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The Suitability of Tarsand as a Stabilizing Agent for Lateritic Soils

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Abstract: This study investigated the suitability of tarsand as a stabilizing agent for lateritic soils. It is an earnest quest to find/discover a rather cheaper means of stabilizing lateritic soils that has become very important for the construction industry. The soil samples were subjected to the general classification and strength tests. The strength tests are, the compaction, unconfined compression and California Bearing Ratio (CBR) and tarsand was introduced as stabilizer in 0, 2, 4, 6, 8 and 10%. The CBR, Maximum Dry Density (MDD) and unconfined compression values all decreased with increasing tarsand contents. For example, MDD reduced gradually from 1919 kg m^{-3} at 0% tarsand to 1765 kg m^{-3} at 10% tarsand, while CBR also reduced gradually from 21.0% at 0% tarsand to 3.40% at 10% tarsand. All these results showed that tarsand is not a suitable stabilizing agent for lateritic soils, especially in the strength assessments.

Key words: Tarsand, stabilization, lateritic soil

INTRODUCTION

The usefulness of lateritic soil to construction works cannot be over-emphasized. Soil has being in use for ages[1] and is still being used today especially in developing nations. The usefulness of soil generally borders on their strength properties, especially their load bearing capacities. An unsuitable soil may be made suitable for construction purpose by the process of soil stabilization. According to Krebs and Walker[2], the use of stabilized soils in road construction had been in practice since the Roman times.

Stabilization is therefore the process of making a poor soil suitable for engineering/construction purposes by improving its properties. Such properties may come in terms of its swelling potential, permeability, shearing and compressive strengths. There are many methods of soil stabilization, the commonest is the mechanical compaction. Other methods entail the addition of certain compounds which tend to increase the strength properties of soil in varying proportions. These compounds are called stabilizing agents, examples are cement, bitumen, lime and pozzolans.

With economic considerations, it becomes vital to utilize materials within reach by soil stabilization rather than spend much more money importing materials for construction works. Tarsand from which bitumen is extracted has a high occurrence in Nigeria and it is hereby examined as a potential stabilizing agent for lateritic soil. It has similar properties as bitumen, which might be effectively harnessed for stabilization. Tarsand is also known as oil sands or bituminous sands, which have oil impregnated rocks composing of highly (viscous) hydrocarbons called bitumen and significant quantities of oxygen, nitrogen and sulphur bearing compounds. The Nigerian tarsand reserve is rated as the fourth largest in the world, occurring along the eastern margin of Dahormey basin stretching across Ogun, Ondo and parts of Delta (former Bendel) States.

Bitumen has been used as a stabilizing agent by various researchers and it has been found suitable most of the time. It is therefore pleasant to investigate the stabilization characteristics of tarsand, bearing in mind that it is much cheaper and much more readily available than bitumen.

Tarsands: Tarsands are extensive stretches of unconsolidated sand containing heavy bituminous viscous oil, which will not flow at ambient temperatures and so cannot be recovered by normal oil well production. Tarsand, which is characterized by its high viscosity and density, is composed primarily of hydrocarbons, sand and water. Its density is measured in API standard. It is clearly different from heavy crude oil by its characteristic physical properties, its high viscosity and high density, which are much higher than those of heavy crude oil. The

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dense nature of tarsand makes the conventional methods of extraction impossible, thereby making it compulsory for the oil impregnated rocks to be mined and processed specially so that bitumen or heavy oil could be recovered.

Researchers have not been able to proffer a specific explanation for the origin of tarsands. Suggestions had been made that some heavy crude oil and tarsands are formed as a result of the oxidative process that occur when oxygen-bearing ground water invades a petroleum bearing reservoir. It was also said to be formed due to the existence of geologically origin young oil, which being formed in the source rock did not have the opportunity of migrating into a reservoir rock (a second necessary condition for the existence of oil in a region, thereby not having been subjected to any overburden pressure or thermal cracking remains thickly dense in nature).

Studies have shown that all tarsand deposits are a mixture of sand grains (quartz and fine sand), water and bitumen. These components are arranged such that oil sand aggregate has sand particles fairly and uniformly embedded into the bitumen film. Tarsands have been discovered to exist in various reserve bases over 88 countries of the world. The major known deposits are those of Venezuela, United States, Canada, Trinidad and Tobago, Nigeria and Malaysia. One of the largest tarsand deposits in the world is that of Alberta in Canada with an estimate, which is over 700 billion barrels.

The Nigerian tarsand deposits occur at the eastern margin of the Dahomey basin, stretching over 120 km from Ijebu-Ife in Ogun State, across Ondo State and parts of the former Bendel (now Edo) State.

Soil stabilization: Soil stabilization is the improvement of the properties of a soil in order to make it suitable for a particular engineering purpose. Lambe[3] defined soil stabilization as the alteration of any property of a soil to improve its engineering performance. Castel[4] and Gidigasu[5] proffered that through soil stabilization, an unsuitable material may be made suitable for a particular purpose.

Meanwhile, the use of stabilizing agents in road construction has being adopted since Roman times[2] and it has been in practice in Nigeria for some forty years. Those properties of soil whose improvement are desired may come in terms of swelling potentials, permeability, shearing and compressive strengths.

The technique of stabilizing a soil by increasing its strength and stability through the introduction of admixtures is called chemical stabilization. The materials, which are commonly used as admixtures, are cement, lime, bitumen and resin. Hydrated lime is mostly used for stabilization. Unless lime was to be used mainly to improve the plasticity and workability of the soil, only A-2 class could be adequately stabilized as a base material while class A-1 soils with some clayey material might be considered[6].

In soil stabilization, certain physical characteristics of clay bearing soils are altered in order to transform such soils into more stable materials for improved road durability. These physical changes may include; decrease in plasticity index (which is a result of an increase in plastic limit) an increase in the unconfined compressive strength and also an increase in CBR (California Bearing Ratio).

Bituminous materials have been used for modern stabilization purposes as dust palliatives on natural soil roads in Southern California in 1998, since then most of research had been carried out on bituminous soil stabilization. The use of bitumen as stabilizing agent is hinged on the cementation process, which increases the soil strength. Another reasons for the use of bitumen for stabilization is its waterproofing property, which preserves the natural stability of soils in dry and well compacted conditions.

Laterites: Laterites are among the most abundant soils that are developed in the tropics, they form thick blankets near the topsoil horizons in the area. Available data on geotechnical characteristics of lateritic soils show that these soils range in performance form excellent to poor for engineering purpose[7].

The term 'laterite' was first used to describe a ferruginous vesicular unstratified and porous material with yellow ochre due to high iron content occurring in Malabar, India. The freshly dug material was soft enough to be readily cut into brick blocks with an iron instrument but it rapidly hardened on exposure to air and was remarkably resistant to the weathering effect of climate. According to Gidigasu[8] laterite was recognized as a tropical and sub-tropical weathering product of various crystalline igneous rocks mostly granites sediment deposits and volcanic ash.

Campbell[9] analysed some Nigerian soils and the following oxides of aluminium, iron and silicon and their relative percentages were found (Table 1).

This gives a ratio of (Si_2O_3 + $A1_2O_3$) of less than 1.33 thus indicating that Nigerian soils are mostly laterites.

The physical, chemical and morphological definitions of laterites were summarized as a highly weathered material, rich in secondary oxides of iron, aluminium or both. It is nearly void of bases and primary silicates, but it may contain large amounts of quartz and kaolinite. It is either hard or capable of hardening on exposure to wetting or drying. Ola[6] defined laterite soils as products

Table 1: Types and the relative percentages of oxides in Nigerian soil

Oxide	Percentage
Quartz SiO_2	21.20
Qcombined SiO_2	5.30
TiO_2	1.10
$A1_2$	19.90
Fe_2O_3	36.70

of tropical weathering with red, reddish brown or dark brown colour with or without modules or concretions and generally (but no exclusively) found below ferruginous crusts.

MATERIALS AND METHODS

This study was conducted between February 1999 and March 2000 in the Transportation Laboratory of Civil Engineering Department, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria.

The materials used are (i) Tarsand, which was obtained from a tarsand reserve at Ijebu-Ife in Ogun state of Nigeria, (ii) Lateritic soil sample, which is an A-2-6 (AASHTO) obtained from a burrow pit in Odogbo, Ibadan, Oyo State of Nigeria, (iii) Water fit for drinking and (iv) Distilled Water.

The soil samples were subjected to the following classification tests: Natural moisture content determination which was determined in the laboratory by measuring the loss in weight of soil samples after drying to a constant weight at 110^0C. The specific gravity was determined in the laboratory by using a density bottle. Consistency limits involved the determination of the liquid limit, plastic limit and the plasticity index, while both the sieve and the hydrometer analyses were carried out for the grain size analysis.

The samples were also subjected to the following strength tests:

Compaction test: A known weight of soil sample was obtained; tarsand was added in 0, 2, 4, 6, 8 and 10% by weight. The soil sample was taken from the part of the sample which passed through sieve No. 4. The mixture of the soil and tarsand was compacted into the standard compaction mould in three layers with 25 blows per layer using a 24.5 N compaction hammer.

Unconfined compression test: This test was carried out to determine the suitability of the lateritic soil for treatment with tarsand and to possibly specify tarsand contents for construction works. The specimens were cured for 24 h, 3 and 7 days, respectively before testing. Testing was done on the unconfined compression machine with strain rate of 0.5 mm m^{-1}. The load rate was calibrated to give 0.2132 kg/Division.

California Bearing Ratio (CBR) Test: This test measures the shearing resistance of a soil under controlled moisture and density conditions. The test yields a bearing ratio number. For this test, 3 kg soil sample was taken from the portion of soil that passed through sieve No. 4 and prepared at the optimum water contents of soil as determined from the compaction test.

RESULTS AND DISCUSSION

The laboratory experiment gave the natural moisture content of the soil as 11.60% and the specific gravity was found to be 2.82. This specific gravity suggests that the soil contains some heavy minerals. General observations on the soil showed that the soil is prone to changes in moisture content and could become a little soft and slippery during the wet season, though hard and gritty during the dry season.

The plasticity index of the soil increased, although not regularly, from 24.93% at 0% tarsand to 30.34% at 10% tarsand (Table 2). Liquid limit increased consistently from 54.00 to 61.50% at 0 and 10% tarsand contents, respectively, while the plastic limit increased sparingly from 29.07% at 0% tarsand to 30.04% at 2% tarsand, then decreased to 28.27% at 4% tarsand, from where it increased consistently to 31.17% at 10% tarsand content.

The Maximum Dry Density (MDD) reduced with increasing tarsand content. The MDD value of 1919 kg m^{-3} at 0% tarsand reduced gradually to 1765 kg m^{-3} at 10% tarsand content (Table 3). The factors responsible for this behaviour could be the grain size distribution of the soil; it's specific gravity and the specific gravity of tarsand. The decrease in maximum dry density of 1919 kg m^{-3} at 0% tarsand to 1910 kg m^{-3} at 4% tarsand content is quite negligible. Considerable reduction was observed between 4 to 10% tarsand contents.

Table 2: Variation of Atterberg limits with tarsand content

Tarsand (%)	Liquid limit (%)	Plastic limit (%)	Plasticity index (%)
0	54.00	29.07	24.93
2	56.12	30.04	26.09
4	57.31	28.27	29.04
6	58.94	30.55	28.39
8	59.91	30.90	29.01
10	61.50	31.17	30.34

Table 3: Effects of tarsand on Maximum Dry Density (MDD)

Tarsand (%)	Maximum dry density (kg m^{-3})	Optimum moisture content (%)
0	1919	13.00
2	1918	14.00
4	1910	14.00
6	1822	14.00
8	1788	13.00
10	1765	13.00

Table 4: Variation of unconfined compressive strength with tarsand content

Tarsand (%)	Strength for 24 h curing period (kg m^{-2})	Strength for 3 days curing period (kg m^{-2})
0	241.11	249.33
2	242.63	250.12
4	243.88	252.12
6	241.88	250.43
8	241.84	249.38
10	241.80	249.03

Table 5: Variation of California Bearing Ratio with tarsand content

Tarsand (%)	24 h (%)	3 days (%)	7 days (%)
0	21.0	22.13	23.98
2	13.6	14.40	15.40
4	10.0	11.20	12.80
6	6.5	8.00	10.60
8	5.0	7.80	10.30
10	3.4	5.20	9.60

The unconfined compressive strength increased negligibly from 241.11 kg m^{-2} at 0% to 243.04 kg m^{-2} at 4% tarsand content for 24 h curing and started dropping from this point to a value of 241.80 kg m^{-2} at 10% tarsand. The trend was the same for 3 days curing period (Table 4). In a nutshell, tarsand has no remarkable influence on the compressive strength of the soil.

The unsoaked CBR decreased with increasing tarsand content from 21.00% at 0% tarsand to 3.40% at 10% tarsand content (Table 5). This was the trend for both the 3 and 7 days soaked samples.

However, since between 2-4% content of tarsand, the maximum dry density of the soil was practically unaffected, tarsand could therefore be recommended for dust reduction in earth roads and as a water proofing material in unpaved earth road constructions. Generally, as shown from all the strength parameters, tarsand is not an effective stabilizing agent for lateritic soil.

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