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Geotechnical Properties of Some Soils in a Tar Sand Area of Southwestern Nigeria

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Abstract

Engineering properties of some soil samples in Idiobilayo and Idiopopo areas of Southwestern Nigeria were studied with the aim of determining their geotechnical properties which can aid in the exploitation plan of the tar sands deposits in the area.
A total of six sampling locations with three samples each were established in the study area. Samples of soil both disturbed and undisturbed were obtained from the trial pits to a depth of about 1.5m at 0.5m vertical interval. The disturbed samples were subsequently subjected to classification tests such as grain size distribution and consistency limits using British standards 1377 procedure. However, the undisturbed samples were subjected to permeability test.
Results obtained in this study showed that the area of study is underlain essentially by sandy soils, with substantial silty content. Clay and gravel content are quite minimal. The particle size distribution curves confirmed a general dominance of silt to coarse-grained sand size particles in the soil matrix with minor but complimentary clayey and gravelly materials. Amounts of fines in the soils are less than 50% except in trial pts 4 and 5 where they are slightly above 50%.
The soils consist of sand (60.0 %) and silt (35.0 %). The percentage of fines (silt and clay sized fraction) in the soils was about 38.0 %, and makes the soils good base for landfill, since recommended percentage of fines, should not be less than 20.0 %. However the obtained values of permeability coefficient of 5.5 X 10^{-6} mm/s to 1.2 X 10^{-4} mm/s call for the lining of the base to avoid groundwater pollution by leachates.

Keywords: *Tar sands, landfill, geotechnical, plasticity index, leachate*

Rezumat. Proprietăţile geotehnice ale unor soluri din zona nisipurilor bituminoase din sud-vestul Nigeriei

Proprietăţile unor mostre de sol din regiunile Idiobilayo şi Idiopopo din SV Nigeriei au fost studiate pentru a determina proprietăţile lor geotehnice care pot fi folosite în planurile de exploatare a depozitelor de nisipuri bituminoase din zonă.
În zonă au fost stabilite şase locaţii, fiind prelevate câte trei probe din fiecare locaţie. Mostre de soluri perturbate şi neperturbate au fost prelevate din gropile până la o adâncime de aproximativ 1,5 m la un interval de 0,5 m pe verticală. Mostrele perturbate au fost supuse ulterior testelor de clasificare privind distribuţia granulometrică şi limitele de consistenţă folosind procedura 1377 din standardele englezeşti. Mostrele neperturbate au fost supuse unui test de permeabilitate.
Rezultatele obţinute în acest studiu au arătat că zona luată în considerare are la bază în principiu soluri nisipoase cu un conţinut nămolos consistent. Distribuţia curbelor granulometrice a confirmat în matricea solului dominanţa generală a particulelor fine de nămol până la cele nisipoase grosiere, cu materiale complementare argiloase şi de pietrişuri. Cantităţile fine din soluri sunt mai mici de 50%, cu excepţia gropilor 4 şi 5, unde acestea sunt uşor peste 50%.
Solurile sunt alcătuite din nisipuri (60,0%) şi aluviuni (35,0%). Procentul de particule fine din soluri (fracţiunea granulometrică prafuri şi argile) a fost în jur de 38,0%, ceea ce face solul să fie o bază bună pentru umpluturi, de vreme ce procentul de particule fine recomandat nu trebuie să fie mai mic de 20,0%. Totuşi valorile obţinute ale coeficientului de permeabilitate de 5.5 X 10^{-6} mm/s to 1.2 X 10^{-4} mm/s necesită căptuşala bazei pentru a evita poluarea apelor subterane prin levigare.

Cuvinte-cheie: *nisipuri bituminoase, căptuşală, geotehnic, indice de plasticitate, levigat*

Introduction

Asphalt impregnated sandstones, otherwise referred to as oil sand (tar sand) and active oil seepages occur in southwestern Nigeria within the Eastern Dahomey (Benin) basin, a marginal pull apart (Klemme, 1975) or marginal sag (Kingston et al., 1983) basin. The oil sand outcrops in an E-W belt, approximately 120km long and 4-6km wide, extending from Edo/Ondo-Ogun States (Enu, 1985).

Occurrence of the seepage and tar sand deposit over the Okitipupa ridge in the Dahomey basin provided the initial impetus for oil exploration in Nigeria. From the turn of the century to date, no less than fifteen groups comprising public and private ventures have shown varying degrees of interest. Arising from these, a total of one hundred and fifteen

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(115) boreholes have been drilled across the basin and have confirmed the presence of oil sands and heavy oil. An intense investigation by Ako et al., (1980) was conducted over 17km^2 area, just north of Agbabu village and this particular study has provided a vast account of information on the oil sand deposits.

The physico-chemical characteristics of the tar sands from outcrops and coreholes in the Agbabu/Ore areas in Ondo state have been extensively reported. The salient aspects of the comprehensive information published within the last two decades covering sedimentological properties, oil saturation, bitumen ultimate analysis, stock-tank properties, calorific values, etc have been published by Adegoke et al (1980); Oshinowo et al (1982); Oluwole et al (1985), Ekweozor and Nwachukwu (1989); Akinmosin et al (2005 and 2006).

Studies carried out on the series of outcrop sections, cores and drilled cuttings obtained from the various exploration Campaign have shown the presence of two horizon-bearing sediments designed as "X" and "Y" horizon, (Fig. 1). "The X-horizon, being the shallower of the two deposits, constitutes the prominent outcropping unit in most areas, though significantly eroded in the north western part of the basin. The thickness varies from 9m to about 22m with an average of 15m.

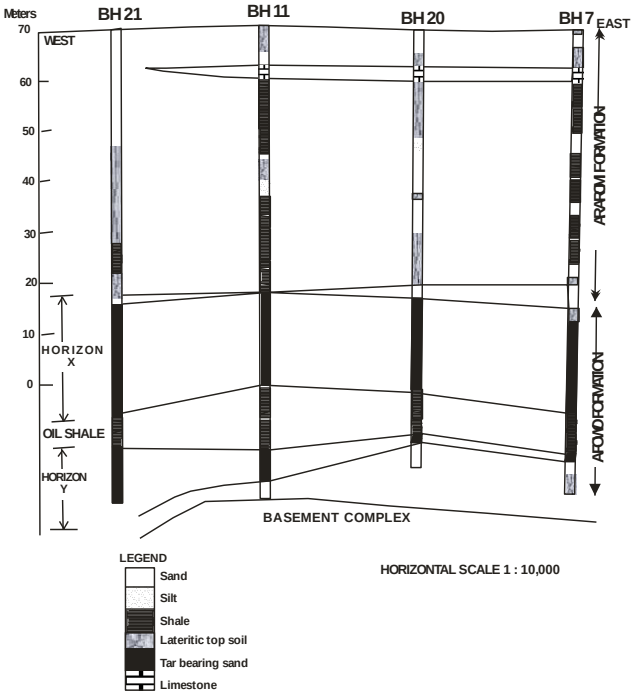

Fig. 1: Schematic geological west-east cross-section showing the stratigraphic sequence and the tar sand horizons in some boreholes (Modified after Ekweozor et al., 1989)

The Y-horizon is the prominent outcropping sequence in the northwestern part of the structure where "X" has been largely eroded. Its thickness varies widely from 3m in the east to 22.6m in the west with an average of about 12m.

A combination of factors has prevented the exploitation of this resource to date, among which are environmental, technological and economic considerations. The most important of which is the environmental effects it may pose to both physical and biological components of the area of occurrence.

The aim of this work is to generate geotechnical properties of some soils in tar bearing area of Southwestern Nigeria which is expected to provide necessary information that will be useful in planning and eventual exploitation of the resource. Moreover this will also help in developing an appropriate environmental management programme to reduce potential negative effects of tar sand mining.

Location of the study area

The study area is Idiobilayo/Idiopopo, a settlement in the South western Nigeria and can be located on topographic sheet 280A, between longitudes 4^{0}34′ and 4^{0}37′ E and latitudes 6^{0}38′ and 6^{0}40′ N. It is accessible by fairly motorable roads and network of footpaths (Fig. 2).

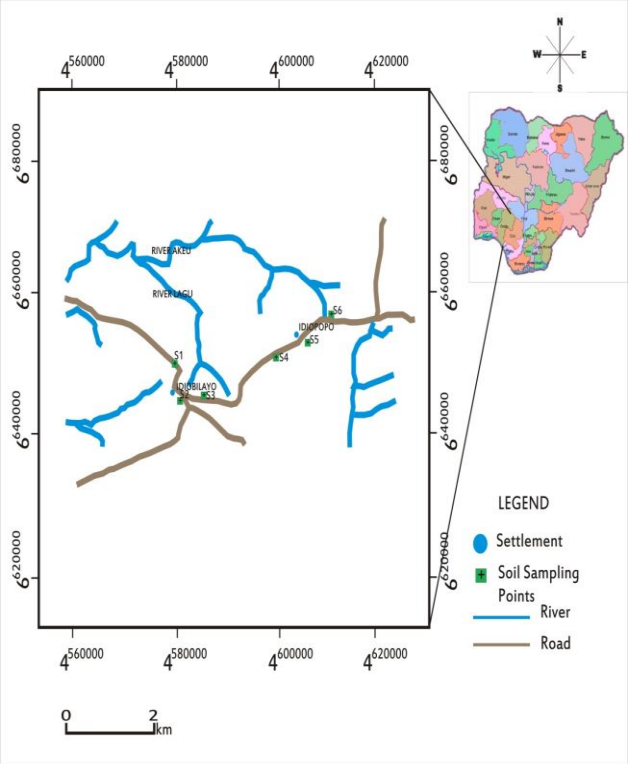

Fig. 2: Map of the study area showing tar sand outcrop locations

The lithostratigraphic units of the Cretaceous to Tertiary sedimentary sequence of eastern margin of Dahomey basin (Fig. 3), are summarized in Table 1.

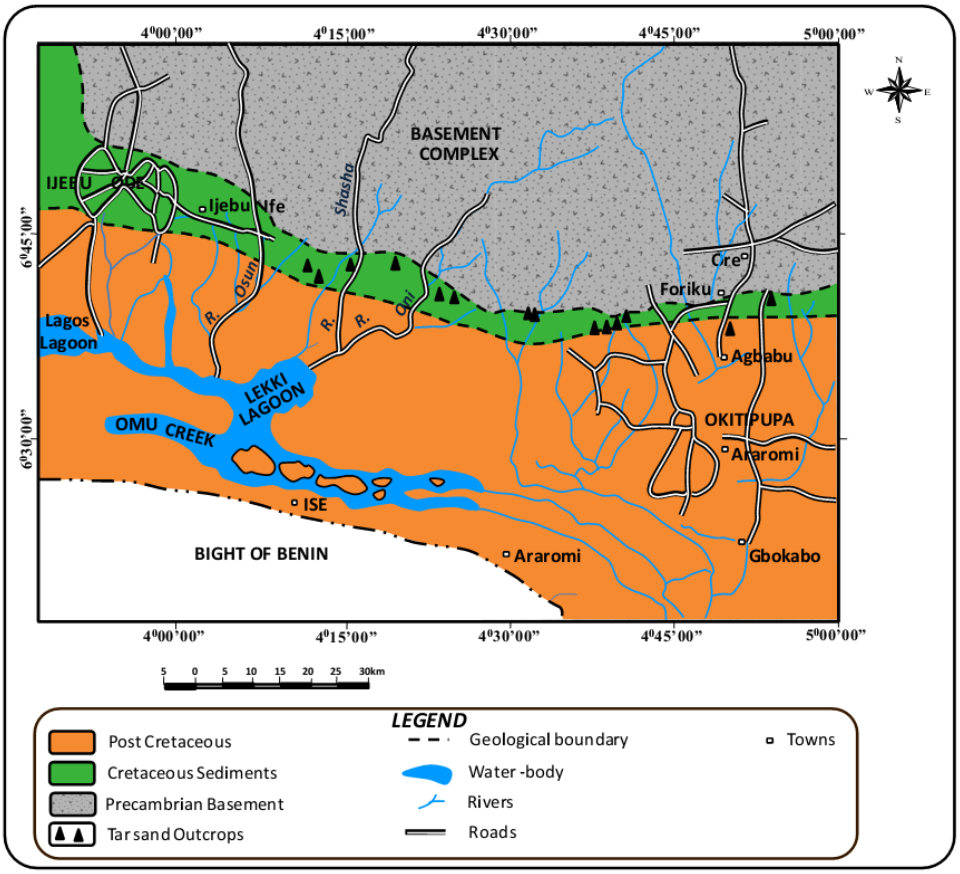

Fig. 3: Generalized geological map of the eastern Dahomey Basin showing Area Extent of the tar sand deposits (modified after Enu, 1985)

Table 1: Regional Stratigraphic Setting of the Eastern Dahomey Basin (after Idowu et al., 1993)

Age		Formation			Lithology
		Ako et al., 1980	Omatsola and Adegoke, 1981		
Tertiary	Eocene	Ilaro Formation	Ilaro Formation		Sandstone
	Paleocene	Oshosun Formation	Oshosun Formation		Shale
		Ewekoro Formation	Ewekoro Formation		Limestone
Cretaceous	Maastrichtian		Abeokuta Group	Araromi Formation	Shale
	Turonian			Afowo Formation	Sandstone/ shale
	Berremian			Ise Formation	Sandstone

Method of study

A total of six sampling locations were established in the study area. Samples were collected by boring pits to depth of about 1.5m below ground surface. Samples of soil both disturbed and undisturbed were obtained from the trial pits to a depth of about 1.5m at 0.5m vertical interval. The disturbed samples collected in polythene bags were obtained using a digger and shovel, while the undisturbed samples were obtained using core cutter (100mmx130mm) with a marshal hammer ramming it into place. The core cutter was sealed on both ends immediately with candle wax melted on the field to prevent loss of moisture. The disturbed samples were subsequently subjected to classification tests such as grain size distribution and consistency limits. However, the undisturbed samples were subjected to permeability test.

Samples were equally collected along the two major slopes in the study area at intervals of 20m from one another in each of the slope. Ten (10) samples were collected all together and carefully packed in polythene bags.

These samples were subsequently subjected to grain size distribution and consistency limit tests.

Results and discussions

Table 2 shows that soil samples in the trial pits at Idiopopo and Idiobilayo have percentage clay size

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range of 3-15%, percentage silt of 15-45%, percentage sand of 44-70% and percentage of gravel of 1-15%. Results obtained in this study showed that the area of study is underlain essentially by sandy soils, with substantial silty content. Clay and gravel content are quite minimal.

Table 2: Grain size distribution of bulk samples

Test Hole Location	Sample Depth(m)	Percentage Clay size particles	Percentage Silt	Percentage Sand	Percentage Gravel
Idiobilayo-A	0.50	15	15	68	02
	1.00	05	39	58	02
	1.50	09	36	50	05
Idiobilayo-B	0.50	03	42	53	02
	1.00	06	38	54	02
	1.50	05	38	55	02
Idiobilayo-C	0.50	09	31	59	01
	1.00	05	40	56	04
	1.50	05	40	53	02
Idiopopo-A	0.50	06	44	45	05
	1.00	05	45	53	02
	1.50	06	44	45	05
Idiopopo-B	0.50	06	41	49	04
	1.00	07	45	44	04
	1.50	09	46	40	05
Idiopopo-C	0.50	03	25	70	02
	1.00	10	25	63	02
	1.50	14	27	67	02

The particle size distribution curves confirmed a general dominance of silt to coarse-grained sand size particles in the soil matrix with minor but complimentary clayey and gravelly materials (Fig. 4 and 5).

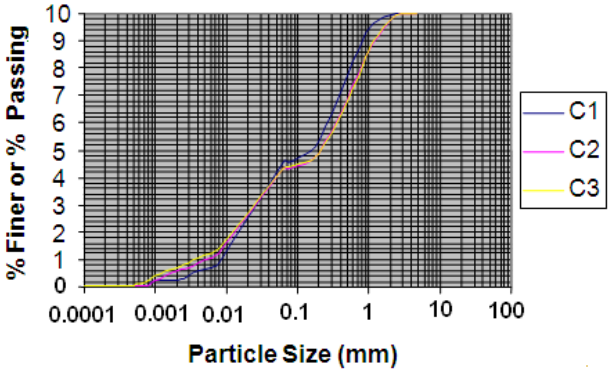

Fig. 4: Grain size distribution curves of sub surface soil samples (Location 2), Idiobilayo

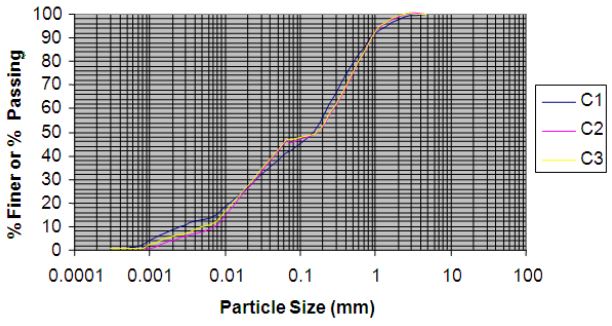

Fig. 5: Grain size distribution curves of sub surface soil samples (Location 3), Idiobilayo

The topsoils in most of the pits are generally loose and silty. With the exception of pits 4 and 5, (Fig. 2) in which some of the horizons are indurated, all the soils are slightly loose with very little evidence of compaction. Amounts of fines in the soils are less than 50% except in trial pts 4 and 5 where they are slightly above 50%. Daniel (1993b) recommends amount of fines of not less than 20% for land fill seals. The soils are thus good for the base of a landfill.

The plasticity index is the measure of the affinity which a soil has for water. Casagrande (1932) did indicate that the higher the value, the poorer would the soil be as an engineering soil. Material with low plasticity do not compress appreciably under load nor do they shirnk extensively when dried so that once they have acquired a firm Consistency near plastic limit; they are quite stable. Plasticity result (Table 3) showed that the plasticity index of soil in Idiobilayo (location A-C) ranged from 2.40 – 20.37 %, while soil in Idiopopo (locations A-C) ranged from 7.72 – 20.37 %. Soils obtained at depths 0.5 m, 1.0 m and 1.5 m in Idiobilayo- A; 1.5 m depth in Idiobilayo B; 0.5 m and 1.0m depths in Idiopopo- A have low plasticity, hence they are good engineering soils and can be used for base of landfill.

Daniel (1993) recommends low plasticity index of between 7 and 10 for landfill seals. Lambe (1951) in classifying soils based on permeability used a permeability co-efficient of 10^{-4}mm/s as a borderline between pervious and impervious soils. The values of permeability coefficient of the soils analysed as shown in Table 4 indicate that all the soils are permeable.

Table 3: Consistency limits of Bulk Soil samples

Test Hole Location	Sample Depth (m)	Liquid Limit %	Plastic Limit %	Plasticity Index %
Idiobilayo-A	0.50	23.0	15.25	7.72
	1.00	25.6	16.13	9.47
	1.50	23.7	13.92	9.78
Idiobilayo-B	0.50	35.3	21.29	14.03
	1.00	44.4	24.06	20.37
	1.50	24.9	22.50	2.40
Idiobilayo-C	0.50	32.5	15.97	16.53
	1.00	42.8	23.11	19.69
	1.50	41.9	25.74	16.16
Idiopopo-A	0.50	23.0	15.25	7.72
	1.00	25.6	16.13	9.47
	1.50	49.8	32.88	16.93
Idiopopo-B	0.50	35.3	21.29	14.03
	1.00	44.4	24.06	20.37
	1.50	31.5	13.70	17.80
Idiopopo-C	0.50	32.5	15.97	16.53
	1.00	42.8	23.11	19.69
	1.50	36.8	16.91	19.89

Table 4: values of Permeability co-efficient of the bulk samples

Test Hole Location	Co-efficient of Permeability (mm/s)
Idiobilayo-A	5.9×10^{-5}
	2.0×10^{-6}
	2.41×10^{-6}
Idiobilayo-B	2.6×10^{-5}
	3.06×10^{-4}
	2.91×10^{-4}
Idiobilayo-C	1.5×10^{-5}
	1.21×10^{-4}
	1.71×10^{-4}
Idiopopo-A	2.0×10^{-6}
	3.0×10^{-6}
	2.5×10^{-6}
Idiopopo-B	9.0×10^{-5}
	2.0×10^{-6}
	2.06×10^{-6}
Idiopopo-C	5.09×10^{-4}
	5.4×10^{-5}
	5.47×10^{-6}

Conclusions

Geotechnical site investigation in a land fill site selection is important to guaranty adequate protection of the environment. Observation and result obtained from all the tests employed in the geotechnical evaluation of the study locations for possible landfill sitting indicate that the soil has suitable characteristics in terms of grading and consistency. However, the obtained values of permeability coefficient of 5.5 X 10^{-6} mm/s to 1.2 X 10^{-4} mm/s call for the lining of the landfill base to avoid groundwater pollution by leachates.

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