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Pure Crude Oil Contamination on Amaoba Lateritic Soil

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ABSTRACT

Crude oil boom in Nigeria created wealth and associated problems which since 1956 have not been fully resolved. Crude oil pollution ranging from leakage of oil pipelines, vandalism of oil infrastructures, spillage as a result of transportation accident on oil platforms and installation etc. Unrecovered crude oil spilled on the land move under gravity saturating the soil on its path which in turn changes the geotechnical properties of the soil. The geotechnical properties of the soil are believed to have been compromised as a result of oil contamination. This research evolved because of the need to investigate the geotechnical properties of pure crude oil contaminated lateritic soil and assess its suitability in construction of civil engineering structures. The initial properties of the soil which served as control such as water content, specific gravity, and particle size analysis were determined and used to classify the soil. Four different variables of contamination were used; 0%, 2%, 4%, and 6% crude oil by mass of the engineering soil. Results show that there was change in the properties of the soil with increase in crude oil contamination. From 0% crude oil contamination, the void ratio decreases with increase in crude oil contamination which also affected the compression index of the soil. The Atterberg limit examination indicated the crude oil contamination affected both the bonding between the soil particles and the fluidity of the entire mixture.

KEYWORDS: crude oil, contamination, lateritic soil. Amaoba, Atterberg

INTRODUCTION

Oil spillage as a result of human activities has affected the ecosystem, and crude oil spills and continuous release of contaminated oil effluents and untreated domestic oil waste-products have been reported as threats to the integrity of the environment.

The 1972 Environment Impact Statement had singled out oil as being the greatest threat to the environment [1]. In Nigeria the exploration of Petroleum Hydrocarbon, liquid waste from Automobile Mechanic workshops, industrial wastes, Palm oil market activities and other oil related human activities contribute to indiscriminate oil spillages. Oil spillage could take place in water or land. Oil pollution on lands depends on a number of factors which include the permeability of the soil, absorption properties of the soil and the partition coefficient [2]. The extent of contamination depends on the Chemical Composition of the contaminant and properties of the soil. Hydrocarbons pollution of soil occurs in several ways, from natural seepage of

hydrocarbon in areas where petroleum is found in shallow reservoir to accidental spillage of oil on the ground.

Regardless of the source of contamination, once crude oil comes into contact with the soil, they alter its physical and chemical properties [2;3] The degree of alteration depends on the soil type and the specific composition of the crude oil spilled. Once spilled, the crude oil under gravity moves down to the groundwater partially saturating the soil in its pathway. Upon reaching the groundwater, this liquid may spread horizontally by migration within the capillary zone, thereby further saturating the soil. Lateritic soil in its form are chemically active soil particles, formed in hot, wet tropical regions with annual rainfall between 705mm to 3000mm on a variety of different type of rocks with high iron content [3]. The most important characteristics of Ferro-Aluminum Silicate minerals and permanent decomposition of Sesquioxide (Oxides of Iron and Aluminum $Fe_3 O_3$ & $Al_2 O_3$) within the profile to form the horizon of materials [3].

This dissertation evolved because of the need to investigate the geotechnical properties of crude oil contaminated lateritic soil and assess its suitability in construction of Civil Engineering structures.

LITERATURE

Pollution caused by petroleum and its derivatives is the most prevailing problem in the environment. The increase in demand for crude oil, results to increase in possibilities of spills of oil into the environment and it is receiving worldwide attention [4]. Recently, some research works was carried out on effect of crude oil contamination on clayey, sandy and lateritic soil [4]. Three different types of soil-silty, poorly graded and lean clay-were used in their work and mixed with 2%, 4%, 8%, 12% and 16% by dry weight of crude oil. The result have shown that an increase in the crude oil content of the soil would result in a decrease in the maximum dry density and optimum moisture content of the soil. The rate of reduction for maximum dry density was faster for the silty, sand and clay than for the sandy soil. [2] , studied the effect of used oil on the strength and compressibility behaviour of lateritic soil. Results showed that the void of the natural soil increase from .34 to .36 when contaminated with 2% oil content and subjected to 50KN/m² loading. Further increase in oil content up to 6% led to decrease in the void ratio to a minimum value of 0.23. At 8% oil content, there was a sharp increase with the void ratio to a value of 0.38. Similar results were obtained when varying loading cases were applied. [4] , carried out research on characterization of oil contaminated soil. The report also stated that, in 1995, several tests were carried out to determine the geotechnical properties of the soil lakes in order to find an alternative for the usage of the contaminated soil for engineering purpose rather than clean it. [4] , reported that according to [5] who studied the effect of oil contamination on the compaction characteristics, shear strength, one dimensional compression and hydraulic conductivity of sand. It was found that when crude oil was used as a pore fluid, the maximum dry unit weight of sand was about 6% higher when compared with water as the pore fluid. [6] , showed in his research that the angle of internal friction of the sand decreases as the percentage of the oil increased. The effect of crude oil on the geotechnical properties of Kuwaiti sand was studied by [7]. They showed in their research that the compressibility of the sand has increased due to the addition of crude oil. Crude oil and its subsidiaries are all common compounds used daily by individuals and the society to support life. However, these crude oil base products and natural crude oil are sometimes spilled to the ground (soil), of which greater percentage are not recovered. Oil spillage on the ground has over the years attracted many researchers who with various processes have tried to recover spill oil.

In Nigeria, oil spillage is common with vandalization of pipe line, oil exploration, spillage due transportation, other human activities which contaminate the soil with oil.

Crude oil is probably one of the most complicated natural mixtures on earth containing compounds which differ in composition and physical properties that are toxic to species of marine and fresh water organisms [8].

Crude oil exploration has been going on in Nigeria for several decades since the discovery of petroleum at Oloibiri in the Niger Delta [9]. This and other related activities in the petroleum industry have sustained the Nigeria economy since 1970s; unfortunately, these highly profitable activities have environmental and biological hazards as observed during incidents of oil spillage [10]. Various oil spills have been reported in Nigeria from 1976 to 1997 and is estimated at 5334 cases of oil spillage releasing about 2.8 million barrels of oil into the land, swap, and coastal waters [11]. Apart from oil spills, crude oil also enters into the environment through Tanker accidents, industrial discharge, refinery effluents, natural seepage and sabotage of oil pipe lines [12]

A UNDP report states that there have been a total of 6817 oil spills between 1976 and 2001, which account for a loss of 3 million barrels of oil which more than 70% was not recovered [13].

The Nigerian National Petroleum Corporation (NNPC) places the quantity of petroleum jettisoned into the environment yearly at 2300 m³ with an average of 300 individual spill annually [14]. However, because this amount does not take into account minor spills, the World Bank argues that the true quantity of petroleum spilled into the environment could be as much as ten times the officially claimed amount. Dutch Shell Focados Terminal Tank failure which produced a spillage estimated at 550,000 barrels (92,000 m³) [15]

In 2010 Baird, reported that between 9million and 13 million barrels have been spilled in the Niger Delta since 1958.

The Shell Petroleum Development Company since 1958 recorded an average of 221 spills per year in its operations area involving 7,350 barrels annually [16]. It is also estimated that NNPC lost about 2300 cubic meters of oil spilled in 300 separate incidences annually between 1976-1996 [17].

Beside all the aforementioned spillage, it is of importance to note that about 70% are spilled on the soil of which only 30% were recovered. In Nigeria today and on monthly bases on the News, oil spillage is a common story line and this has an impact on the soil on which civil engineering structures are built. Therefore the researcher has undertaking this study to evaluate the impact on the soil.

RESEARCH METHOD

Method of investigation was focused on the following;

1. Identification and classification of sample
2. Study of the geotechnical properties of samples
3. Evaluation of the effect of crude oil contamination on soil sample.

Soil sample from Amaoba borrow pit was used in the investigation of both pure sample classification and evaluation of the effect of crude oil contamination on the geotechnical properties of the said sample. The samples were acquired from 3 different locations on the site, forming the Sample one, Sample two and Samples three used in the laboratory works.

Approximately 50kg of each soil disturbed samples were collected, about 45% was air dried for compaction and California Bearing Ratio test. The laboratory tests were limited to the following in accordance with [18;19]: Particle Size Analysis test, Water content, Specific Gravity, Shear Strength test, Compaction Test, Consistency limit test, California Bearing Ratio test and Consolidation test.

RESULTS AND DISCUSSION

Table 1: Properties of Natural Soil Sample.

Properties	Value
Natural Moisture Content	13.49%
Plastic Limit	18%
Liquid Limit	40%
Plasticity Index	22%
Coefficient of uniformity	4.23
Coefficient of Curvature	4.54
Specific Gravity of the soil	2.6
Specific Gravity of the Crude Oil	0.83

Table 2: Sieve Analysis for Natural Sample

Sieve Size	Sample1 % Passing	Sample2 % Passing	Sample2 % Passing
2.000	100.0	97.3	87.9
1.180	91.4	86.9	68.7
0.600	66.2	64.3	45.4
0.425	46.5	48.3	31.5
0.150	9.1	12.4	5.5
0.075	2.5	3.2	0.0
Pan	0.0	0.0	0.0

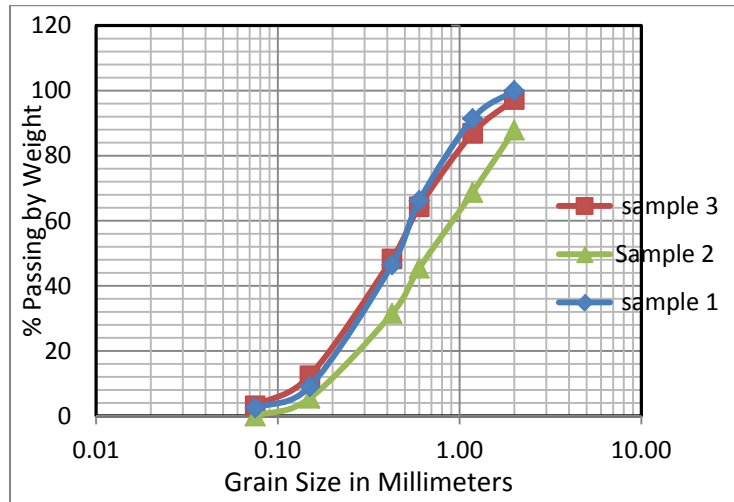


Figure 1: Particle Size Analysis of Natural Sample

Table 3: Atterberg Limit at 0%

Atterberg Limit						
Liquid Limit					Plastic Limit	
Point #1	Point #2	Point #3	Point #4		Point #1	Point #2
32.00	28.00	40.50	34.00	<i>Wet Soil+Can</i>	35.00	40.00
24.60	22.00	31.00	28.00	<i>Dry Soil+Can</i>	31.00	35.00
8.00	8.00	8.00	8.00	<i>Can</i>	8.00	8.00
12	16	26	36	<i>Blows</i>	<i>Difference: 1.1 %</i>	
44.6%	42.9%	41.3%	30.0%	<i>w%</i>	17.4%	18.5%

Table 4: Atterberg Limit at 2%

Atterberg Limit						
Liquid Limit					Plastic Limit	
Point #1	Point #2	Point #3	Point #4		Point #1	Point #2
37.00	35.00	46.00	33.00	<i>Wet Soil+Can</i>	29.00	20.00
28.20	27.20	35.40	26.20	<i>Dry Soil+Can</i>	25.00	18.00
8.00	8.00	8.00	8.00	<i>Can</i>	8.00	8.00
13	18	28	34	<i>Blows</i>	<i>Difference: 3.5 %</i>	
43.6%	40.6%	38.7%	37.4%	<i>w%</i>	23.5%	20.0%

Table 5: Atterberg Limit at 4%

Atterberg Limit 4%						
Liquid Limit					Plastic Limit	
Point #1	Point #2	Point #3	Point #4		Point #1	Point #2
47.00	33.00	46.00	30.00	<i>Wet Soil+Can</i>	29.00	29.00
35.00	25.50	35.00	24.00	<i>Dry Soil+Can</i>	25.00	26.00
8.00	8.00	8.00	8.00	<i>Can</i>	8.00	8.00
12	16	26	36	<i>Blows</i>	<i>Difference: 6.9 %</i>	
44.4%	42.9%	40.7%	37.5%	<i>w%</i>	23.5%	16.7%

Table 6: Atterberg Limit at 6%

Atterberg Limit 6%						
Liquid Limit					Plastic Limit	
Point #1	Point #2	Point #3	Point #4		Point #1	Point #2
39.00	32.00	37.00	36.00	<i>Wet Soil+Can</i>	19.00	23.00
28.00	24.00	29.00	28.00	<i>Dry Soil+Can</i>	17.20	20.40
8.00	8.00	8.00	8.00	<i>Can</i>	8.00	8.00
10	17	33	36	<i>Blows</i>	<i>Difference: 1.4 %</i>	
55.0%	50.0%	38.1%	40.0%	<i>w%</i>	19.6%	21.0%

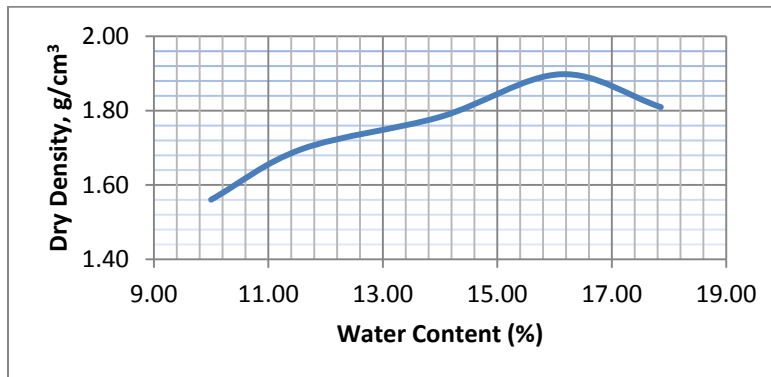


Figure 2: 0% Contamination on compaction

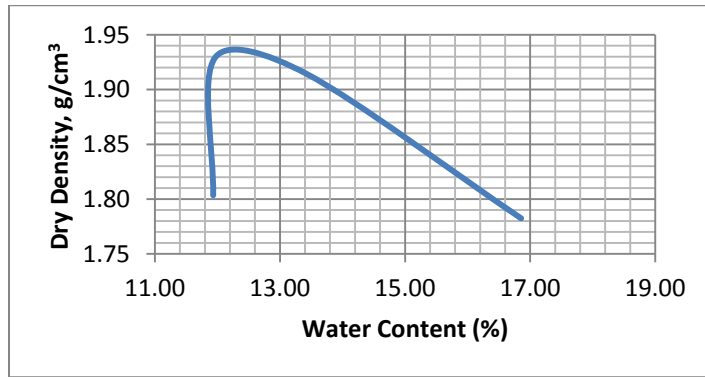


Figure 3: 2% Contamination on compaction

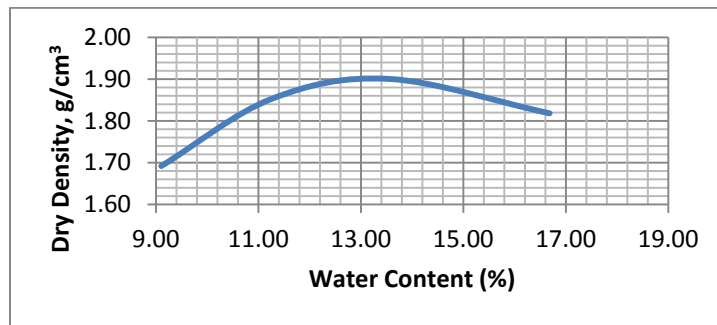


Figure 4: 4% Contamination on compaction

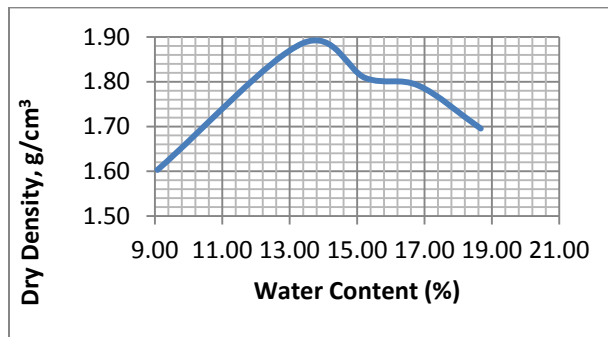


Figure 5: 6% Contamination on compaction

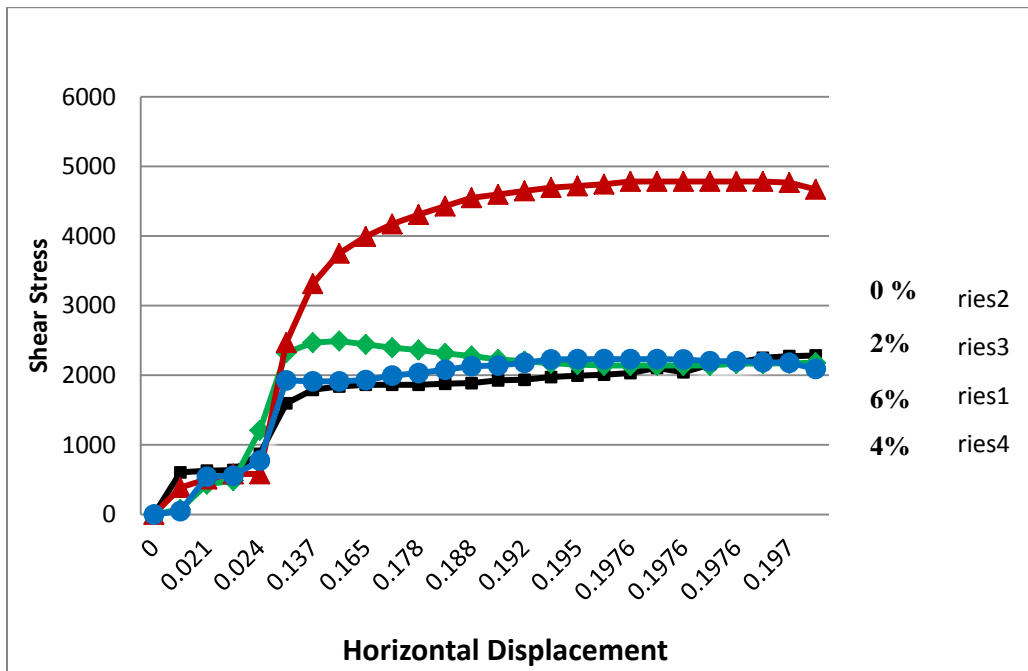


Figure 6: Shear Strength at 10N

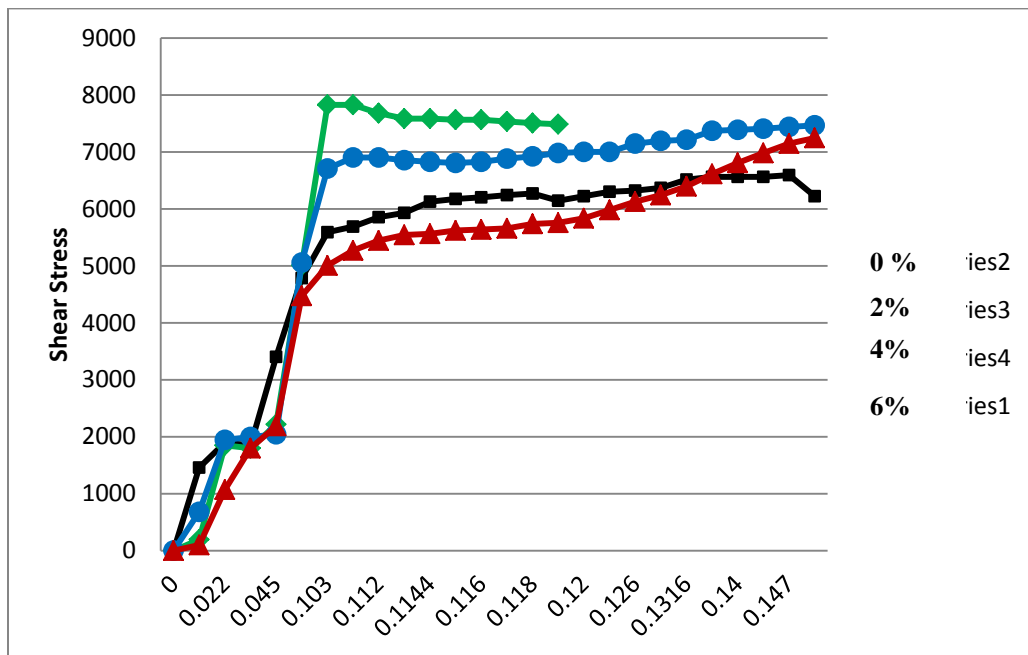


Figure 7: Shear Strength at 20N

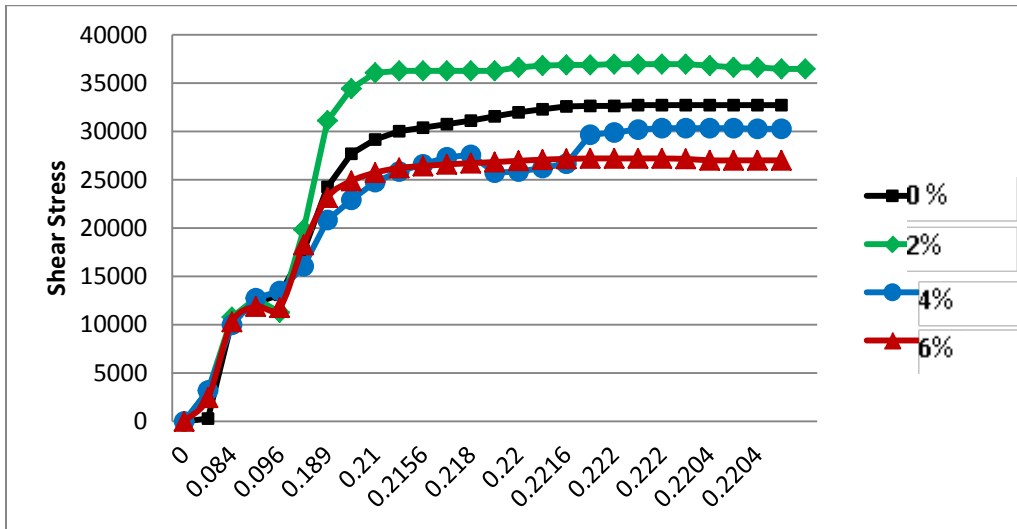


Figure 8: Shear Strength at 50N

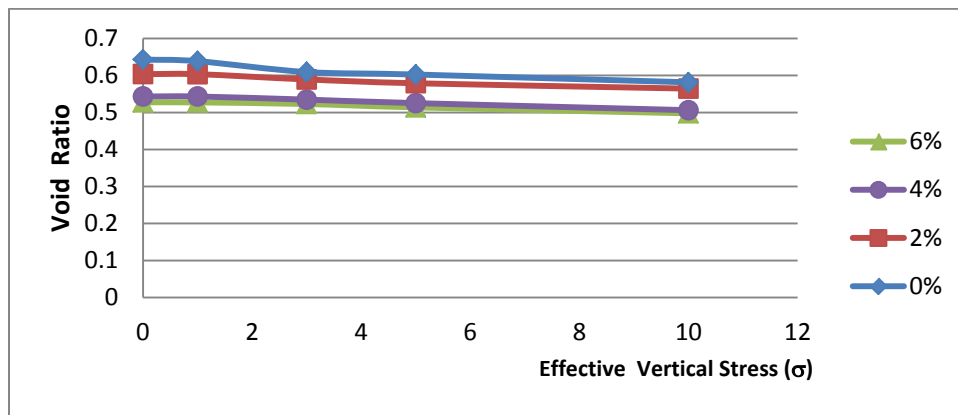


Figure 9: Void Ratio

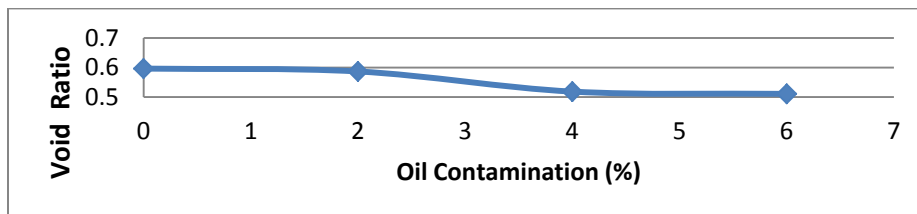


Figure 10: Void Ratio with respect to percentage of Oil Contamination.

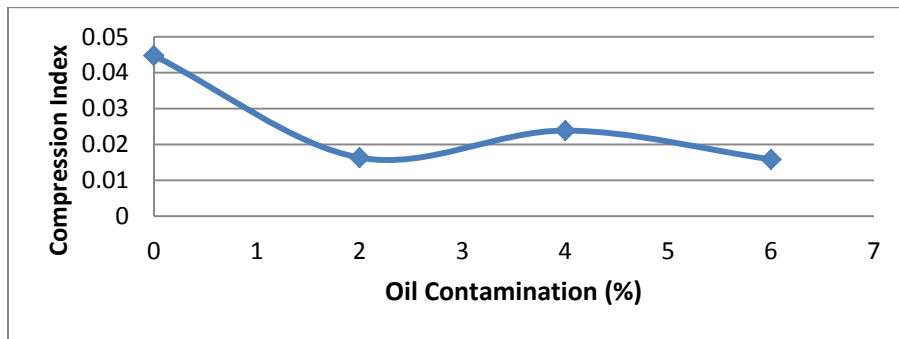


Figure 11: Compression Index with respect to percentage of Oil Contamination

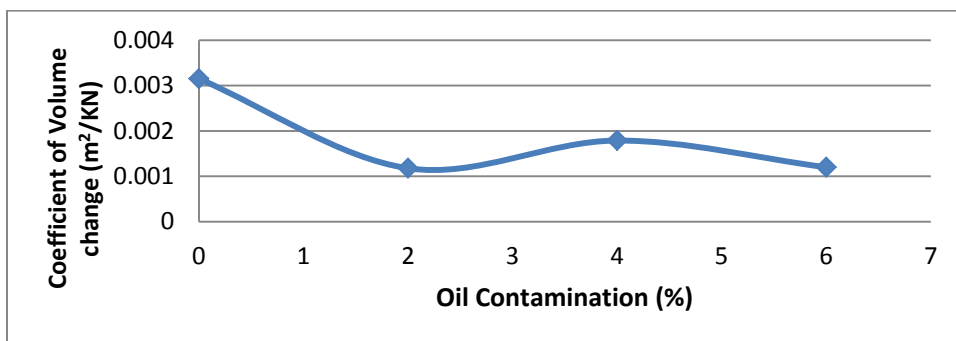


Figure 12: Coefficient of Volume change with respect to percentage of Oil Contamination

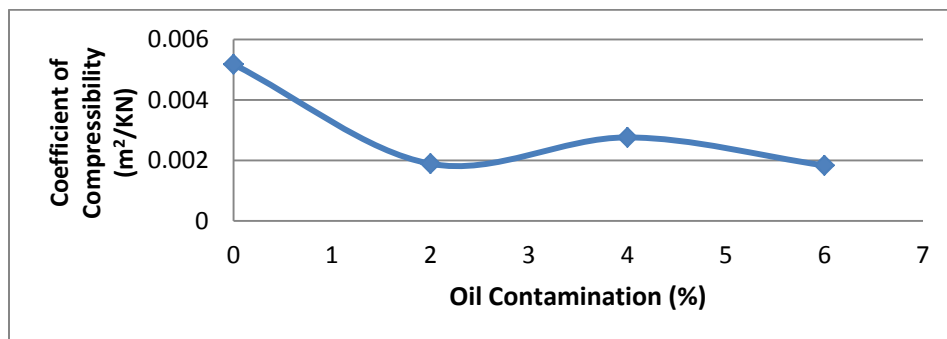


Figure 13: Coefficient of Compressibility with respect to percentage of Oil Contamination

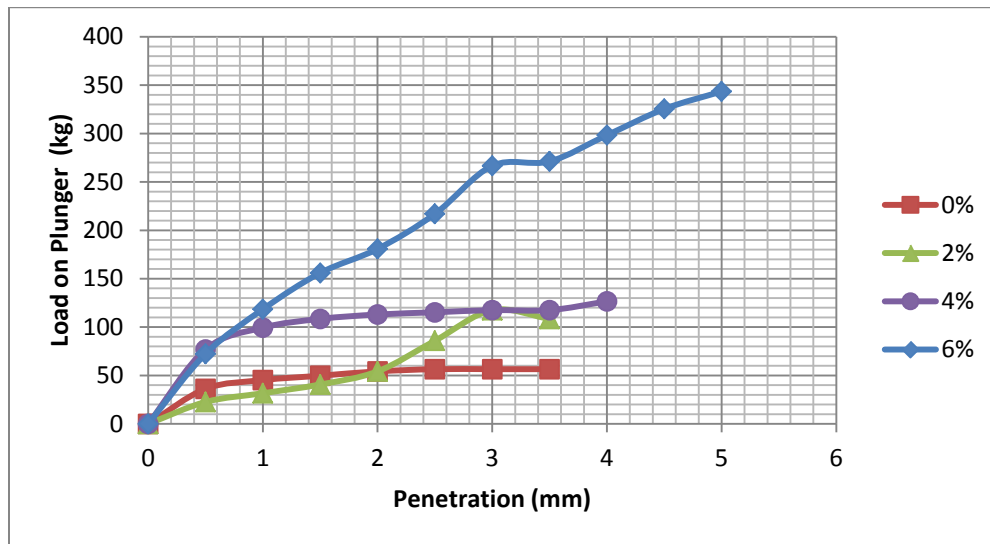


Figure 14: Load on Plunger against Penetration of different oil contamination

The effect of the increase in oil contamination on the soil can be compared with the natural sample (**Tab.1**) and standard specification governing the same as may be required in any field of engineering. Using AASHTO (American Association of State and Highway Transportation Official) classification system, the study sample from Amaoba borrow pit belongs to Granular materials A-2-6 (**Fig.1**)

[20], reported that the plasticity of a soil is its ability to undergo deformation without cracking or fracturing. Refer to **Tables 3, 4, 5 & 6** it was observed that the Liquid Limit for natural soil was 40%, it decreased to 38% at 2% oil contamination, and thereafter increased to 40% and 46% for 4% and 6% oil contamination respectively.

Refer to **Figures 6, 7 & 8**; it was also observed that the shear stress was highest at 2% and lowest at 6% oil contamination. Though crude oil and its constituents are non-Polarizing liquid when mixed with soil and do not increase the plasticity of a soil. At 2% the crude oil content was just enough to form and increase the intermolecular force between the particles of the soil which gave rise to increase in the shear strength. On increase from 2%, increases the liquidity of the soil and since to bind the soil particles together, hence reduction in shear strength and increase in liquid limit of the soil.

Refer to **Figs. 2, 3, 4, & 5**, using Standard Proctor compaction tests (ASTM-D698, method A) [21], compaction tests were carried out on 0%, 2%, 4%, and 6% crude oil contamination of the soil samples. It was observed at 2% crude oil contamination, the sample attained a maximum dry density of 1.93g/cm^3 with an OMC of 12.2% as against the natural sample of OMC 16.2% and Max. Dry Density of 19.8g/cm^3 . With further increase of crude oil contamination, there was a slight decrease in Max. Dry Density and increase in OMC up 14% at 6% crude oil contamination. This increase led to

The from the test procedures, it is evident that the maximum crude oil contamination that the sample soil can hold within the giving compacting effort and applied stress is 2%. In compaction and Consolidation of the soil, excess crude oil was expelled from the sample soil when the crude oil contamination was increased from 2%.

Refer to Figs. 9, 10, 11, 12, 13 & 14; the sample has a maximum value of $0.00518\text{m}^2/\text{kN}$ for Coefficient of Compressibility, $0.00315\text{m}^2/\text{KN}$ for Coefficient of Volume change and $0.0447\text{m}^2/\text{kN}$ for Compression Index at 0%. These values decrease with increase in crude oil Contamination with a little increase at 4%.

Refer to Fig.14, the California bearing ratio relatively and considerably increased with increase in the pure crude oil contamination that when it was 50% for uncontaminated amaoba lateritic soil at 3mm penetration, it recorded 120% for 2% and 4% contamination and 270% for 6% contamination. There was also a remarkable increase to 340% at 6% contamination which is a huge advantage in pavement construction.

CONCLUSION

From the foregoing, it has been established that the difference in OMC and MDD is because of the soil interaction with the oil, the vibration frequencies of the mixture differ from that of the oil-free soil. The extent of the shifts of the frequencies is a measure of the interaction between them. The higher the shifts towards the positive frequencies indicate the formation of strong bonds whereas, the smaller shifts in the frequencies are interpreted in terms of simple Van der Waal's attractions [22]. It was discovered that increase in crude oil contamination of the soil stabilizes the soil. This is due to the bonding mechanism introduced by the crude oil into the soil. The co-existing of oil-soil-water mixture can pose the following situation;

1. Oil may absorb onto the surface of the soil constituents
2. Oil may form bonds which link the soil particles together
3. Oil may exist separately in the soil pore fluid.

It is expected that within the aforementioned situation above, the related interaction within the co-existence depends upon the proportion of each constituents on percentage contamination and the induced stress. The major mode of interaction as mentioned above is via Van der Waal's attraction forces. As the number of contact points between the crude oil and soil particle surfaces increase, direct chemical bond formation between the SO_3^- anionic head of the oil and a metal cat-ion on the surface. These bonds are relatively strong [22; 23]. The presence of crude oil in the soil leads to stabilization of the soil. It is also deduced that the increase in crude oil contamination increases the surface area interaction between oil and soil particles which produces a stronger chemical bond hence its stabilization. From the forgoing, soil contaminated with crude oil can be used as pavement material on rural roads. It may not be used as base material on roads with Asphalt or concrete wearing course as this research do not cover the effect of aging on crude oil contaminated soil. The result of the CBR has shown that pure crude oil between 4% and 6% contamination is highly beneficial to pavement construction. In view of the above, pure crude oil can be used up to 4% to improve engineering soil with its promising potentials for soil improvement and stabilization. This makes oil spillage advantageous to engineering soil users.

REFERENCES

1. Afolabi, O.A. Adeyemi, S.A. and Imevbore, A.M .A.(1985) "Studies on toxicity of some Nigerian crude oils to some aquatic organisms". In *Proceedings of 1985 International Seminar on Petroleum Industry and the Nigerian environment*. Federal Ministry of Works and Housing, Kaduna, pp.269-272.
2. Al-Sanad, H. A., Eid, W. K. and Ismael, N. F.(1995) "Geotechnical Properties of Oil-Contaminated Kuwaiti Sand," *Journal of Geotechnical Engineering*, Vol, No.5., pp. 407-412.

3. Arora K.R.(2011) Soil Mechanics and Foundation Engineering (Geotechnical Engineering) *Standard Publishers Distributors, Delhi, India.*
4. ASTM Standards D5002 – 99(2010) “Standard Test Method for Density and Relative Density of Crude Oils by Digital Density Analyzer” ASTM International, West Conshohocken, PA, D02.04.0D / [05.02](#), www.astm.org.
5. Bronwen Manby(2007) “The Price of Oil” *Human Rights Watch*, 1999, Retrieved November 9.
6. BS 1377(1995) “Methods of testing Soils for Civil Engineering purposes”. British Standards Institution, Her Majesty’s stationery Office, London.
7. BS 1924(1990) “Methods of Testing for stabilized Soils”.British Standards Institution, Her Majesty’s stationery Office, London.
8. Cormack, D. (1983) Response to Oil and Chemical Marine Pollution. *Applied Science Publishers Limited. Glasgow, Scotland*, 12p.
9. Dublin-Green, W.F.; Nwankwo, J.N. and Ilechukwu, D.O. (1998) “Effective regulation and management of HSE issues in the petroleum industry in Nigeria”. *SPE International conference on Health, Safety and Environment in Oil and Gas exploration and production*. Caracas, Venezuela, 7-110 June 1998. Paper No. SPE 40/26.
10. Ehab Taher Shaheen(2011) Effect of Crude Oil Products on the Geotechnical Properties of Sandy Soil, A Thesis In Civil Engineering College of the American University of Sharjah, 2011. U.A.E
11. Ghaly, A. M. (2001) "Strength Remediation of oil contaminated sand," *The Seventh International Conference on Solid Waste Technology and Management, July 2001, Philadelphia, USA*,.
12. <http://www.cbrplus.com/Technical.html>, 2014.
13. Nwilo,P.C. and Badejo, O. T. (2001) Impacts of Oil spills along the Nigerian coast: *The Association for Environmental Health and Sciences*.
14. Obeta, I.N and Eze-uzomaka, O.J. (2013) “Geotechnical Properties of Waste Engine Oil Contaminated Laterites”. *Nigerian Journal of Technology Vol. 32, No.2, 2013, pp. 203-210*.
15. Obeta, I.N and Ohwogano, J. (2015) Application of Used Engine Oil in Soil-Cement Stabilization, *Nigerian Journal of Technology (NIJOTECH) Vol. 34, No. 1, January, 2015, pp. 104-108. Faculty of Engineering, University of Nigeria. ISSN 1115-8443*
16. Onyelowe, K.C. and Agunwamba, J.C. (2012) Geotechnical Examination Of The Geophysical Properties of Olokoro Borrow Site Lateritic Soil for Road Works, *Nigerian Journal of Technology (NIJOTECH) Vol. 31, No. 3, November, 2012, pp. 397-400. Faculty of Engineering, University of Nigeria. ISSN 1115-8443*
17. Otobo, A.J.T. (1995) Fisheries issues in the Niger Delta. Unpublished paper presented at the National workshop on integrated coastal Zone Management in the Niger Delta.

18. Purj, V. K. (2000) "Geotechnical Aspects of Oil-Contaminated Sands," *AEHS*, 2000, pp. 9(4):359-374.
19. Raymoand N, Young, Lanya F. Mohammed, and Abdel M.O.Mohamed (1994) Retention and Transport of Oil Residue in a Loam Soil, *American Society for Testing and Materials STP 1221, Philadelphia*.
20. Shell Petroleum Development Company(2006) People and the Environment, Annual Report. The Guardian Newspaper, 2006;Tuesday June 13, p16
21. Twumasi, Y. and Merem E. (2006) GIS and Remote Sensing Applications in the Assessment of Change within a Coastal Environment in the Niger Delta Region of Nigeria. *International Journal of Environmental Research & Public Health* 3(1) 98-106. www.ijerph.org
22. United Nations Development Programme (2006) *Niger Delta Human Development Report. Abuja, Nigeria*, p185&186
23. Zabbey, N., Nwadukwe, F. O., and Deekae, S. N. (2007) Effect Of Crude Petroleum Oil (Bonny Light) On The Survival Of The Fry Of African Catfish, *Clarias gariepinus*, *FRY African Journal of Applied Zoology & Environmental Biology*, Vol. 9, 20 – 25, www.uniportjournals.com/ajazeb

