Effect of Moisture Variation on the Strength Characteristics of Laterite: A Case Study of Abeokuta, Ogun State, Nigeria

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Abstract

Nigeria, a country in the tropical region is characterized with heavy rainfall and high temperature. It is therefore appropriate to say that climatic factors affect its roads. Many of the roads are flooded with water after heavy rains due to inadequate drainage system. The roads in Ogun State are plagued with various distresses and failures. This study examined the effect of moisture variation on the strength characteristics of laterite in Abeokuta, Ogun State, Nigeria. Samples of laterite soils were obtained from Oke-Mosan burrow-pit, Abeokuta and engineering properties such as the natural moisture, sieve analysis, Atterberg limits, compaction and the strength characteristics were evaluated. The un-soaked California Bearing Ratio (CBR) value of the soil compacted at optimum moisture content was 32%. The effect of moisture variation on the strength of laterite was determined from results of CBR of the compacted laterite soils soaked in water for 5 days to simulate the worst moisture condition in the field for the laterite. The result showed that an increase in the soaking period of the compacted soil sample from 1 to 5 days result in decrease in the CBR of the soil from 6.57% to 6.16% also, there was also increase in the bulk density from 2060.74 kg/m^3 to 2169.20 kg/m^3. The study revealed that affinity for water and the corresponding low shear strength of the laterite soils are responsible for the failure of roads in Abeokuta metropolis.

Keywords: Laterite, Moisture variation, Strength characteristics, Abeokuta

Introduction

Laterite is the product of intense weathering, in hot and wet tropical areas, of the underlying parent rock which is enriched in iron and aluminium. The soil name "laterite" was coined by Buchanan (1807) in India, from a Latin word "later" meaning brick. Nearly all kinds of rocks can be deeply decomposed by the action of high rainfall and elevated temperatures. The percolating rainwater causes dissolution of primary rock minerals and decrease of easily soluble elements as sodium, potassium, calcium, magnesium and silicon. The process gives rise to a residual concentration of more insoluble elements predominantly iron and aluminium. The iron oxides goethite and hematite cause the red-brown colour of laterites (Aleva, 1994).

In this tropical part of the world, laterites are used as a material in road construction and they form the sub-grade of most tropical roads. They are also used as sub-base and base courses for low cost roads, which carry low to medium traffic. In some rural areas of Nigeria, laterites are used as material in building construction for moulding of blocks and plastering (Muhammed, 2000). The problems encountered on major highways in Nigeria are mainly as a result of deficiency in the properties of the sub-grade, sub-base, and base courses of the road pavement. The engineering properties of soil are considered in the design and construction of road and the soil property of main interest to an engineer is the strength characteristics. That is the ability for the pavement to withstand the dynamic axle load being transferred to the soil beneath. Fine grained soils or granular materials that contain excessive amount of fines are generally more sensitive to water changes than coarse-grained soils. An unpaved road may possess the required strength when constructed initially but exposure to water can result in loss of strength, coupled with detrimental effect of traffic operation (Rosa and Jeb, 2000). Also, Oguara (2006) noted that not all laterite soils encountered on a site can be used directly for construction purposes due to poor strength characteristics of the soil. To prevent mud pumping, sub-bases must be either free- draining or be resistant to the erosive action of water. This study therefore examined the effect of the factors on the load bearing capacity of laterite soil and determines ways of improving such properties.

Study Area

The study area is Abeokuta – the capital of Ogun State, South-West Nigeria. There are two main seasons: the wet and dry season. The wet season extends from April to October, the wettest month being June. The Dry Season, which is very hot, is between November and March. The seasonal climatic conditions over Nigeria gives rise to more predominant annual rainfall occurrence in the south than the north. Abeokuta lies in the fertile part of the country, the surface of which is broken by masses of grey granite. Geographical coordinates are 7^0 9' 39'' North and 3^0 21' 54'' East. The city is characterised with good and bad roads. The study site is an active burrow- pit from which laterite, which is used for the construction of many roads within Abeokuta is obtained. The burrow pit used is located at Oke-Mosan in Abeokuta-South Local Government Area of the State. One noticeable feature of the bad roads is lack of drainage facilities. Absence of drainage means that there is usually stagnancy of rainwater on roads for days.

Material and Method

Disturbed soil samples were collected at sufficient depth from the burrow-pit, in air-tight polythene bags. Collected samples were thoroughly mixed and air-dried before use after determining the natural moisture content in the laboratory. Soil Classification tests were performed and the soil classified in relation to American Association of State Highway and Transportation Officials (AASHTO) and Unified Soil Classification System (USCS). The moisture content, particle size distribution and Atterberg limits tests were conducted on the laterite samples. Compaction and California Bearing Ratio (CBR) tests were also conducted. All tests were performed in accordance with BS 1377 (BSI 1990).

Results and Discussion

The soil properties determined by laboratory experiments are summarized in Table 1. The sample was soaked for a period of 5 days and the average moisture content of the compacted laterite sample in the mould was calculated for each soaked day. Figure 1 shows an increase in the average moisture content absorbed after each day of soaking. The CBR, which represent soil strength decreases with increasing number of soaking days (Figure 2). The relationship between the CBR and average moisture content (Figure 3) reflected a downward curve. The downward direction of the curve implies that the CBR of the laterite decreases with increase in the amount of moisture content absorbed.

Table 1: Summary of Soil Properties

Physical Properties	Quantity/Unit	Specifications	References
AASHTO Classification	Silty sand A-2-4		
USCS Classification	Poorly graded sand and silt SP-SM		
Coefficient of Uniformity, C_u	3.125		
Coefficient of Curvature, C_c	1.125		
Liquid Limit, LL	32.64%	< 50%	FMWH (1970)
Plastic Limit, PL	23.37%		
Plasticity Index, PI	9.27%	< 30%	Ditto
Consistency Index, I_c	2.88		
Maximum Dry Density, MDD	1.945 Mg/m^3		
Optimum Moisture Content, OMC	8.80%		
Natural Moisture Content, NMC	5.97%		
CBR (un-soaked)	32%		
CBR (after day 1 of soaking)	6.57%	6 – 20% (fair to good sub-grade under Casagrande's classification).	FMWH (1970) and RRL (1952)

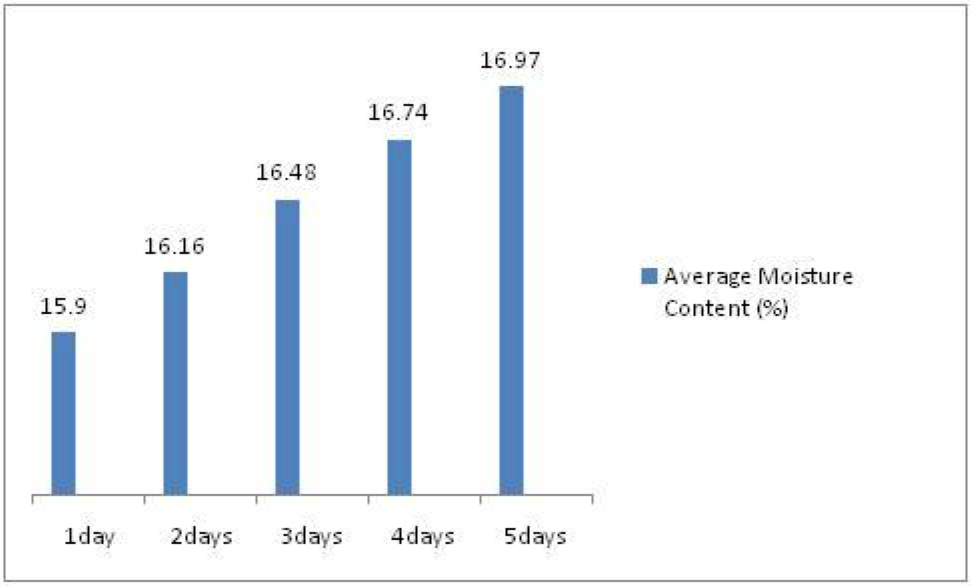

Figure 1: Moisture Content Variation with Soaking Period

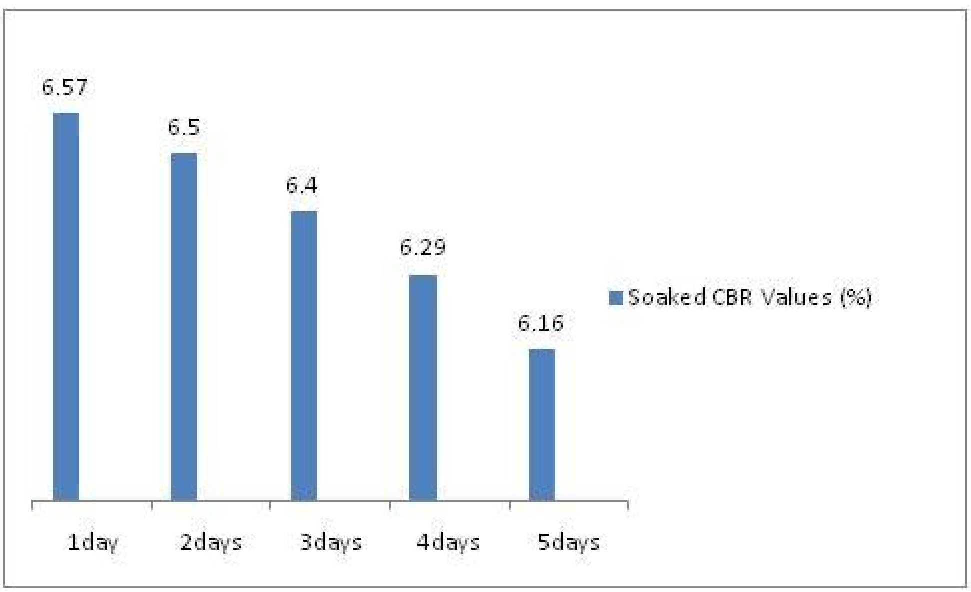

Figure 2: Variation of CBR Values with Soaking Period

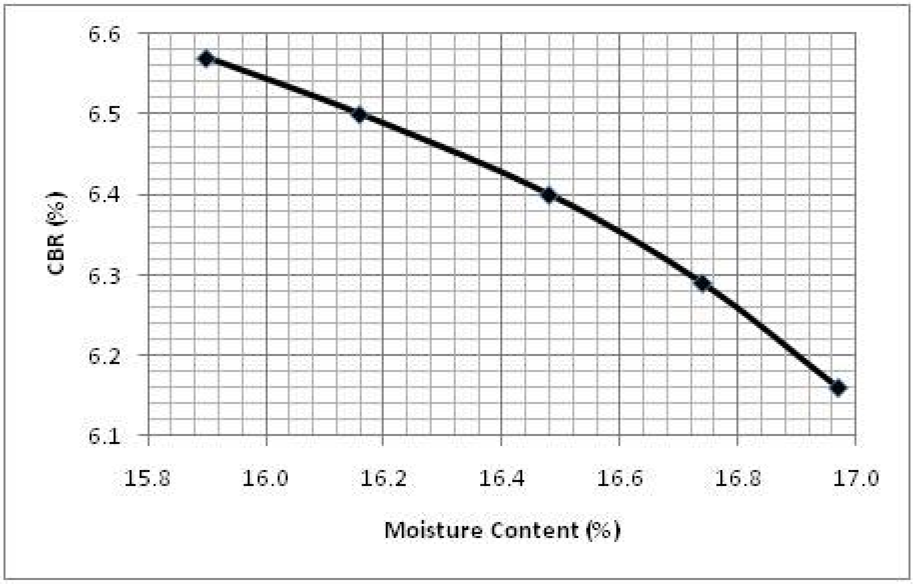

Figure 3: Relationship between CBR and Average Moisture Content

The soaked and remoulded laterite sample was weighed and its bulk density determined for the soaking period under consideration. The bulk density of the soil increases from day 1 to the day 4 of soaking (Figure 4). The same bulk density (2169.20 kg/m^3) is recorded for day 4 and 5. The result indicated that the soil became saturated by day 4. Soaking beyond the 4th day would therefore have no impact. Figure 5 showed the relationship between the CBR and the bulk density of laterite soaked for a period of 1 to 5 days. The CBR decreases with increase in the bulk density of the soil. The top face of the soaked soil has a CBR value greater than the bottom face (Figure 6), indicating that the contact face absorbed more water.

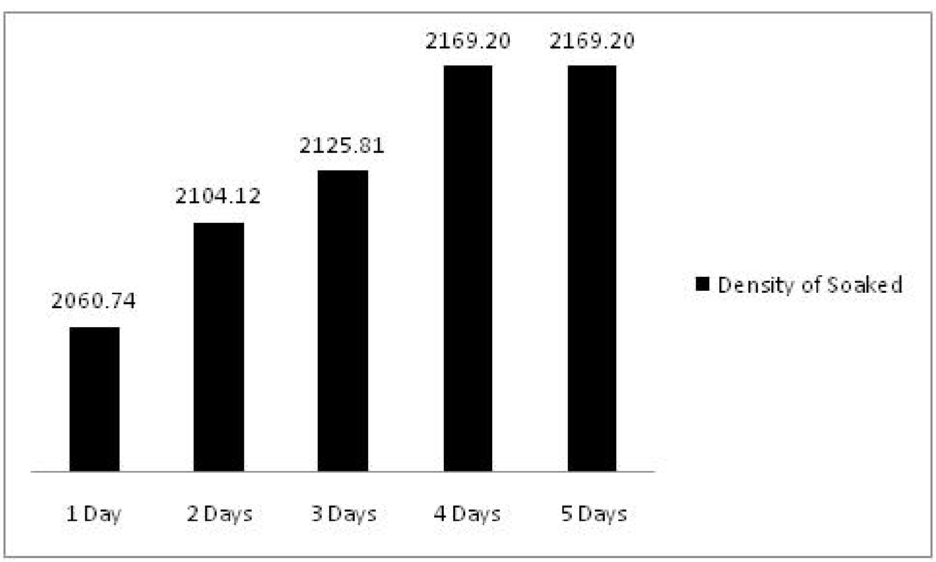

Figure 4: Variation of Bulk Density with Soaking Period

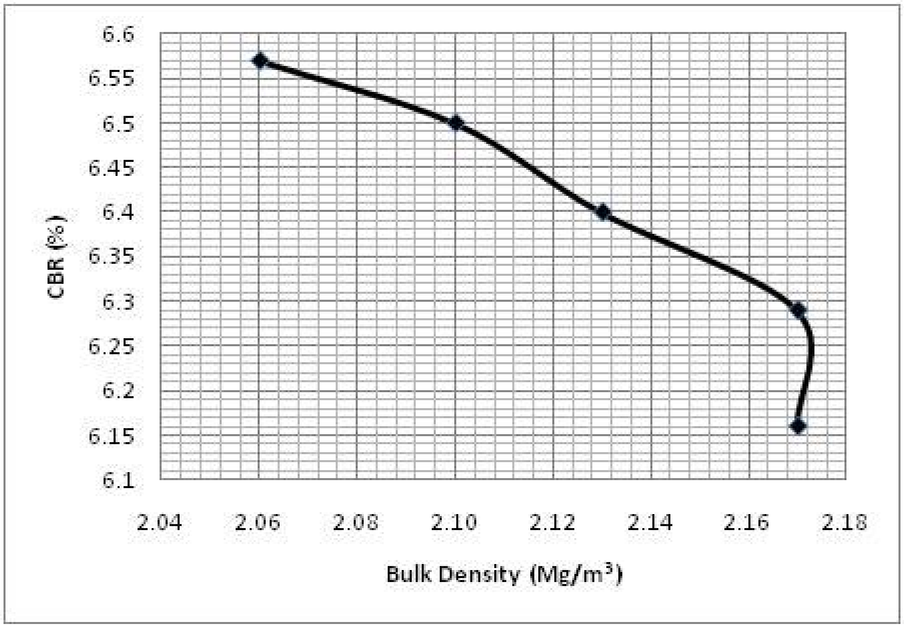

Figure 5: Relationship between CBR and Bulk Density of Laterite

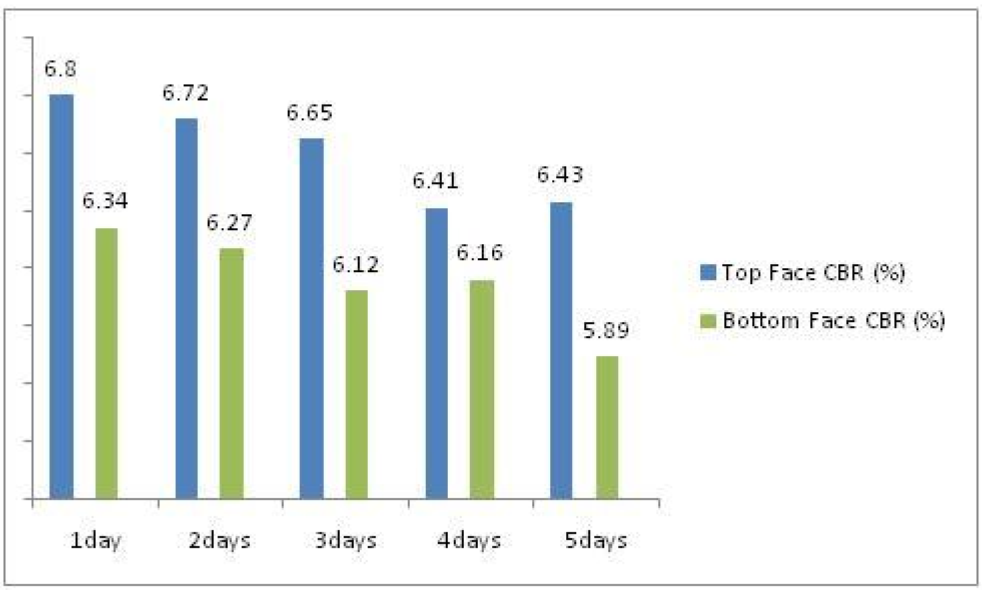

Figure 6: Variation of CBR along the Mould

Conclusion

The study revealed that the CBR of laterite soil decrease with increase in number of soaking days in water. The reduction in CBR may be attributed to the water holding capacity of the soil which made it yield when subjected to load. The situation of soil breakdown may be worsened by water, due to the softening effect on the soil and to the strength reduction it causes. The above consequently leads to pavement distress and partially to failure. An understanding of the dependence of the CBR strength of local soils on water content will contribute towards better design and maintenance practices. Provision of adequate drainage and stabilization of the soils are also recommended.

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