Effect of Crude Oil Contamination on the Index Properties, Strength and Permeability of Lateritic Soil

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Abstract: This research investigated the behavior of crude oil contamination on the geotechnical properties of lateritic soil. The contaminated lateritic soil was prepared by adding different percentages of crude oil 2%, 4%, 6%, 8%, 10%. The Index properties test, compaction, shear strength test (California bearing ratio test and direct shear box test), and permeability test were determined on both contaminated and uncontaminated specimen, the uncontaminated specimen served as control. The results showed that crude oil contamination caused an increase in linear shrinkage, liquid limit, plastic limit and plasticity index between 0% -10% contamination.
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Key words: Crude oil, Lateritic soil, Contamination, Shear strength, Geotechnical properties.

1.0 Introduction

Crude oil contamination ranging from leakage of oil pipelines, vandalisation 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 (Al-Samad et al 1995).

Lateritic soil are generally use for road construction in Nigeria. Lateritic soil in its natural state generally have low bearing capacity and low strength due to high content of clay. The ability to blend the naturally occurring lateritic soil with some chemical additives to give it better engineering properties in both strength and water proofing is very essential (Evgin and Das 1992).

Presently, there is no consensus of opinion or undisputable proof about the effect of crude oil on the engineering behavior of lateritic soil. When soil is contaminated by crude oil, it is subjected to a change in its engineering properties (Mashalah et al. 2007). Lateritic soil when electro-achemically active is mostly affected by the environment (Rehman et al., 2007). Oil contamination affects the stability and permeability of compacted clay in landfill sites and oil leaks causing expansion or contraction of the soil on which pipelines are laid (Rahman et al., 2010).

Since the advent of engineered waste disposal, most industrial wastes are discharged after treatment into land based containments. However, industrial wastes in contact with soil, or accidental spillages of chemical substances, may lead to changes in soil properties, resulting in improvement or degradation of the engineering characteristics of soil and sometimes leading to functional or structural failure of structures. Any change in engineering properties or behavior of soil strata may lead to loss of bearing capacity and an increase in total or differential settlement of foundation systems of the structure (Rahman, et al., 2007). Recent case histories of structural damage to industries and residential buildings from chemical contamination of soils serve to emphasize the importance of the modification of engineering properties of soil by chemicals (Hossam et al., 2008). (Murat and Mustafa 2010) stated that the presence of chemicals may influence the soil properties and behavior and that detailed understanding of the different phases of the soil is critical when considering re-use of contaminated soil.

Much attention has been paid to the effect of crude oil spills on the environment in terms of pollution of surface and ground water, flora, fauna, air pollution and fire hazards (Youdeowei 2008). But little research has been done on the nature of soil-crude oil interaction and the effects of crude oil on the geotechnical properties of soil. Most of the Built Environment and infrastructure, such as houses, roads and bridges are built on soil. Soil contamination with crude oil could alter the effective grain size of soil particles, liquid limit, plastic limit, shrinkage limit, specific gravity, hydraulic conductivity (permeability), compaction characteristics, strength properties and consolidation. Modification of soil properties can then cause or exacerbate various geotechnical problems such as; landslides, ground subsidence, settlement, erosion, progressive failure, underground structural stability, foundation durability and corrosion (Elisha

2009), (Mohammed and Shahaboddin 2008) (Obeta and Ohwoganohwo 2015) and (Singh et al., 2009).

2.0 Materials and Method

The soil used in this study was obtained from a borrow pit, having a deep lateritic soil profile at Igando, Alimosho Local Government in Lagos State, Nigeria. It was collected from the sidewall of the soil profile at about 1.8 m depth below the top of the pit. Samples were collected in sacks while some were stored in a water-tight container for laboratory determination of their moisture content. The soil sample was classified as inorganic clay of low plasticity (CL) based on the Unified Soil Classification System, USCS and A-7-6 with the AASHTO soil classification system. The samples collected in sacks were transported to the laboratory, air-dried, passed through a 4.75 mm sieve and thoroughly mixed. The soil was then mixed with varying percentages of crude oil.

The thoroughly mixed soil sample was divided into six parts. Crude oil was added to each of the parts in 2, 4, 6, 8 and 10% proportions by dry weight of the soil sample respectively. The soil-crude oil mixtures were thoroughly mixed and stored in containers for 24 hours to allow for homogeneity of the mixtures. The moisture contents, atterberg limits, sieve and hydrometer grain size analysis, specify gravity, linear shrinkage, compaction, California bearing ratio (CBR) permeability, consolidation and shear strength test. Sieve and hydrometer analyses were carried out on the contaminated and uncontaminated soil samples.

3.0 Results and Discussion

The Properties of the uncontaminated Soil is shown in Table 1. The effect of the increase in oil contamination on the soil was compared with the natural sample shown in table 1. The soil is classified as A-2-7 with a group index of 6 according to the Association of American States Highway and Transportation Officials Classification System (AASHTO). It is also classified as sandy clay (SC), according to the Unified Soil Classification System (USCS).

Table 1: Properties of Natural Soil Sample.

Physical Property	Lateritic soil
Liquid Limit (%)	41.18
Plastic Limit(%)	19.00
Plasticity index (%	22.18
Shrinkage limit (%)	13.75
Natural Moisture Content (%)	14.49
Max. Dry density(Mg/m^3)	2.060
Opt .Moisture content(%)	22.0
Unsoaked CBR%	16.25
Specific gravity	2.50

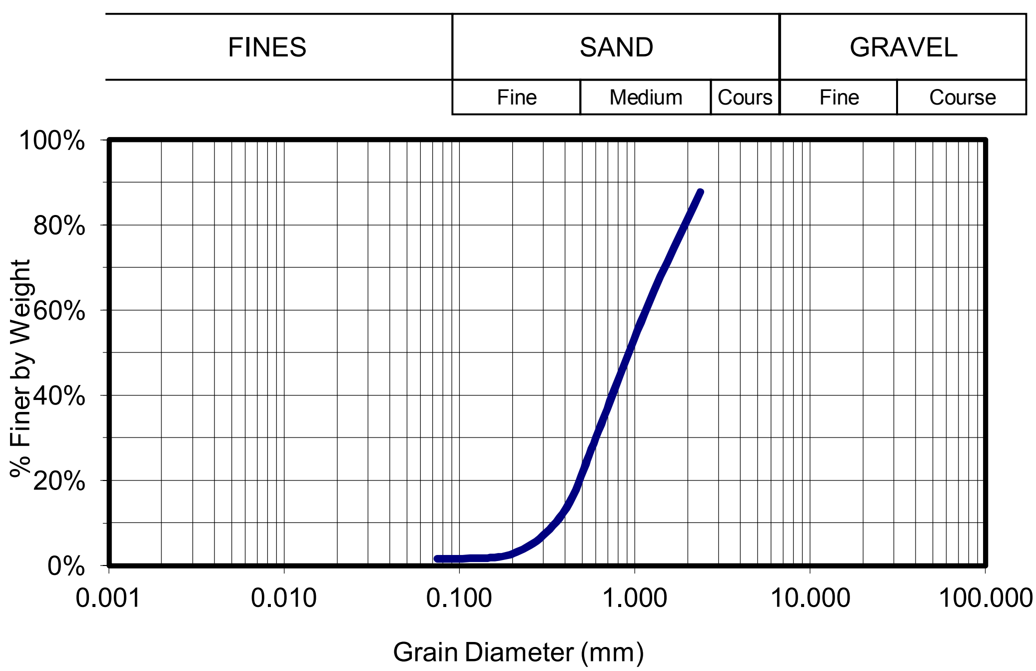

Figure 1: Grain size analysis of the natural soil

Table 2: Sieve Analysis for Natural Sample

Aperture size (mm)	Weight retained (W_1 in gram)	Percentage (%) retained (W_2 in gram)	Percentage (%) passing (W_3 in gram)
2.360mm	24.6	12.3	87.7
1.180mm	53.6	26.8	60.9
0.600mm	61.8	30.9	30.0
0.425mm	30.4	15.2	14.8
0.300mm	15.8	7.8	7.0
0.120mm	7.8	3.0	3.1
0.150mm	2.6	1.3	1.8
0.0750µm	0.4	0.2	1.6
Dust +(receiver)	3.2	1.6	0.00

3.2 Atterberg Limits

It was observed that the Liquid Limit for natural soil was 41.18%, it increased to 43% at 2% oil contamination, and thereafter increased to 47.20% and 50.95% for 4% and 6% oil contamination respectively as shown in Table 3 and Figure 2. The plastic limit and plasticity index increased as the crude oil content increased in the soil. There was an increase in the shrinkage limit from 2 to 4% addition of crude oil and a reduction at 6%; and an increase at 8 and 10%. This increase in index properties values is associated with the bonding action in the clay minerals of the lateritic soil. The plasticity of a soil is its ability to undergo deformation without cracking or fracturing.

Table 3: Variation of Atterberg limits with crude oil content.

CRUDE OIL (%)	LIQUID LIMIT %	PLASTIC LIMIT %	PLASTICITY INDEX %	SHRINKAGE LIMIT %
0%	41.18	19.00	22.18	13.75
2%	43.00	20.1	22.90	13.90
4%	47.20	20.9	26.30	14.40
6%	50.95	21.67	29.28	12.50
8%	53.73	22.88	30.85	14.00
10%	55.00	24.83	30.92	15.90

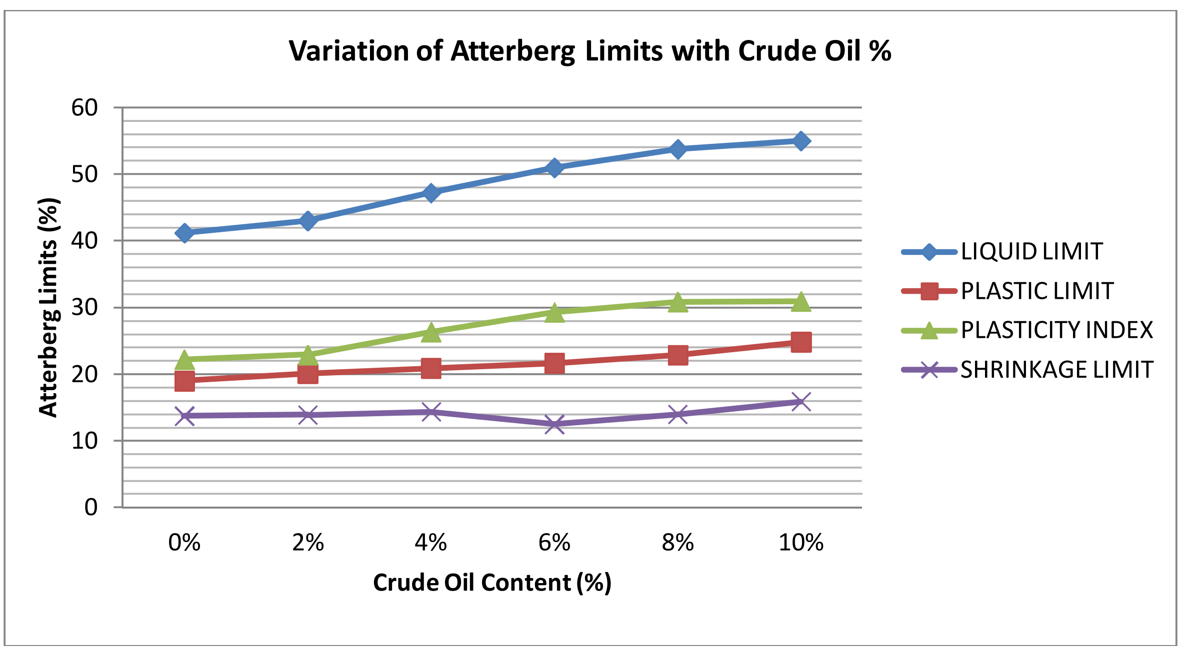

Figure 2

3.3 Shear Strength

The results of the shear strength are shown in Figure 3 for both contaminated and uncontaminated soil. It was observed that the shear stress was high at 2% and 4% addition of contaminant and a reduction by 60% at 6% crude oil contamination down to 10% but still higher than the 0% content of the contaminants. 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. Increase from 2% increased the liquidity of the soil binding the soil particles together. From observation, the crude oil negatively affected the cohesion, frictional, and gravitational forces by reducing the cementation of the individual clay particles present in the soil.

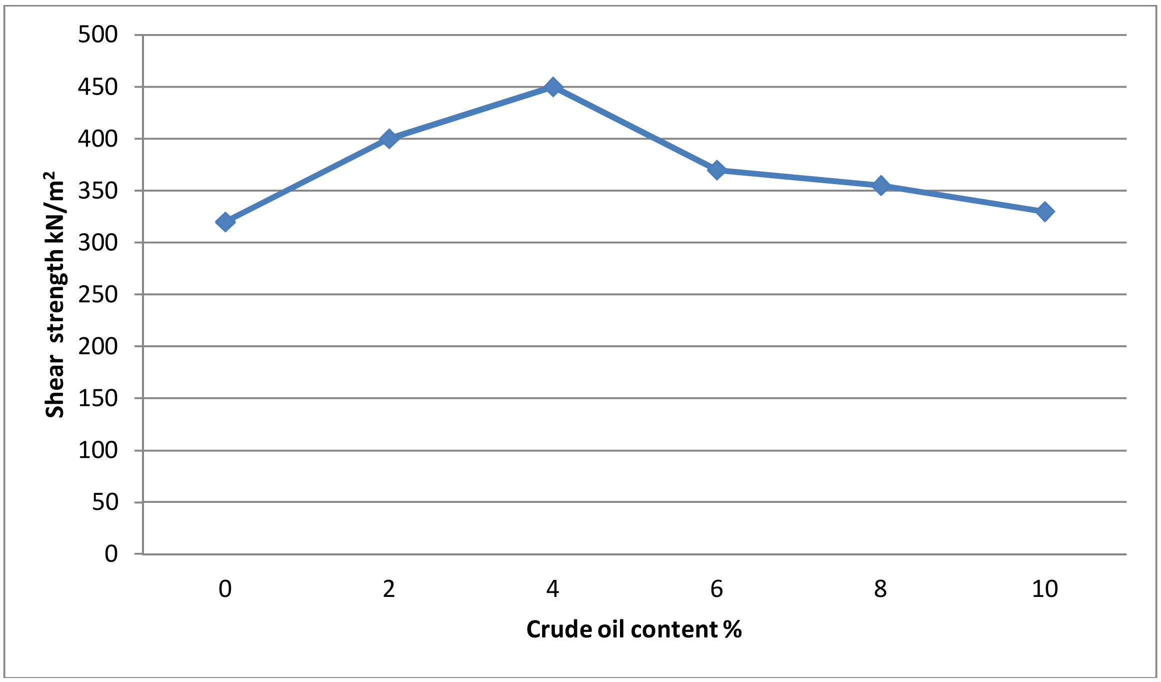

Figure 3

4.0 Discussion

1. The liquid limit, plasticity limit, plasticity index and linear shrinkage values of the contaminated soil are higher than that of the uncontaminated soil. This increase in index properties values is associated with the bonding cation in the clay minerals.

2. This decrease in shear strength values can be attributed to the fact that crude oil has a higher viscosity than water and also to the lubrication and slippage of the soil particle caused by the presence of the crude oil. So the crude oil contaminated soil has lower shear strength compared to uncontaminated soil.

3. The compressibility increases distinctively as the oil content increases. This behavior can be attributed to the lubrication effects of the oil. Therefore, the contaminated soil will more easily be compressed into denser configurations.

4. Remediation work or use of crude oil contaminated soil for any possible geotechnical application requires a good knowledge of the geotechnical properties and behavior of the crude oil contaminated soil.

5. The result of this research therefore the need for soil remediation if buildings, oil and gas facilities and other structures are to be erected on crude oil polluted sites.

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