Engineering Properties of Unused and Cement Stabilized Used Laterite Soils

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Abstract
The practice of building local housing units with laterite is common in Ogbomoso, Oyo State, Nigeria. This practice helps to reduce the rising cost of building construction. This paper investigates the engineering properties of both used and unused laterite soils with intent to reuse the laterite soil in construction of housing units. Disturbed samples of both used and unused laterite soils were investigated for engineering index, compaction and strength properties. Sieve analysis, atterberg limits, specific gravity, compaction, air-dry moisture content, triaxial compression and compressive strength tests were performed on the samples of two types of soils in accordance with BS 1377-2; 1990. The results from the study revealed that the geotechnical properties of the unused laterite soil samples are better than that of the used laterite soil samples, which supports their suitability and preference for construction of local houses than the used laterite soil samples. However the used laterite soil can be re-used or reutilized to build local houses in subtropics by addition of 0.5% Portland cement. Furthermore, addition of 0.75% Portland cement to the used laterite soil makes it stronger and more suitable for construction of housing units than the unused laterite soil.

Keywords:
Laterite, compaction, geotechnical, construction, strength

1. Introduction
Housing is a basic and essential need of man. The rising cost of buildi ng materials and construction has made it necessary in many urban and rural areas of Nigeria to develop alternative low cost

construction techniques. Amongst the low cost techniques being developed as applicable in Ogbomoso area is the use of unused laterite and used laterite soils for construction of houses because of its availability. According to Laa et al. (2003) "Inavailability of local construction materials have for a long time been encountered in some places or at some times. Lateritic soils, where mostly available are extensively used as local construction material in engineering works for building housing units but they require critical investigations before they are used for road works, airfield embankments or fills for small earth dams and other engineering foundation works".

According to Gidigasu (1976), "Laterite soils are mostly reddish brown soils used extensively for construction works. They are rich in oxides of aluminium and iron and may have been formed under previous climatic condition. The term "Laterite" was originally used to describe materials which could irreversibly harden when cut from the weathering profile and air dried, so that it could be used as bricks, from the Latin word 'later' meaning bricks". Information on the genesis, nature distribution and geotechnical characteristics of laterite soils could lead to the formulation of a methodology and criteria on which to establish standard procedures for the identification and evaluation of laterite soil for engineering purposes (Gidigasu, 1974).

Laterite as a soil group is more commonly found in the leached soil of humid tropics. It is difficult to assess the strength parameters of lateritic soils from the existing literature due to variability in test methods, degree of compaction, and actual soil characteristics (Attoh – Okine and Fekpe, 1999). Laterite profile has pallid layers of cached white clayey horizon overlying a mottled layer or zone surrounded by a strongly and intensely weathered profile (Egwurube, 2001). Soil wetness shows moisture content which directs the response and feedback mechanisms between the atmosphere and land surface (Mallick et al, 2009). Liquid limit differs based on pre-test treatment: either the soil was oven-dried, sun-dried or air-dried. However, plastic and shrinkage limits give insignificant differences to different pre-test methods (Ola, 1982). Laterite soils are affected by water. Increase in water content of the laterite soil may lead to a loss of strength. For this reason, laterite is sometimes stabilized. According to Egwurube (2001) "Stabilization is the improvement of poor quality materials for construction in order to enhance conformity to the required specifications. Additives like lime, bitumen, fibre and Portland cement are used to stabilise road pavement". Shear strength characteristics of soil is of great importance to engineers and researchers as it gives the reaction of the soil to applied load (Chia-Nan et al., 2009).

The geotechnical characteristics and field performance of laterite soils are of great importance to engineers and engineering geologists involved in the identification and evaluation of laterite soils for construction purposes. Judicious use of laterite soil in construction requires thorough examination via conduct of laboratory experiments. This was done in prospecting used laterite soils from Ogbomoso for reuse in construction of local houses, following the assessment of the effect of cement (an addictive) on the used laterite soils after the comparison of the engineering properties of used and unused laterite soils (Adeboje, 2003). This paper investigates the engineering properties of both used and unused laterite. It also examined the reusability of laterite soil in construction of local houses by comparing the geotechnical properties of used and unused laterite soils. The effect of Portland cement as addictive on the used laterite soil was also investigated.

2. Materials and Methodology

2.1 Materials

Disturbed samples were collected for the two types of specimen – the used and unused soils in Ogbomosho area of Oyo State, Nigeria. Five unused soil samples were collected from Igbo-Ile, Iresa Adu, Ogbomoso and were labelled samples A_1, A_2, A_3, A_4, A_5. Five used soil samples were collected from a collapsed mud house behind the Eid Prayer Ground, Ogbomoso and were labelled sample B_1, B_2, B_3, B_4 and B_5 respectively.

2.2 Soil Index Properties

Fresh soil samples collected and tested within 3 months were used in order to prevent alteration of the properties of the soil. All the samples were air-dried for 1-day before testing in order to simulate field conditions as suggested by Peck (1971). A summary of the particle size analysis is presented in Table 1. A summary of the soil index properties is presented in Table 2.

Laboratory tests were performed on the samples in accordance with British Standard, BS 1377-2 (1990) for the natural soil and BS 1924 (1990) for the treated soil. The soil was characterized and classified by the following tests: Atterberg limits, compaction and unconfined compressive strength (UCS).

2.3 Compaction Tests

Tests involving the compaction tests and unconfined compressive strength were carried out using the British Standard Proctor compaction energy levels. The BS (Proctor) compaction mould was used, the compactive effort consists of the energy derived from a 4.5kg rammer falling through 45cm onto five layers, each receiving 10 blows.

3. Results and Discussion

3.1 Sieve Analysis and Particle Size Distribution

The results of the sieve analysis and particle size distribution are presented in Table 1. The percentage of soil material passing through No.200 BS sieve were 66.15 - 75.06% for unused laterite soil samples and 10.72 - 13.11% for used laterite soil samples. The percentages of soil material passing through No 40. BS sieve were 83.09 - 87.44% for unused soil samples and 33.03 - 37.34% for used samples. The percentage of material passing through No.10 BS sieve were 92.42 - 94.26% for unused soil samples and 53.34% - 60.78% for used soil samples. The results showed that the used soil samples are well graded. The values of the properties for the samples and sieve fall within acceptable limits of BS 1377-2; 1990.

Table 1: Cumulative percentage of soil sample passing through sieves

Sample Sieve No.	Unused Laterite Soils					Used Laterite Soils			
	A_1	A_2	A_3	A_4	A_5	B_1	B_2	B_3	B_4
¾"	-	-	-	-	-	87.95		-	-
3/8"	99.32	-	99.32	99.28	99.18	77.45	85.91	89.19	89.58
3/l6"	98.31	99.21	98.20	98.34	98.15	65.54	7427	74.56	74.64
No. 7	95.78	94.44	95.73	95.72	95.72	60.89	68.45	68.30	69.91
No. 14	92.60	94.26	92.52	92.51	92.42	53.34	59.70	59.25	59.95
No.25	87.44	89.29	87.02	87.55	87.11	39.93	44.41	44.27	44.73
No. 36	83.97	84.91	63.09	84.06	83.44	33.07	36.58	36.18	36.67
No. 72	76.77	79.21	75.65	76.80	76.51	21.82	24.70	24.27	25.09
No. 200	66.65	75.06	66.15	66.73	66.30	10.72	12.49	12.37	12.90
D_{10}	-	-	-	-	-	0.075	0.060	0.075	0.070
D_{30}	-	-	-	-	-	0.38	0.30	0.40	0.30
D_{60}	-	-	-	-	-	1.30	1.30	1.40	1.30
Cu	-	-	-	-	-	17.33	21.67	18.67	18.57
Cc	-	-	-	-	-	1.48	1.15	1.52	1.00
Remark	-	-	-	-	-	Well graded	Well graded	Well graded	Well graded

3.2 Soil Index Properties

The index properties of the soil are presented in Table 2.

Table 2: Index Properties of the Soil Samples

Property	Un-used Laterite Soils					Used Laterite Soils				
	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5
Liquid limit, %	50.00	49.75	19.25	49.75	17.80	35.50	36.60	35.80	35.45	36.25
Plastic limit, %	26.65	27.32	6.72	25.86	11.47	21.81	23.69	21.73	22.16	21.43
Plasticity Index, %	23.35	22.43	12.54	23.89	6.33	13.69	12.91	14.07	13.29	14.82
L.S, %	7	6	6	6	6	6	3	2	1	3
Specific Gravity	2.35	2.43	2.63	2.63	2.63	2.56	2.74	2.65	2.05	2.65
Optimum moisture content, %	20.4	18.8	20.8	18.0	22.8	7.60	7.20	7.60	7.40	7.60
Maximum Dry Density, MDD (Mg/m^3)	1.48	1.50	1.47	1.48	1.45	2.08	2.08	2.08	2.08	2.08
Air dry Moisture Content, %	2.11	2.37	2.13	2.10	2.44	1.10	0.05	0.72	0.72	0.74

3.2.1 Atterberg Limits

Federal Ministry of Works and Housing (1973) recommended liquid limit of 50% maximum, plastic limit of 30% maximum and plasticity index of 20% maximum for use in construction work. The plasticity index obtained for most of the unused soil samples was greater than 20% except for sample A3 and A5. The implication of this is that most of the unused laterite samples do not meet the requirement. The plasticity index for all the used laterite soil samples were less than 20%. This showed that all the used soil samples meet the requirement for use in construction work. Only two unused soil samples (A3 and A5) met the requirement for use in construction work.

3.2.2 Specific Gravity

According to Gidigasu (1976) the S.G. of quartz (which forms half or more of laterite soil) is 2.65. Wright (1966) gave the standard range of values of specific gravity of soil to be between 2.60 and 2.80. The specific gravity as shown in Table 2 for the soil samples show that samples A_3, A_4, A_5, B_2, B_3 and B_5 while samples A_1, A_2, B_1 and B_4 did not comply.

3.2.3 B.S Compaction

According to O'flaherty (2002) the ranges of values that may be anticipated from compaction are:

Clay	MDD	1.44 - 1.685 Mg/rn^3,
	OMC	20 - 30%
Silt Clay	MDD	1.60 – 1.845Mg/rn^3,
	OMC	15 - 25%
Sandy Clay	MDD	1.76 - 2.165Mg/rn^3,
	OMC	6 - 15%

Therefore, samples A_1-A_5 are predominantly clays while samples B_1-B_5 are predominantly sandy clays as shown in Table 2. Since the clayey materials are most suitable for construction of local houses, the unused laterite soils are considered applicable for construction work.

3.2.4 Air-Dry Moisture Content

The values of Air-dry moisture content for samples A1 - A5 ranges between 2.10% and 2.44% while that of B_1 - B_5 ranges between 0.50 and 1.10%, Table 2. The values are considered suitable; they were used in preparing the soil samples for BS compaction, triaxial compression and compressive strength tests.

3.2.5 Triaxial Compression

The results of the triaxial compression test are shown in Table 3. The values of apparent cohesion for the unused soil samples are fairly higher than those of the used soil sample while the shearing resistance for the unused laterite soil samples are greatly higher than those of used soil samples. The implication of this is that the unused soils are held together by higher cohesive force than the used soils. The used soil samples have lower values of angle of internal friction than that of the unused laterite soil samples owing to the fact that the used soil samples have earlier undergone compaction. This indicates that the used soils will shear under load more easily than the unused soil samples. The values obtained are satisfactory.

Table 3: Cohesion and Shearing Resistance of Laterite Soils

Sample	Unused Soil Samples					Used Soil Samples				
	A_1	A_2	A_3	A_4	A_5	B_1	B_2	B_3	B_4	B_5
Cohesion (kN/m^2)	90	112	122	142	186	98	110	118	112	67
ϕ (Degree)	44	41	38	36	31	18	14	14	15	21

3.2.6 Compressive Strength

The results of the compressive strength test are presented in Tables 4, 5 and 6. The crushing stresses of the used soil sample cubes were less than those of the unused soil sample cubes as shown in Fig.1. The numerical values of the compressive strength test for unused and used laterite soils are presented in Tables 4 and 5 respectively. By addition of cement (a binding medium) to the used laterite soil at 0.25, 0.50 and 0.75%, the strength of the used laterite soil increased as shown in Figure 1 and presented in Table 6. It can be deduced that the strength of the used soil samples were improved to equal that of the unused soil samples by the addition of 0.5% cement at specified ages and that the strength of the used soil samples were improved beyond that of the unused soil samples by the addition of 0.75% cement content.

Table 4: Average Compressive Strength for Unused Laterite

Age (Days)	Samples ID	Sample 1 Compressive Strength (kN/mm^2)	Sample 1 Compressive Strength (kN/mm^2)	Average Compressive Strength (kN/mm^2)
7	A_5	2.20	2.10	2.15
14	A_5	2.90	2.90	2.90
21	A_5	2.30	2.20	2.25
28	A_5	2.30	2.30	2.30

Table 5: Average Compressive Strength for used Laterite

Age (Days)	Samples ID	Sample 1 Compressive Strength (kN/mm^2)	Sample 1 Compressive Strength (kN/mm^2)	Average Compressive Strength (kN/mm^2)
7	B_5	1.50	1.50	1.50
14	B_5	1.70	1.80	1.75
21	B_5	1.40	1.50	1.45
28	B_5	1.40	1.50	1.45

Table 6: Compressive Strength (n/mm^2) of used Laterite soil with Addition of Cement

Age (Days)	Percentage of cement 0.25 %	0.25 %	Aver-age	0.50 %	0.50 %	Aver-age	0.75 %	0.75 %	Aver-age
7	1.90	2.00	1.95	2.20	2.20	2.20	2.40	2.40	2.40
14	2.60	2.60	2.60	2.90	2.80	2.85	3.00	3.00	3.00
21	2.10	2.00	2.05	2.30	2.20	2.25	2.50	2.40	2.45
28	2.00	2.00	2.00	2.20	2.30	2.25	2.50	2.40	2.45

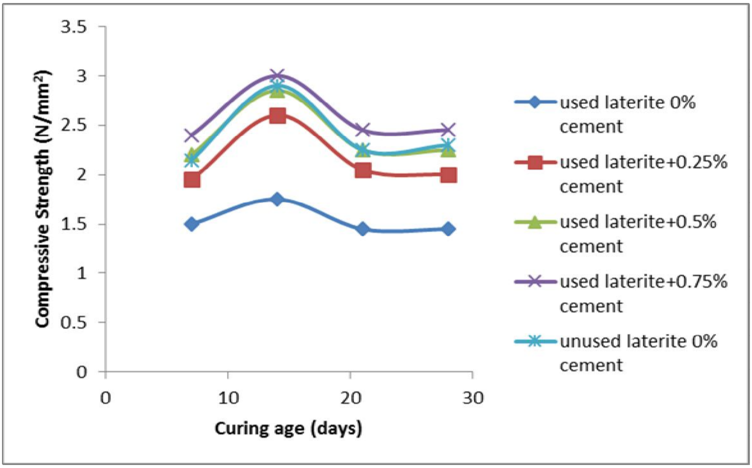

Figure 1 Graph of compressive strength against curing ages

4. Conclusion

The results of the experiments carried out on the engineering properties of used and unused laterite soils show that:

i. The geotechnical properties of the unused laterite soil samples are better than that of the used laterite soil samples. The values of optimum moisture content, maximum dry density, plastic limits, liquid limit and shrinkage limit for used laterite are less than that of unused soils.

ii. The results from compressive strength revealed that the strength of unused laterite soil is greater than that of the used laterite soil.

iii. The addition of 0.5% of cement increased the strength of the used laterite soil a compressive strength of over 2.20N/mm^2 which is comparable or equal to that of the unused laterite soil.

iv. The unused or naturally existing laterite soils should be used for construction of local houses instead of used laterite soil. However, the used laterite soil can be re-used or reutilised to build local houses by addition of 0.5% Portland cement.

v. The addition of 0.75% of Portland cement to the used soil improves its strength beyond that of the unused soil and makes the cement stabilized soil suitable for construction of housing units.

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