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Engineering Properties of crude Oil contaminated clay Soil in Niger Delta Region of Nigeria

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ABSTRACT

Rivers state is one of the major oil producing states in the Niger-Delta region that has experienced oil pollution due to constant oil spills. The degradation has attracted the attention of both local and international organization like UNESCO, UNEP, WHO. E.t.c. The impact has become so serious that made British Broadcasting Co-Operation after visiting Rivers and Bayelsa State in 2009 declared Nigeria as oil pollution capital of the world. This research paper investigated the effect of crude oil pollution on selected geotechnical properties of clay soil in Akiogbologbo located in Engeni Ahoada L.G.A of Rivers state. The geotechnical parameters investigated are California bearing ratio (CBR), Coefficient of Permeability (K), consolidation parameters (Coefficient of consolidation Cv, Coefficient of volume compressibility av and Settlement S), Shear Strength Î, Cohesion C, and angle of internal friction Ø. The soils were collected at a depth of 2m. The collected samples were mixed with crude oil at different percentages between (0% - 14%) of the dry weight of the samples at 2% interval. Laboratory tests were conducted on both the contaminated and uncontaminated samples, Variations in the properties of the contaminated as well as uncontaminated samples were obtained at each level of contamination. The results show that CBR, and Coefficient of permeability (K) decreased from 12.6% and 3.28 × 10^{-4} cm/s at 0% contamination to 0.6% and 2.0 × 10^{-4} cm/s at 14% contamination, consolidation parameters Cv, av, and S increased from 6.46 × 10^{-7} KN/m^2 , 1.1 × 10^{-2} Kn/m^2 and 2.98mm at 0% to 9.65 × 10^{-7} KN/m^2, 1.23 × 10^{-2} KN/m^2 and 3.3mm at 14% contamination respectively. Angle of internal friction increased from 11^o at 0% to 13^o at 14%, Shear strength decreased from 125.11 KN/m^2 at 0% to 87.96 KN/m^2 at 14% cohesion decreased from to 81.93KN/m^2 at 0% to 58.87 KN/m^2 at 14% contamination. Changes on the value of the geotechnical parameters shows crude oil has negative impact on geotechnical properties of clay soil.

Keywords—Crude oil, Clay soil geotechnical parameters contamination, Niger-Delta.

I. INTRODUCTION

Soil contamination by crude oil and its product is one of the most widespread and serious geo-environmental problems confronting many oil producing nations in the world. Different contaminants have different chemical properties which influences geochemical reactions induced in the soil. Thus the level of contamination is affected by the chemical characteristics of the contaminants and to some extent physio-chemical properties of the soil concerned [4]. It is a well-known fact that petroleum products constitute one of the most prevalent sources of environmental pollution in the world today. Nigeria which is rated as the 6th largest oil producing nation is not left out in partaking of the negative effect of pollution [6]. It's Niger-Delta where most of the oil activities take place has experienced huge oil spills as a result of oil exploration refining and transportation. It is however very difficult to access oil spills in the Niger Delta region of Nigeria, owing to insincerity on the part of the operators of oil sector to give accurate report of occurrence of spillages in the region [10]. The amount of spillages in the Niger Delta region ecosystem over the past 50yrs is estimated to be more than 9million tons [11]. Again according to the Federal Government of Nigeria about 7000 oil spills may have occurred between 1970 and 2000[1]. Also the federal government documents a total of 2405 oil spills

accidents between 2000 and 2006 which represent an alarming rate of approximately 300 spills per annum. The rate of spill incident has escalated to such an unacceptable level in Niger Delta region leading to social and political issues like corruption, youth restiveness e.t.c. [2]. There are several reasons for the huge number of spills, these include lack of maintenance of oil pipelines. Most of the pipelines which convey oil are obsolete. According to international standards, oil pipelines supposed to be replaced after every 20years. Some of the pipes are laid above the ground exposing them to wear and tear [9]. Others are sabotage transportation, production and drilling process. Regardless of the source whenever these spills occur they impact negatively on the lives of the people in the area where they occur. It wipes out aquatic life and crops, fills the air with hazardous gases leaving its victims unable to find the life nature originally provided.

In general oil contamination causes massive environmental degradation, it is a serious geo-environmental problem as it impacts negatively on both Agricultural and geotechnical properties of soil.as well as groundwater. It percolates steadily into subsurface environment and water system. These hydrocarbons when they penetrates soil, affects the quality of the soil and changes the physical properties of the contaminated soil. In previous researches, it has been shown that oil contamination reduces the permeability strength and Atterberg limits of the soil[6]. Therefore it is pertinent to study geotechnical properties of oil contaminated soils for Engineering and Environmental purposes.

The objective of this paper therefore is to present changes on geotechnical properties of clay soil when clay soil samples were mixed with varying percentages of crude and subjected to laboratory testing. The geotechnical properties investigated are California bearing ratio (CBR), consolidation parameters (coefficient of consolidation Cv, compressibility coefficient Av and Settlement S), others are shear strength, angle of internal friction and cohesion C.

II. Materials and Method

The materials for this study are clay soil and crude oil. The clay soil was obtained from Akiogbologbo in Engenni Ahoada L.G.A. of Rivers State. The crude oil was obtained from a nearby Agip drilling rig location. Disturbed soil samples were collected at approximately 2.0m depth. The samples were air dried and mixed with water equivalent of natural moisture content. The clay soil samples were divided into eight equal parts with one sample as control (0% contamination).

The level of contamination was calculated as percentage by weight of uncontaminated prepared samples. Each sample was mixed with crude oil at 2%, 4%, 6%, 8%, 10%, 12%, and 14% level of contamination. The samples were placed in a closed container and kept in the laboratory for 14days for proper reaction between the samples and the oil. About 14 samples were prepared for each parameter standard and comprehensive laboratory investigation based on ASTM standard method of soil testing was conducted on the samples to determine the effect of crude oil the on geotechnical parameters. The following Geotechnical properties were investigated ; Shear strength, angle of internal friction and cohesion using unconsolidated undrained triaxial test (ASTM D 2850), Coefficient of permeability using constant head permeameter (ASTM D 2434), consolidation parameter (Cv, av, and S) using consolidometer (ASTM 2435), California bearing ratio CBR (ASTM 2434).

III. RESULTS AND DISCUSSION

Fig. 1 shows the result of variation of CBR of polluted clay soil with different concentration of crude oil

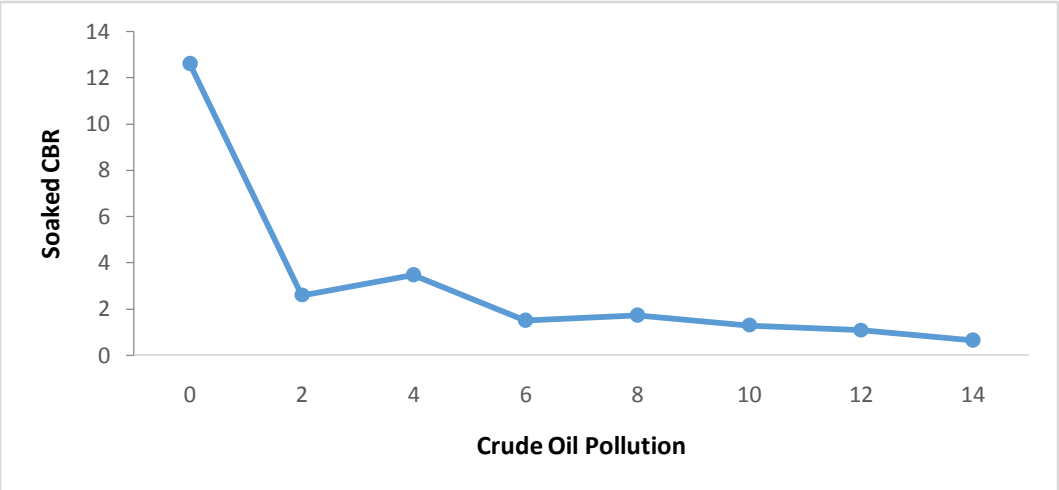

Fig 1: Variation of Soaked *CBR* of polluted clay soil with different concentration of crude oil

For crude oil contamination, the *CBR* decreased from 12.61% at 0% contamination to 0.66% at 14% contamination. The decrease in the *CBR* is as a result of lubricating effect of oil which caused the soil particles to slide over each other accounting for the decrease in the *CBR* values.

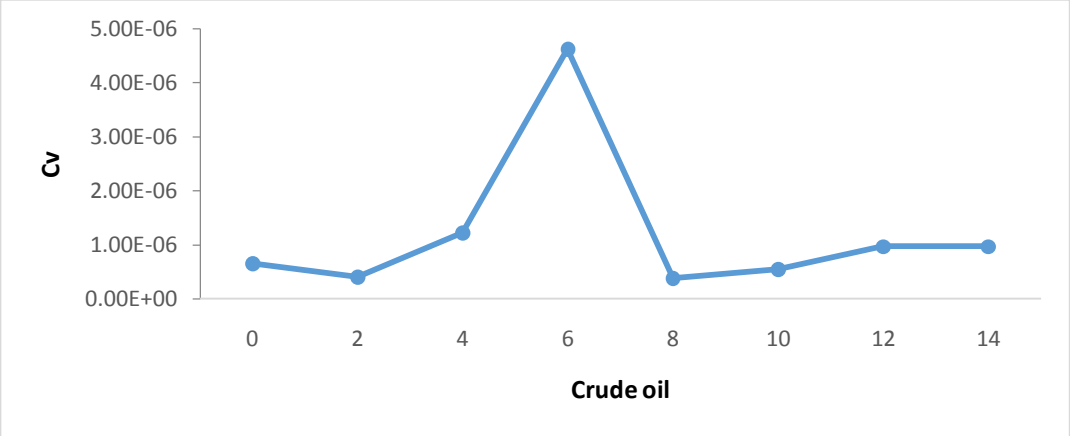

Fig. 2 Variation of Coefficient of Consolidation (C_v) of polluted clay soil with different concentration of crude oil

For clay contaminated with crude oil, the coefficient of consolidation increased from $6.46x10^{-7}$ m^2/s at 0% to $9.65 \times 10^{-7} m^2/s$ at 14%. The increase in the coefficient of consolidation Cv is as a result of increased oil contamination. This could be due to initial settlement and extrusion of oil from the soil material with increasing loading through the process of compressibility and consolidation which is time dependent. This result is in agreement with [3] but disagrees with earlier works by [8]. The increment in consolidation may also be as a result of reduction in void ratio as a result of the presence of oil, therefore the viscous properties of crude oil greatly influenced the rate at which the compressibility of the soil under applied pressure is behaving.

Fig. 3 shows the result of Variation of Coefficient of Compressibility (a_v) of polluted clay soil with different concentration of crude oil.

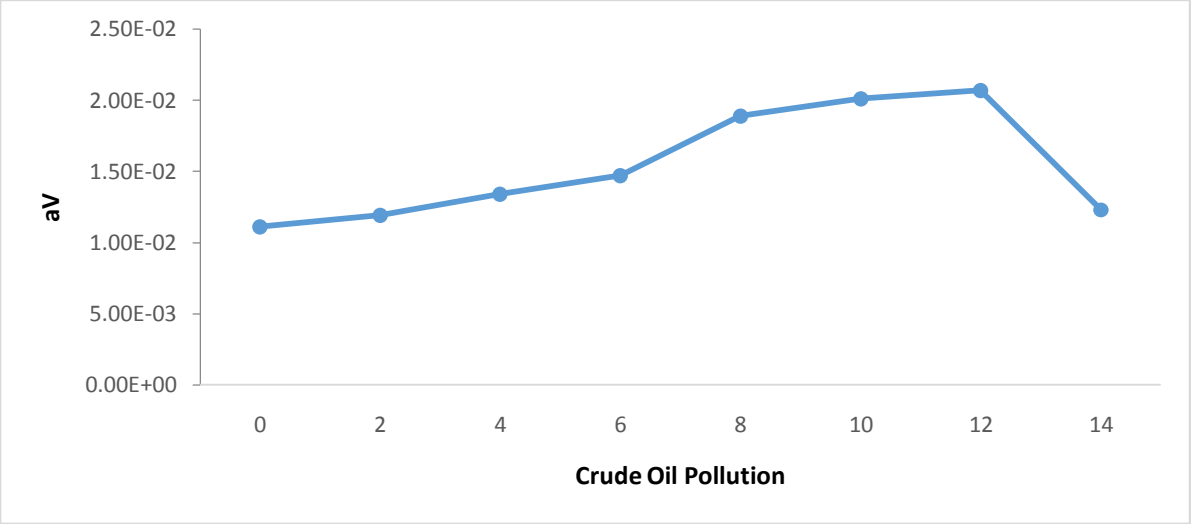

Fig.3 Variation of Coefficient of Compressibility of polluted clay soil with different concentration of crude oil

The volume compressibility (av) increased progressively from 11 x 10^{-2} m^2KN at 0% to 2.6 x 10^{-2}at 12% contamination before decreasing to 1.25 x 10x $10^{-2}m^2KN$at 14%. This could be due to initial settlement and extrusion of oil from the soil material with increasing loading through the process of compressibility and consolidation which is time dependent. This result is in agreement with [3] but disagrees with earlier works by [8].

Fig. 4 shows the result of Settlement of polluted clay soil with different concentration of crude oil

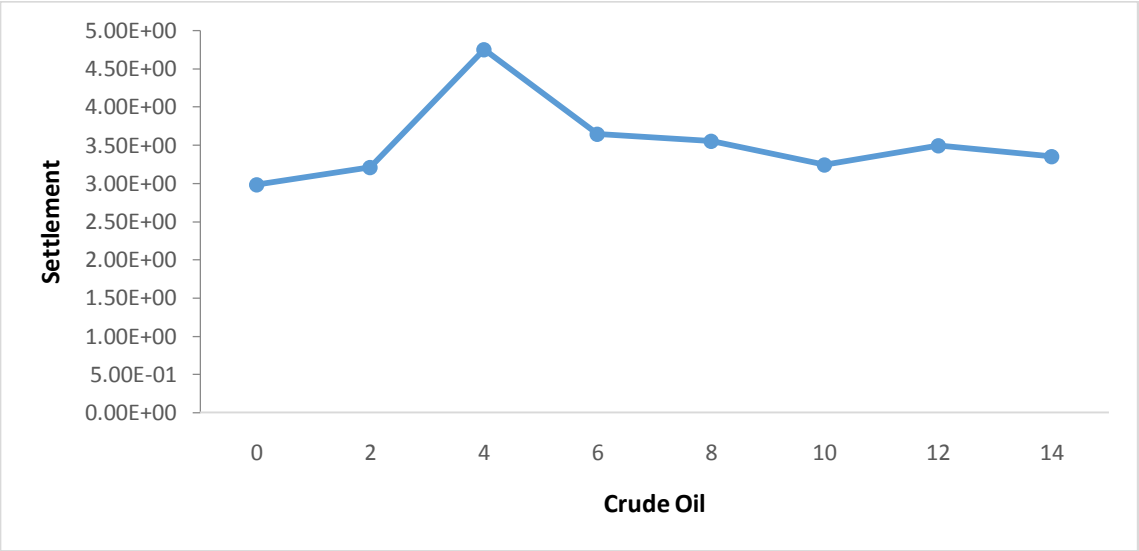

Fig. 4 Variation of settlement test of polluted clay soil with different concentration of crude oil

The settlement increased from 2.98mm at 0% to 4.75mm at 4% and decreased steadily to 3.35 mm at 14% contamination level.

Fig.5 shows the result of Permeability test of polluted clay soil with different concentration of crude oil.

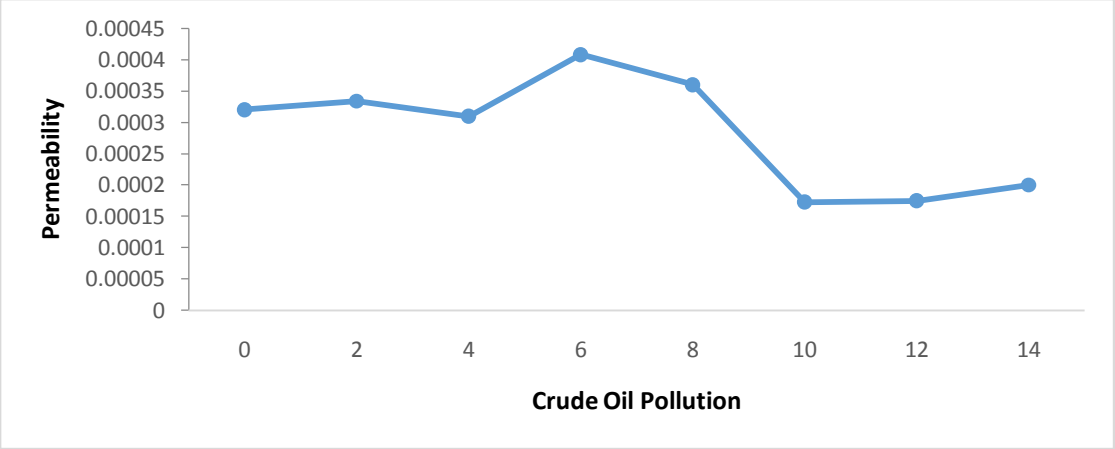

Fig. 5 Variation of permeability coefficient of polluted clay soil with different concentration of crude oil

The value of the coefficient of permeability (k) first increased to 4.1 X 10^{-} 4 cm/s at 6% contamination before decreasing to 2.0 x 10^{-4}cm/s at 14% contamination (about 12%) reduction. The decreased may have been caused by crude oil which were entrapped in the pore spaces thereby blocking the free flow of water through the soil mass.

Fig.6 shows the result of Variation of Friction Angle of polluted clay soil with different concentration of crude oil

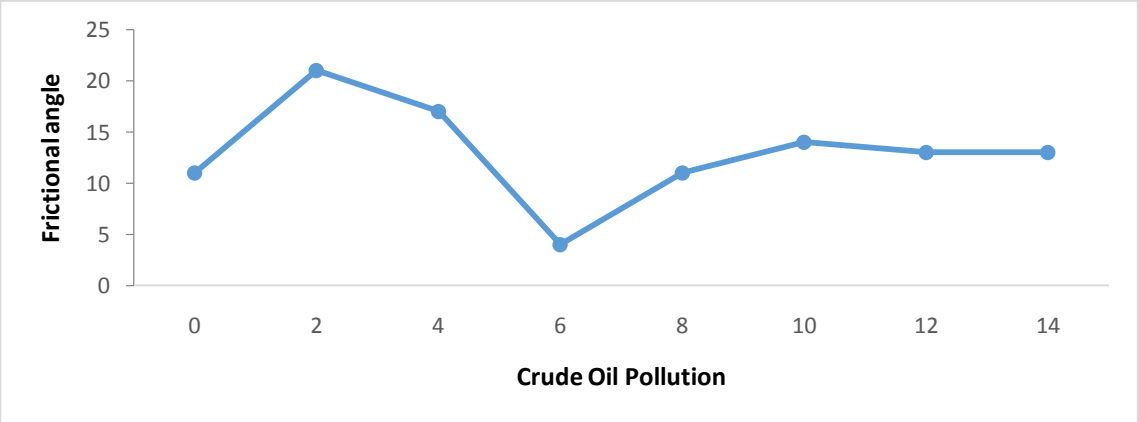

Fig.6 Variation of Friction Angle of polluted clay soil with different concentration of crude oil

The angle of internal friction increased from 11° at 0% to 21° at 2% contamination after which it showed an inconsistent decrease. It decreased from 21^0 to 4^0 at 4% contamination before increasing to 13^0 at 14%

Fig.7 shows the result of Variation of Shear Strength Parameters of polluted clay soil with different concentration of Crude oil

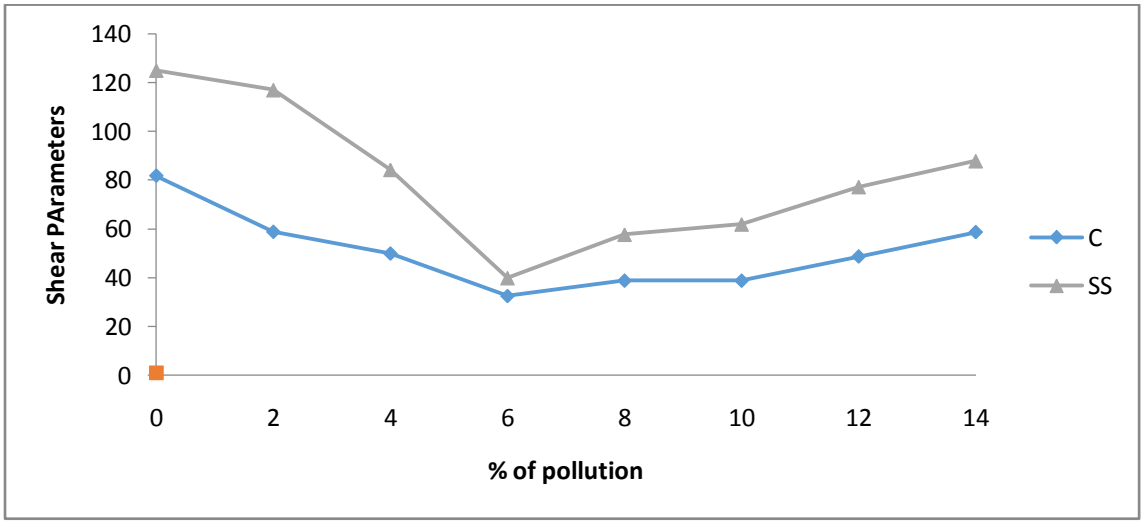

Fig.7 Variation of Shear Strength Parameters of polluted clay soil with different concentration of Crude oil

For clay contaminated with crude oil, the cohesion decreased from 81.93KN/m² at 0% contamination to 48.87KN/m² at 12% and increased again to 58.87KN/m² at 14% contamination. The angle of internal friction increased from 11° at 0% to 21° at 2% contamination after which it showed an inconsistent decrease. The shear strength showed progressiveon decrease from 125.11 KN/m² at 0% contamination to 87.96 KN/m² at 14% contamination. The decrease is a result of lubricating effect of the crude oil. Test specimen used in this study were prepared by mixing soils with contaminants which however forms a different soil structure [4]. Long term contamination showed a reduction in shear strength with decrease in pore dielectric constant. The crude oil decreased the pore fluid viscosity which eventually led to reduction of soil shear strength. The results however are in agreement with the work of [4].

IV. CONCLUSION

Laboratory investigation was carried on both uncontaminated at contaminated samples at different level of contamination 0%, 2%, 4%, 6%, 8%, 10%, 12% and 14%.
CBR, Coefficient of Permeability decreased. Cv, av and S increased as a result of contamination. Shear strength î, Cohesion C decreased while Ø increased.
From the result of this investigation it is not advisable to erect buildings and other Civil Engineering structures on soil contaminated with crude oil without proper geotechnical investigation. This is necessary to establish the level of contamination and carry out necessary remedial measures before such structures can be erected in the site.

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