and laterite-sand mixtures can often be used with advantage in the construction of such roads since these mixtures tend to ease the problem of corrugation, pot-holing, etc. (2). In some developed countries like South Africa, this method of soil-improvement in which one type of soil is added to a parent soil or aggregate to improve its strength and stability, often referred to as mechanical stabilisation is also widely used.

In the eastern parts of Nigeria, laterites occur in the northern parts of the tropical savannah area: around Okigwe, Abakaliki, Awka, Enugu and Nsukka. Apart from the work of Ackroyd (3) on the laterites obtained from some parts of Western Nigeria, very few tests have been reported on Nigeria laterites and what follows is a part of a project (4) initiated to fill this gap in the case of laterites of Eastern Nigeria. The main objectives of the tests are: (i) to determine whether the properties of the laterites can be improved sufficiently by mixing them with sand to make them acceptable for surfacing earth roads; (ii) to determine the extent of the improvement in the properties of the sand-laterite mixture and their suitability for bases for roads carrying medium density traffic.

SOIL SAMPLES FOR EXPERIMENTS

Since the project was a pilot one. the samples of laterites for the experiments were collected from locations which have been used or are being used by the Ministry of Works and other road building agencies (wherever possible) in winning materials for road construction. Table 1 shows the locations from which samples were obtained and it will be seen from the table that samples were obtained on a fairly wide basis, representative of the areas of occurrence of the laterites and consequently the laterite types of eastern Nigeria. The depth of sampling would correspond approximately to horizons B and C.

The sand for the experiment was obtained locally from the Ezimo stream situated east of Nsukka. It is of pale reddish brown, poorly rounded and consists mainly of quartz (95 %).

Table 1: source of laterite sample

Sample No	Lacation of Burrow pit	Route (Rd)
1	Near Iyahe	Abakaliki - ogoja Rd.
2	Mile 71 ½	Abakaliki – ogoja Rd.
3	Eungu army barracks	Enugu-abakaliki Rd
4	Nsukka urban	Nsukka-Ibeagwani Rd.
5	Abagana	Enugu-onitsha Rd
6	Mile 31 (from okigwe)	Okigwe-Afikpo Rd.

EXPERIMENTAL PROCEDURE

a) Pretreatment of Soil Samples: The laterite samples were collected in large containers and stored in the laboratory. Samples to be tested were first spread out to air dry the soil samples. It is known that the type of pretreatment given to laterite samples affects their engineering properties, but it was thought that the above pretreatment approximates best to the conditions often met during construction in which laterites are left in heaps on the road side before use. The sand was also air dried in the laboratory and constant checks showed that the sands thus treated contained no measurable quantity of moisture.

(b) Grain Size Analysis: The laterite samples were wet sieved through the various British Standard sieves and the grain size analysis continued with a hydrometer. Samples were treated with hydrogen peroxide and hydrochloric acid where necessary. The sand was sieved dry.

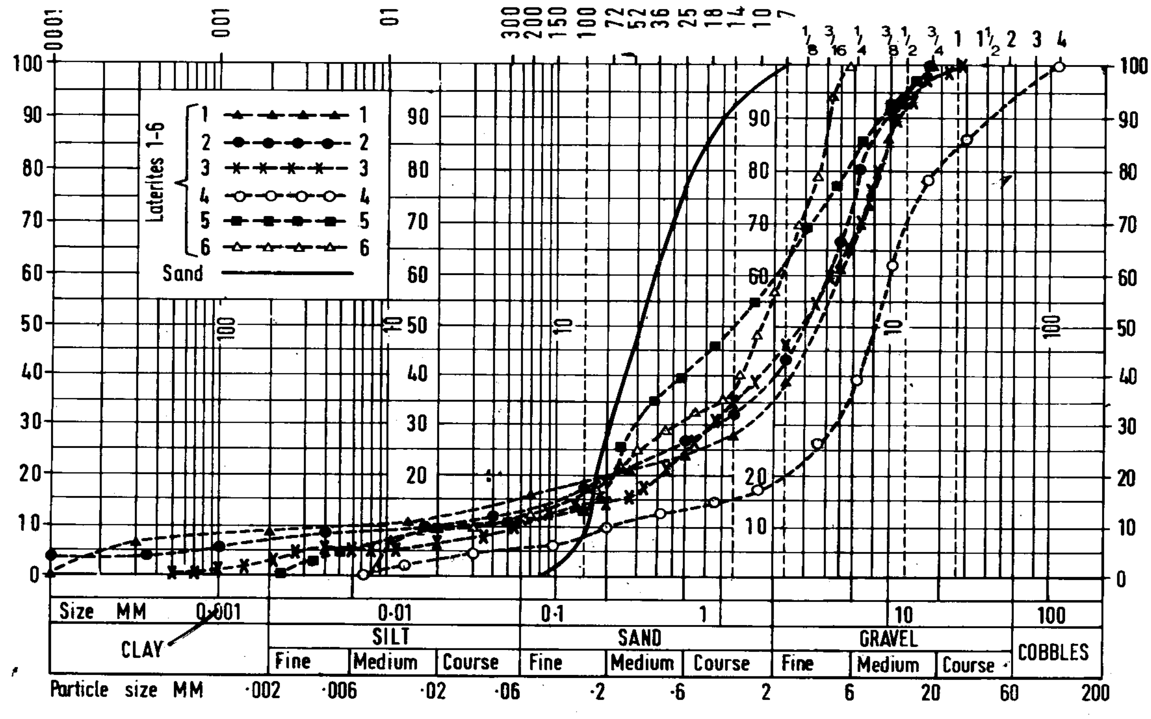

Fig 1 GRADING OF LATERITES AND SAND

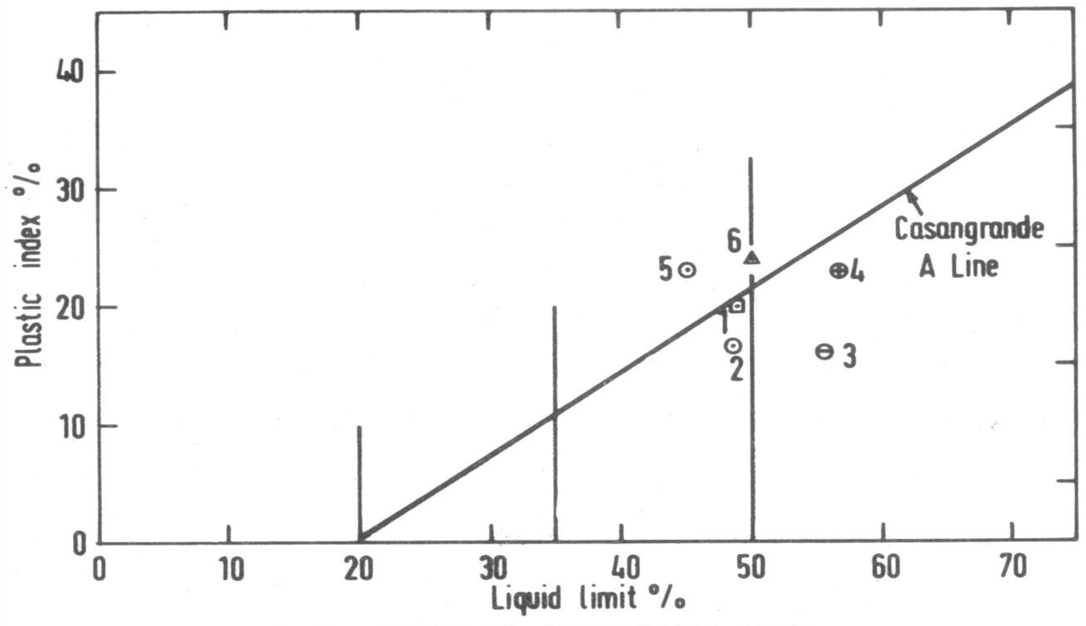

Fig 2 DIFFERENT LATERITE ON CASANGRANDE CHART

(c) Compaction Tests and Atterberg limits:
For Atterberg limits and compaction tests, distilled water was used throughout. The percentage of sand used was based on the dry weight of the laterite samples. Each batch of the sand-soil mixture was mixed with the required quantity of water in a mechanical mixer, equilibrated for twenty-four hours and then compacted.

All tests, including the linear shnnkage limit test, except where shown to the contrary, were conducted according to the latest relevant British Standard. Laterite samples were first broken up in such a way that the soil particles were reduced to their natural individual sizes.

The moisture-density relationships were determined by using the standard Proctor and the California Bearing Ratios (CBR) 15.24 cm moulds (6 ins dia). Compaction was at two energy levels shown in Table 2.

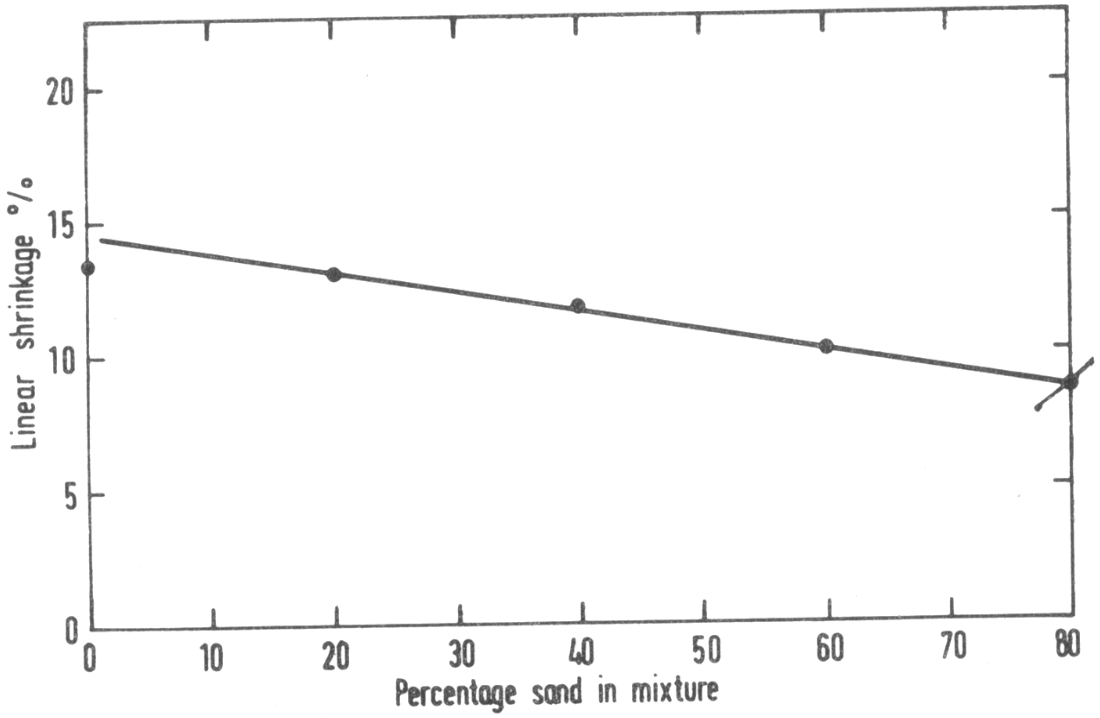

Fig. 3. TYPICAL VARIATION OF LINEAR SHRINKAGE WITH SAND PERCENTAGE IN MIXTURE. LATERITE SAMPLE 4

Table 2:- Details of compactive Efforts for moisture-density determinations.

No of Layers	Blows per Layer	Hammer Weight kg	Compactive Efforts 10^3 Joles/m^3	Type of Test and Mould
5	25	4.5(10)*	1078(22,500)	West African standard (WAS) CBR mould
3	25	2.5(5.5)	594(12,375)	British standard (proctor) proctor mould

*Figures in brackets are in imperial units

Fresh Soil sample was used for each test since it was possible that the first compaction might have broken down the soil and aggregate particles and in view of the fact that the recompaction of the soil may lead to a different result from the obtained from its first use (1)

(d) California Bearing Ration (CBR) Tests:

The preparation of the laterite-sand mixtures was as in the moisture-density tests. All examples were tested unsoaked as it is know that under Nigerian conditions, the soaking of stabilised samples does not reflect the likely field conditions (8).

Samples for the CBR test were compacted at moisture contents dry of the optimum after moisturizing and were then tested immediately afterwards.

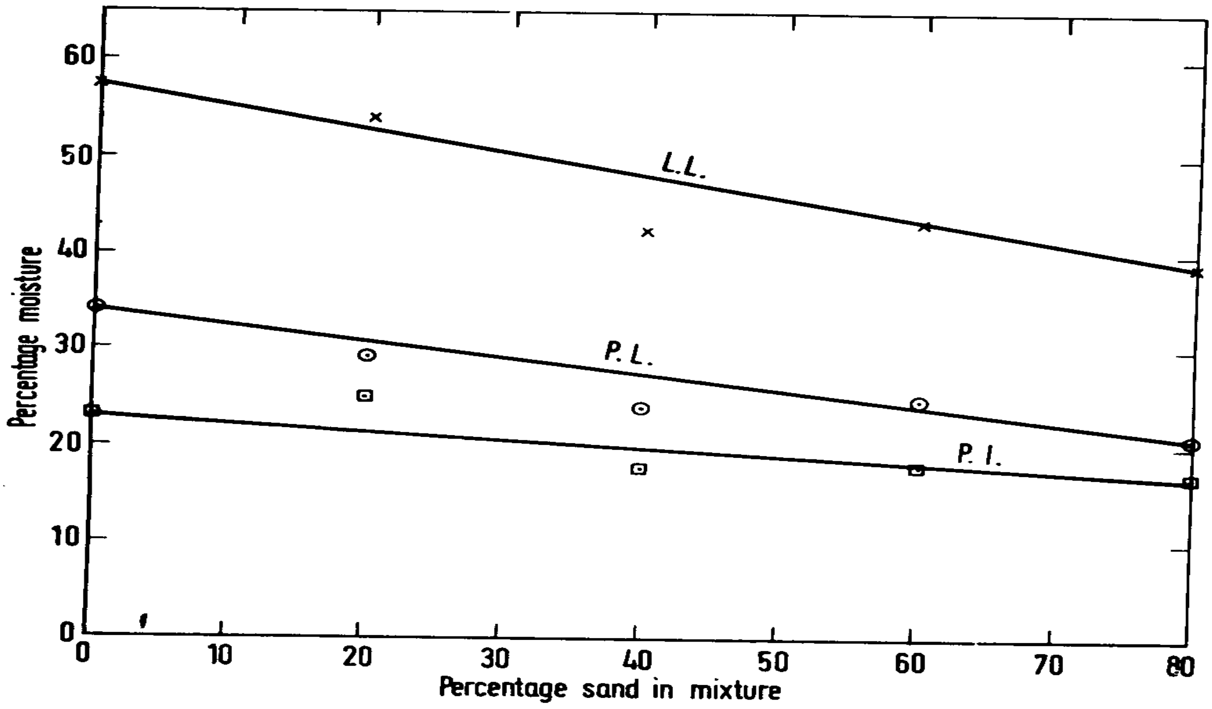

Fig. 4. VARIATION OF ATTERBERG LIMITS WITH PERCENTAGE OF SAND IN MIXTURE FOR LATERITE 4

RESULTS AND DISCUSSIONS

a) **Effects of Sand on Laterite Grading:** The grading curves for the laterites and the sand are shown in Fig. 1. The graphs show that the laterites are coarsely graded, lacking in fine particles. A comparison of the grading curves show with those obtained by De Graft-Johnson et al (5) for Ghana laterites shows that the curves do not seem to fit into any of the four families obtained by De Graft-Johnson. This is to be expected, for as has been noted before, only laterites formed under identical geological and soil climatic conditions can be expected to have approximately the same properties.

Fig. 2 shows the position of the laterites on a Cassangrande plasticity classification chart. As in Ghana laterites, the samples do not plot in a region on the chart and for that reason, the chart does not appear to form a suitable basis for the classification of the samples. The problem of classifying laterites has been examined by De Graft-Johnson (5) and a detailed discussion of the subject is considered outside the scope of this article.

(b) **Effect of Sand on Linear Shrinkage and Atterberg Limits of Laterites:**

Table 3 presents the linear shrinkage, the Atterberg limits and other properties of the laterites without sand mixture, while Figs. 3 and 4 show the typical variation of the linear shrinkage and the Atterberg limits respectively with the addition of sand.

Both the linear shrinkage and Atterberg limits are often used in specifications for the selection of materials for road sub-bases, bases and surfacings in the case of the so-called unimproved or low cost roads. Thus O'Reilly and Millard (9) Suggest that for surface courses in seasonally wet tropical regions, the materials for the surfacing should satisfy the following specifications:
Liquid limit 45 %
Plastic index 6-20%
Linear shrinkage 4-10%

Ackroyd (3) has suggested a maximum liquid limit of 25 % and a plastic index of 6 % Referring to Table 3, it will be seen that none of the samples of laterites satisfies the above specifications. In particular it will be noted that only two types of laterites have a linear shrinkage less than 10.

Figures 3 and 4 graphs taken together, show that the effect of adding sand to the laterites is to decrease the Atterberg limits and the linear shrinkage. Experimental evidence (2) seems to suggest that materials which lack fines are most liable to corrugations and the improvements in the grading of laterites, in the Atterberg limits and the linear shrinkage make the mixtures particularly suitable for surfacings in earth roads.

Table 3 - Index and Other Properties of the Laterites

Laterite Sample No.	1	2	3	4	5	6
Specific Gravity	2.70	2.72	2.77	2.44	2. 36	2.57
Liquid Limit (LL)%	49.0	48.7	56.4	572	45.0	50.0
Platic Limit (PL) %	28.7	32.0	40.4	34.1	22.0	26.0
Plastic Index (PI) %	20.3	16.7	16.0	23.1	23.0	24.0
Linear Shrinkage %	14.8	8.6	14.0	13.3	9.5	11. 2

The linear decrease of the Atterberg limits with increasing percentage of sand appears to be a phenomenon common to all laterites, although the rate of decrease varies with the laterite type. Muktabhant and Ongskul (1) have tested an equation for the plastic index variation based on a sample of laterite mixture they tested. This linear equation is dependent on the plastic index of the original laterite sample and the percentage of the mixture passing No. 40 United States standard sieve.

For such equations to be comprehensive, it is believed that they should be derived from the results of several samples of the same type of laterites collected over a given area-the results being treated statistically to test the equation derived (5). For this reason no attempts have been made to derive the equations of the linear variations shown on the graphs.

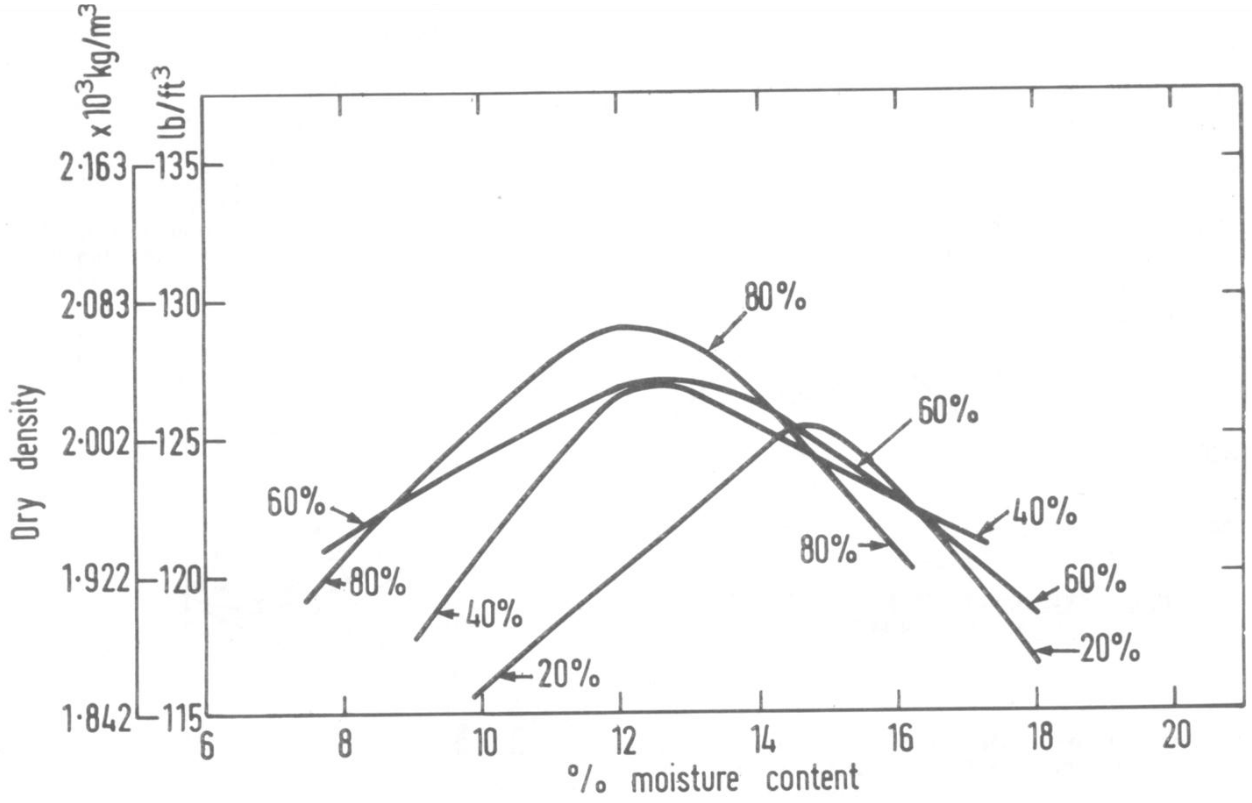

Fig. 5. TYPICAL MOISTURE CONTENT — DENSITY RELATIONSHIP FOR LATERITE 1 — BRITISH STANDARD COMPACTION (PROCTOR)

(c) Moisture Content-Dry Density Curves:
The relation between the dry density and the moisture content of the sand-laterite mixtures are shown in Fig, 5 and Fig, 6 with the percentage of sand in each mix shown on the graph. These curves show the following:

i. The greater the compactive effort the higher the maximum dry density. This is usual with most forms of stabilisation.
ii. The greater the percentage of the stabiliser (in this case sand) up to a given maximum percentage, the greater the dry density in

general. Increase of some stabilisers decrease the dry density of laterite and other types of soil (2)

iii. The greater the percentage of the sand up to a given maximum (dependent on the laterite), the smailer the optimum moisture content.

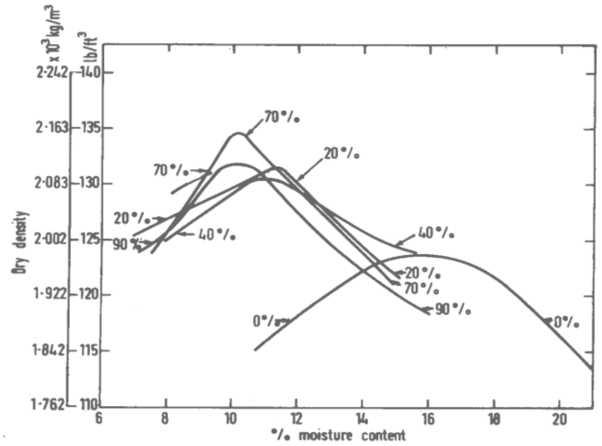

Fig. 6. TYPICAL MOISTURE CONTENT DENSITY RELATIONSHIP FOR LATERITE 6 WEST AFRICAN COMPACTION LEVEL

(d) Variation of Maximum Dry Density and Optimum Moisture Content with Percentage Sand: The Variation of the maximum dry density and optimum moisture content with percentage sand is shown graphically in Figs. 7 and 8 and on Table 4 for other results not presented on the graphs. From the graphs and tables, the general effect of increasing the percentage of sand in the mixture is to increase the maximum dry density (MDD) and to decrease the optimum moisture content (omc) till an optimum maximum dry density is attained,

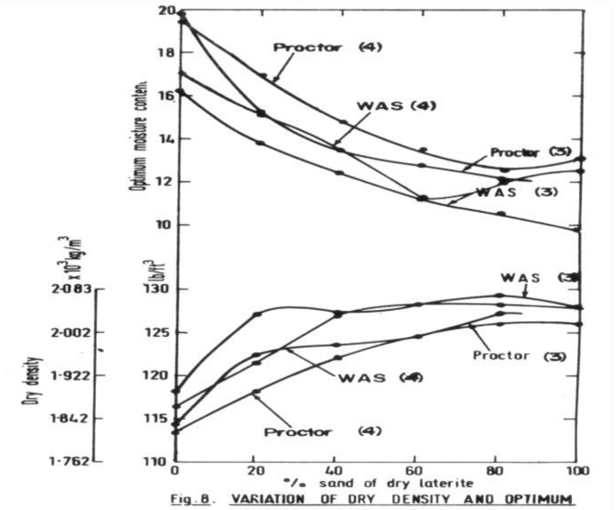

Fig. 8. VARIATION OF DRY DENSITY AND OPTIMUM MOISTURE CONTENT WITH THE PERCENTAGE DRY SAND FOR LATERITE 3 & 4

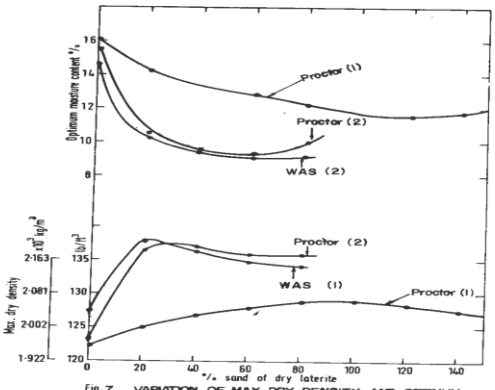

Fig. 7 VARIATION OF MAX DRY DENSITY AND OPTIMUM MOISTURE CONTENT WITH DRY DENSITY LATERITES 1 AND 2

In general, the above results agree with those obtained by Muktabhant and Ongskud (1) but differ in details from them. Their result showed that there is an optimum percentage of sand at which their mixture attained the optimum maximum dry density and a minimum optimum moisture content simultaneously. A study of the graphs and Table 4 shows that some of the mixtures attain their minimum optimum moisture content at sand percentages different from those giving the optimum maximum dry density for each level of compaction used. As expected, the graphs [or the British Standard compaction (Proctor) Show in each case a greater optimum moisture content with a corresponding lower maximum dry density.

Table 4 – Variation of Maximum Dry Density and Optimum Moisture Content with Percentage Sand

Laterite Sample No.	Percentage Sand	MDD 10^3kg/m^3 (1bf/ft^3)*		OMC %		%Increase in MDD		% Decrease in OMC	
		Proctor	WAS	Proctor	WAS	Proctor	WAS	Proctor	WAS
5	0	1.71 (106.7)	1.76 (110.1)	17.6	15.8	0	0	0	0
	20	1.79 (112.0)	1.87 (117.3)	16.1	14.5	4.95	6.6	8.5	8.2
	40	1.87 (116.5)	1.98 (123.7)	15.4	13.5	9.2	12.3	12.5	14.5
	60	1.88 (117.5)	2.06 (128.3)	13.7	10.4	10.2	16.5	16.5	34.2
	80	1.95 (121.9)	1.96 (122.5)	11.5	11.5	14.3	11.3	34.7	27.8
	100	1.94 (121.0)	—	12.6	—	13.4	—	28.4	—
	120	2.02 (126.1)	—	12.2	—	8.2	—	30.7	—
	0	1.94 (120.9)	1.98 (123.5)	18.4	15.8	0	0	0	0
	20	2.04 (127.2)	2.10 (131.5)	14.9	11.3	5.2	6.5	19	28.5
	30	—	2.07 (129.2)	—	12.6	—	4.6	—	20.2
	40	2.05 (128.0)	2.08 (130.0)	13.4	10.8	5.9	5.4	27.2	31.8
	60	2.06 (129.0)	—	13.0	—	6.7	—	29.4	—
	70	—	2.15 (134.5)	—	9.9	—	8.9	—	37.4
	80	2.08 (130.0)	—	12.5	—	7.5	—	32	—
	100	2.1 (131.0)	2.12 (132.5)	11.5	9.6	8.3	7.3	37.5	39.2
	120	—	2.08 (130.0)	—	10.5	—	5.3	—	33.5
	150	2.03 (127.0)	—	12.5	—	5.1	—	32	—

* Figures in brackets = MDD in lbf/ft^3

Table 5-variation of CBR valves with percentage send samples 1, 3 and 4

Sand percentage	Sample 1		Sample 2		Sample 3	
	CBR%	% Dry of Optimum	CBR%	% Dry of Optimum	CBR%	%Dry of Optimum
0	33	1.0	31	2.3	42	1.1
20	–	–	51	7.6	–	–
40	47	1.0	40	6.3	–	–
60			36	5.3	77	32
70	52	14	–	–	–	–
80			57	3.6	60	1.7
90	43	1.1	–	–	–	–

Table 6- variation of CBR valves with percentage sand samples 2, 5 and 6

Sand percentage	Sample 1		Sample 2		Sample 3	
	CBR%	% Dry of Optimum	CBR%	% Dry of Optimum	CBR%	%Dry of Optimum
0	35	2.1	30	2.2	38	1.1
20	42	2.1	–	–	34	1.5
40	53	2.1	38	5.5	40	1.0
60	–	–	45	2.6	–	–

(e) **Variation of the CBR Value with Sand Percentage:** It is known that soil samples attain their maximum strength as measured by the CBR test at moisture contents different from the optimum. For many types of soil the maximum value is attained at moisture contents dry of the optimum. In practice for any given sample, this maximum is obtained by trial and error by compacting at moisture contents near the optimum. The amount of testing at each sand percentage to determine this value is usually large and was considered beyond the resources of the project.

An alternative approach was adopted: this was to test samples at variable moisture content but always dry of the optimum. Tables 5 and 6 show the results of some of the tests. On each table and for each sample, the first column gives the CBR value and the second column the percentage by which the moisture content of compaction was lower than the optimum.

Muktabhant and Ongskul (1) found that their mixtures have maximum CBR value at percentages varying from 1.8 to 1.1 dry of the optimum-the percentages showing an irregular pattern with increasing sand content. The results of the *above* tables were obtained by testing in three moisture content ranges: the first (samples 1 and 6) using moisture content as in Muktabhant and Ongskul; the second (sample 2) using a constant moisture content at variable laterite-sand ratios and the third (samples 3.4 & 5) using variable moisture content greater or equal to the values used in the first two. Assuming that the maximum CBR is always obtained at a moisture content dry of the optimum, it can be concluded that some good improvement *have* been obtained as shown on Tables 5 and 6, At a heavier compaction, like those used in some of Muktabhant and Ongskul's experiments, the CBR values shown on Tables 5 and 6 will, in the minimum and at the same moisture content double their values, based on the results obtained by Muktabhant and Ongskul. Without any further improvements, the results of Tables 5 and 6 are considered good and for medium density traffic. most of the C BR values will give an economic base thickness

The irregular nature of the values of the CBR obtained in this report and in other places may be due to a number of factors: the age and origin, of the laterites but more importantly to their chemical and physio-chemical properties, particle structure and mineral constituents.

CONCLUSION

The results obtained *have* shown that the *various* properties of laterites normally relevant in road and pavement construction can be improved to a very appreciable extent by mixing laterites with sand and the following conclusions can be drawn from the experimental investigations.

a) With proper selection of sand for sand- laterite mixtures, the limits specified for surfacings for earth roads (and which limits will produce materials not liable to corrugations) can be easily attained.

b) The mixing of sand to laterites reduces the Atterberg limits and the linear shrinkage of the laterites. Both the Atterberg limits and the linear shrinkage decrease linearly with the increase in the percentage of sand. The linear equation expressing the Atterberg limits and linear shrinkage as a function of the sand percentage may be obtained for each type of laterite by testing several samples from different horizons and using a statistical analysis to derive the equations.

c) Each laterite sample attained the greatest maximum dry density at a sand percentage which in general corresponds to that giving the minimum optimum moisture content. Percentage increases in the maximum dry density and decreases in the optimum moisture content are in the range of 4% –15% and 9%–40% respectively.

d) The CBR values show an irregular pattern with increase in the sand percentage but all samples gave good CBR values. When some samples are compacted at moisture contents considerably lower than the optimum good values of CBR are still obtained.

e) The only expense involved in procuring sand for stabilisation will be the hauling costs which may include the small cost of winning the sand. With cement and lime costing about ₦1.50 (£0.80 sterling) per bag of 50 kg (112 Ibs) or more, sand is the least expensive of materials with which the laterites may be improved and gives a mode of stabilisation likely to require the minimum in special construction equipments

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