COMPACTION CHARACTERISTICS OF OIL CONTAMINATED RESIDUAL SOIL

J. R. Oluremi[1*], A. P. Adewuyi[2], A. A. Sanni[3]

[1,3]Department of Civil Engineering, Ladoke Akintola University of Technology, Ogbomoso. Nigeria.
[2]Department of Civil Engineering, Federal University of Agriculture, Abeokuta, Nigeria.

ABSTRACT

Oil spillage during transportation, leakages of underground tanks in fuel stations as well as an indiscriminate spill of spent oil in motor mechanic workshops has increasingly become very prevalent in Nigeria. This study examined the effect of oil contamination on the strength properties of lateritic soil. Crude oil was simulated by rigorously mixing engine oil, diesel, kerosene and gasoline (petrol) together in ratio 1:1:1:1. Lateritic soil samples were artificially contaminated with the simulated crude oil in the range 0% to 8% of the dry weight of soils in a step concentration of 2% and subjected to basic geotechnical laboratory tests using British Standard light (BSL) and West African Standard (WAS) compactive efforts. The results show a gradual increase in the proportion of gravelly formed particles while sand and silt contents decrease with increase in oil content. The plastic and liquid limits of the soils decreased as the crude oil content increased. The maximum dry densities (MDD) decreased from 1.06 to 1.03 mg/m^3 and 1.12 to 1.04 mg/m^3, while optimum moisture content (OMC) increased from 13.12 to 14.8% and 11.8 to 13.3% for both BS and WAS compactive efforts respectively as oil content increased. The unconfined compressive strength (UCS) of samples for both BS and WAS compactive efforts were 239.6 kN/m^2 and 253.8 kN/m^2 respectively and increased with oil content up to 2% and thereafter decreased with further contamination. A significant influence of oil contamination on the engineering properties of soils is evident, and remediation and reuse of contaminated soil are imperative.

KEYWORDS: *Oil contaminated soils; geotechnical tests; lateritic soil; maximum dry density; optimum moisture content; unconfined compressive strength*

1.0 INTRODUCTION

Soil as well as water contamination which could be natural or anthropogenic in nature has been a great threat to both human and terrestrial habitats in all regions of the world. Soil pollution often results from human activities such as natural minerals exploration, direct and indirect discharge of industrial wastes into the body of water and disposal on unsanitary dumpsites and the leaching of wastes from landfill sites.

* Corresponding Email: jroluremi@lautech.edu.ng

Although associated with biological and geochemical cycles, organic and inorganic contaminants concentration in soils are influenced by anthropogenic activities such as natural resources exploration, agricultural practices, industrial activities and waste disposal methods (Ndiokwere & Ezehe, 1990; Zauyah, Julian, Noorhafizh, Fauzih, & Rosemani, 2004; Usman, Shu'aibu, & Ayodele, 2002; Eja, Ogri, & Rikpo, 2003; Ebong, Etuk, & Johnson, 2007). More importantly, soil contaminations from accidental spillage of oil, leakages of underground storage facilities, indiscriminate dumping of residues from atomic power generating plants and excessive use of agricultural inputs such as herbicides and fertilizers. Consequentially, contaminated soil has been classified as solid waste of non hazardous type (Meegoda, Huang & Mueller, 1992) as well as hazardous waste depending on the nature of the wastes. It is thus of greater concern not only to the environmentalists and hydrologists but also to geotechnical engineers.

Environmental pollution has caused unprecedented depletion of human, terrestrial and aquatic lives and vegetation through the ingestion of contaminated surface and groundwater, inhalation of its particulate matter, dermal contact with chemical wastes, eye sour and irritation from its gaseous emission, highly toxic land. Pollutants commonly found as a source of pollution to eco-system include but not limited to hydrocarbons, halogenated organic compounds, non-chlorinated pesticides and herbicides, nitrogen compounds and radionuclide and heavy metals such as lead, nickel, chromium, arsenic, mercury and zinc. Furthermore, notable sources of pollution to soils in Nigeria are the heavy metals, petrochemical hydrocarbons, herbicides and pesticides. The 1998 National Quality Survey of EPA revealed that the most frequent chemical indicators for the highest level of sediment contamination were polychlorinated biphenyls (PCBs), mercury, organochlorine pesticides, and polycyclic aromatic hydrocarbon (PAHs), with PCBs and PAHs being the most frequent. These chemicals are very toxic, tend to bioaccumulate in fatty tissues and are mostly derivative of crude oil. It is estimated that several million pounds of PCBs have entered the environment worldwide during the 50 years of its production (Abramowitz, Harkness, McDermott & Salvo, 1992).

Crude oil, which is a complex mixture of n-alkanes, aromatic hydrocarbons and non-hydrocarbon compounds such as polar fractions with hetero-atoms of nitrogen, sulphur and oxygen (NSO) and asphaltenes, has stood out as one of the resources of economic importance. While its discovery contributes immensely to the economic development of the host nation, the environmental degradation of the components of eco-system through its exploration, production and processing, transportation and storage poses a threat to human and natural environments. Hydrocarbon liquid percolates and infiltrates into the soil pores under gravity during exploration, spills, and leakage thereby saturating the soil in its pathway and thereafter reaches the underground water (Pamukcu & Hijazi, 1992). The liquid further spreads laterally once it reaches the groundwater within the capillary layer of the vadoze zone of the ground soil.

In Nigeria, recurring contamination of its soil, creeks, swamps, river and streams has been on the increase due to increase in petroleum exploration and refining activities coupled with other operations of petroleum companies in Niger Delta region of Nigeria (Okpowasili, 1996; Onifade, Abubakar, & Ekundayo, 2007). Oil bunkering and vandalization of pipelines are also other major sources of the oil spill. A total of 2005 oil spill incidents were reported in Nigeria by oil companies between 1976 and 1986 with an estimated total quantity of oil spilled being 2,038,711 barrels (Ifeadi & Nwankwo, 1987).

Figure 1(a) and 1(b) show the nature of crude oil contaminated soil resulting from the oil spill in Eleme township of Eleme Local Government Area of River State.

Figure 1(a). Crude oil contamination of soil at Eleme L. G. A., Porthacourt, Nigeria. Source: Oluremi and Osuolale (2014)

Figure 1(b). Crude oil contaminated soil and vegetation at Eleme L. G. A., Porthacourt, Nigeria. Source: Oluremi and Osuolale (2014)

The UN Environment Programme (UNEP) has announced that Shell and other oil firms systematically contaminated a 1,000 sq km (386 sq mile) area of Ogoni land, in the Niger Delta (Vidal, 2011). Consequently, the Niger Delta is now rated as one of the most polluted places in the world (Jadin, 2010). One major construction material in civil engineering is soil commonly used as the foundational structure for buildings, roads, embankments and dam construction. Therefore, it is necessary to assess the influence of oil on its geotechnical properties so as to determine the suitability of such contaminated soil as civil engineering construction materials.

Oluremi and Osuolale (2014) carried out an extensive review of the applicability of oil contaminated soil as materials for civil engineering construction works. Extensive investigations have been reported on the effect of oil contamination on the geotechnical properties of soils (Meegoda & Ratnaweera, 1994; Al-Sanad & Ismael, 1997; Ratnaweera & Meegoda, 2006; Mashalah, Amir & Majid, 2007; Vipulanandan & Elesvwarapu, 2008). The influence of oil contamination on the geotechnical properties of basaltic residual soil by artificially contaminating the soil with engine oil in a step-wise concentration of 4% of the dry weight of soil sample was studied by Rahman, Hamzah, Taha, Ithnain and Ahmad, (2010a). It was discovered that oil contamination enhanced the liquid and plastic limits of the soil with a remarkable reduction in the maximum dry density (MDD) and optimum moisture content (OMC) of the soil compared to uncontaminated soil. Al-Sanad *et al.*, (1995) and Al-Sanad and Ismael (1997) investigated Kuwaiti sand contaminated with crude oil. The results showed an increase in compressibility and reduction in angle of internal friction (ϕ) from 32° to 30° for specimens prepared at a relative density of 60% and mixed with 6% of heavy crude oil which correspond to 25% reduction in the bearing capacity. However, geotechnical investigation of oil contaminated soil in Nigeria has not been greatly explored.

This paper, therefore seeks to investigate the impact of oil contamination on the geotechnical properties of residual soil in Nigeria. The study is imperative because of the continual contamination of soil as a result of the spillage of petroleum products due to tanker accidents during transport, leakages of underground storage tanks in fuel stations and even oil spillage during exploration and processing of petroleum.

2.0 MATERIALS AND METHODS

2.1 Materials

The material used in this research work were lateritic soil and oil formed by mixing engine lubricating oil, diesel, kerosene and gasoline (petrol) together.

2.1.1 Sample collection

The soil sample used was a disturbed lateritic soil obtained from a borrow pit at Oniyan Village, a suburb of Ogbomoso, in Surulere Local Government, Southwestern Nigeria on longitude 4° 17′60″E and latitude 8° 0′0″N and at an altitude 455 m. The borrow pit is a fill material source for the on-going Federal Highway construction project of Ogbomoso-Ejigbo Road. The oil used for the artificial contamination of soil sample in this study was simulated as a mixture of four petroleum products namely engine lubricating oil, diesel, kerosene and gasoline (petrol) obtained from a fuel station and mixed together in equal proportions of 1:1:1:1. The simulated concept was employed because direct access to crude oil was denied, not even officially for experimental purpose, due to the security situation within the oil producing regions of Nigeria's Niger Delta to check the unethical exploration, theft and indiscriminate possession.

2.1.2 Samples preparation

The soil sample was air-dried, pulverized to break down soil aggregations and sieved through BS Sieve 5.6 mm aperture because the specified BS Sieve No 4 (4.76 mm aperture) was not available. A 40 kg of soil sample was weighed into five buckets each. The soil sample in each bucket was thoroughly mixed with the oil at the stepwise concentration of 2% in the range 0% to 8%. The mixtures were then left for at least two weeks to achieve oil saturated homogeneous mixtures (Megoda, Chen, Gunasekara & Pederson, 1998).

2.2 Methods

Key engineering properties such as particle size analysis, Atterberg limits, compaction, and unconfined compressive strength (UCS) tests for each soil sample were determined in accordance with BS 1377 (1990) and Head (1980). The soil samples were completely used within three months of collection to avoid alteration of its properties which might result from long time storage.

2.2.1 Particle size distribution analysis

Sieve analysis was carried out on each of the oil contaminated samples to assess the impact of the oil content on the aggregation of the soil particles before and after contamination.

2.2.2 Atterberg limits

Atterberg limits test were carried out in accordance with British Standards BS 1377 and BS 1924 respectively to determine the index properties of the virgin soil and 2% to 8% oil contaminated soil.

2.2.3 Compaction

British Standard Light (BSL) and West African Standards (WAS) or 'Intermediate' compactive efforts were employed to determine the moisture–density relationships of the prepared samples. The British Standard Light (BSL) is generally achieved on the field globally, while West African Standard (WAS) is an effort adaptable to West African region because of the nature of the soil. British Standard light is an energy obtained by using 27 blows of 2.5 kg rammer dropped from 300 mm height on each of the three layers of soil sample placed inside a 1000 cm^3 mould, while West African Standard is a compactive effort exerted by using 10 blows of 4.5 kg rammer from 450 mm height on each of the five layers of soil sample placed inside a 1000 cm^3 mould. Samples were prepared for compaction by mixing predetermined quantity of oil contaminated soil with the appropriate quantity of water inside a tray and then compacted at selected and desirable energy level in order to obtain its moisture-density relationship.

2.2.4 Strength characteristics

California bearing ratio (CBR) and UCS tests are two most common tests for evaluating the strength of the soil. Although UCS test is more popular, it is not the most appropriate for all cases of soil strength determination (Osinubi, 2006). UCS test was employed in this study because of the relative ease of experimentation and timely determination of soil strength.

3.0 RESULTS AND DISCUSSION

3.1 Sieve analysis

Figure 2 presents the particle size distribution for the virgin and oil contaminated soil samples. The particle size distribution showed that the percentage of gravel present in the lateritic soil increases with increase in crude oil contamination. This is due to aggregation of the particles in the soil with oil acting as a binding agent to form larger silt-like size materials similar to the trend observed by (Rahman et al., 2010b; Ijimdiya, 2013). The proportion of clay and silt material decreased with oil contamination from 46.1, 45.0, 43.9, 39.2 and 36.5% for 0% to 8% oil contamination respectively.

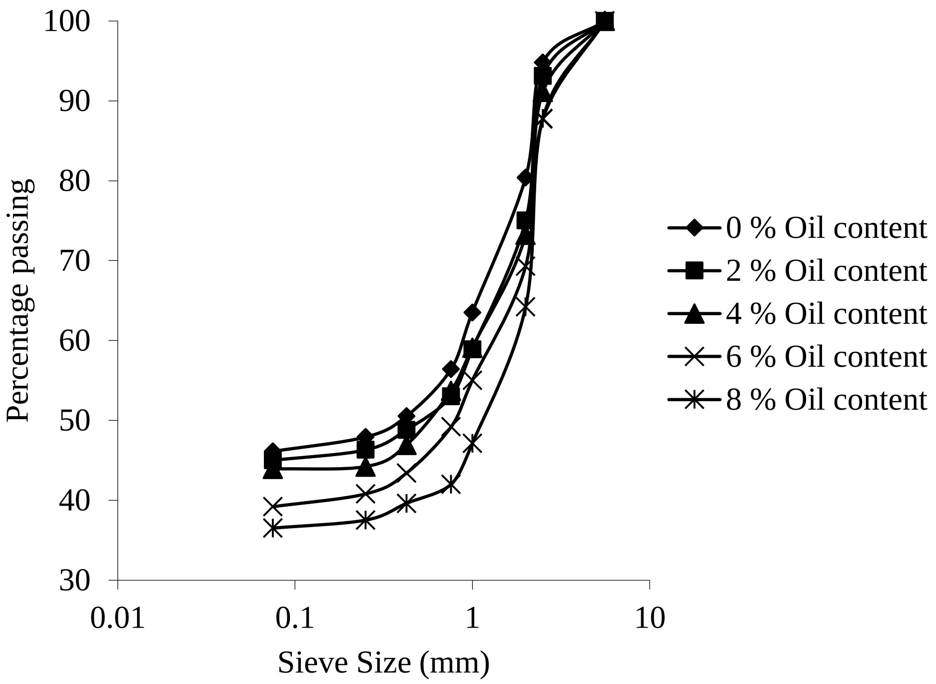

Figure 2. Particle size distribution for both virgin and oil contaminated soil

3.2 Atterberg limits

Figure 3 presents the relation between the consistency indices from Atterberg limit tests with varying oil content. The liquid limit (LL) and plastic limit (PL) were highest for the virgin soil and decreased as the oil content in the contaminated soil increased. It is quite evident that the plasticity index (PI) was at its peak at 2% oil content and decreased almost linearly for 4% to 8% oil contents. These trends of results were similar to (Al-Mashhidani, 1999; Rasool, 1999; Zulfahmi et al., 2010) on the investigation of the effect of hydrocarbon products contamination on the geotechnical properties of soils. Their results showed that a decrease in both liquid limit and plastic limit with the increase in oil content.

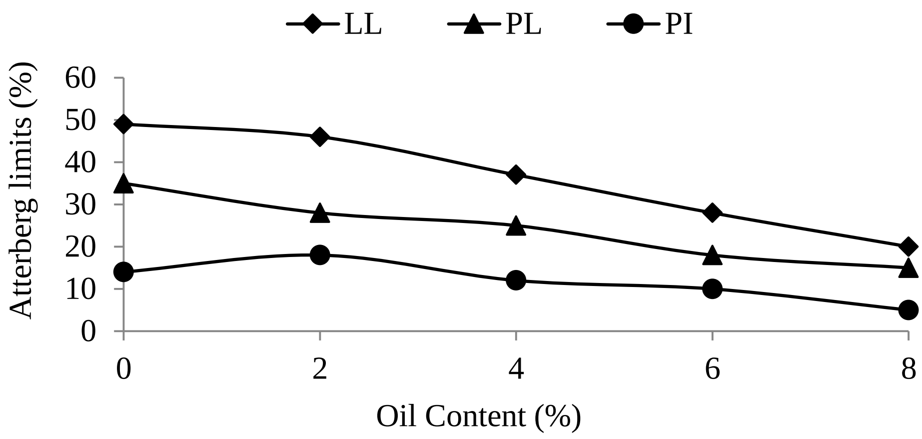

Figure 3. Variation of consistency indices with oil content

Similar results were obtained in (Al-Baoey, 2011; Abbawi, et al., 2013) on laboratory testing program of fine grained soil from AL- Samawa- Depot site contaminated with crude oil. However, a contrary result was obtained in (Habib et al., 2007; Rahman et al., 2010b) on the study the geotechnical behaviour of oil contaminated fine-grained soils in which case there is an increase in the atterberg limits value with the increase in crude oil content.

3.3 Compaction tests

As typified in Figures 4a and 4b, the dry density of the samples reduced with the increase in the oil content for both compactive energy used. The MDD of the samples decreased in a decreasing order for both BSL and WAS compactive efforts. However, the OMC increased in a decreasing order for the BSL, but increasing order for the WAS as the oil contamination contents increased.

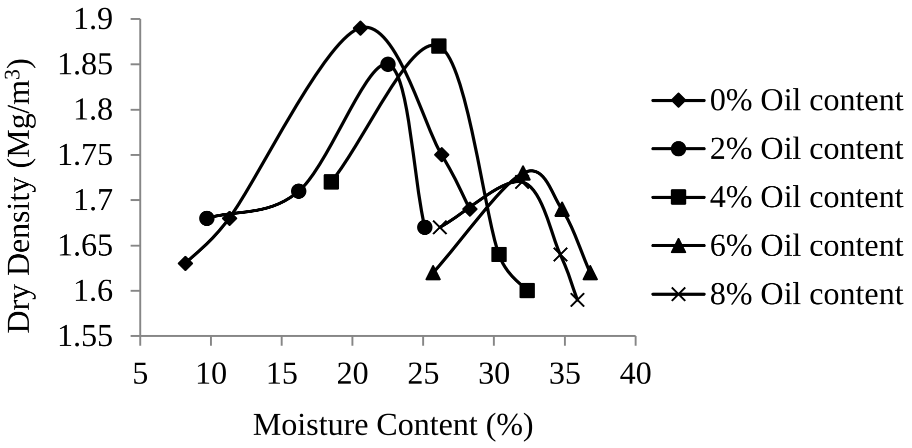

Figure 4(a). Compaction characteristics of soils with varying oil contents for BSL

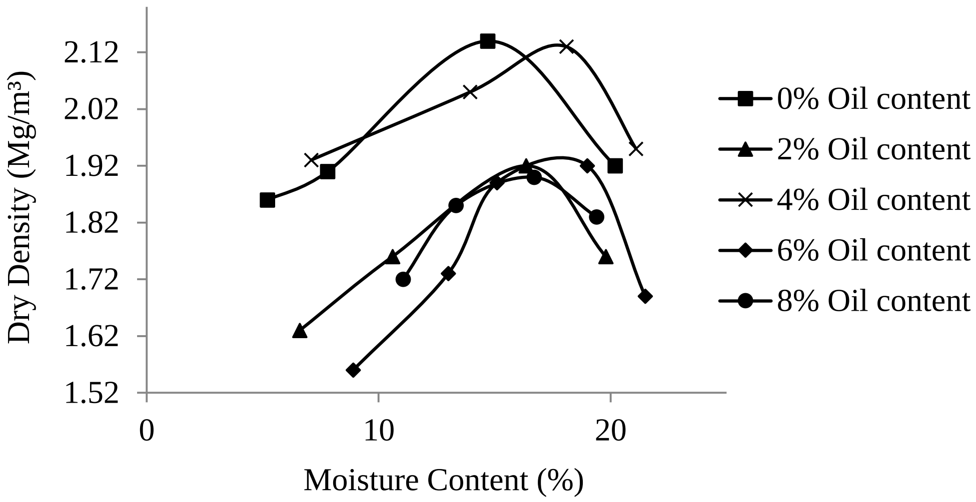

Figure 4(b). Compaction characteristics of soils with varying oil contents for WAS

From Figures 4c and 4d respectively, peak MDD of 1.06 and 1.12 kg/dm³ were attained for the natural soil (0 % oil contamination) with corresponding OMC of 11.8 and 13.13 % for both BSL and WAS respectively. It is quite obvious that the soil samples have almost the same MDD for both BSL and WAS at 8 % contamination level. Minimum MDD of 1.04 kg/dm³ was observed for 8 % contamination with the corresponding OMC of 14.3% and 14.8% for both BSL and WAS respectively.

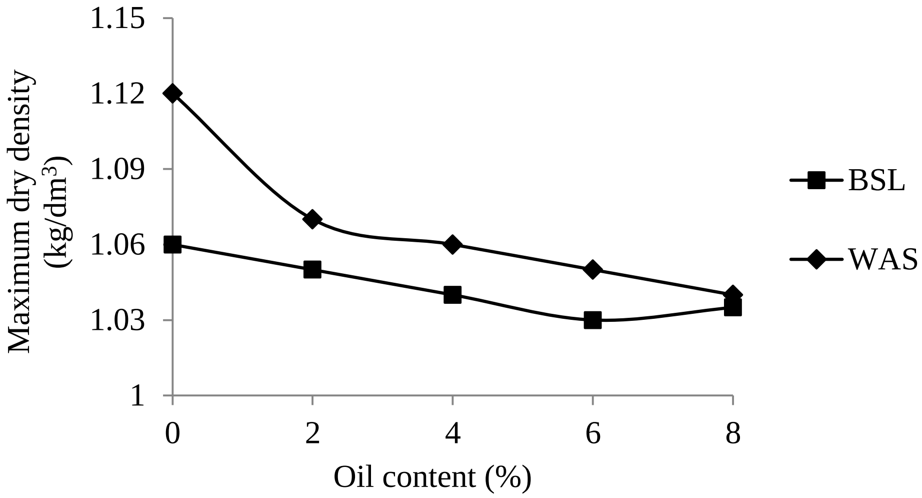

Figure 4(c). Variation of maximum dry density with varying oil contents

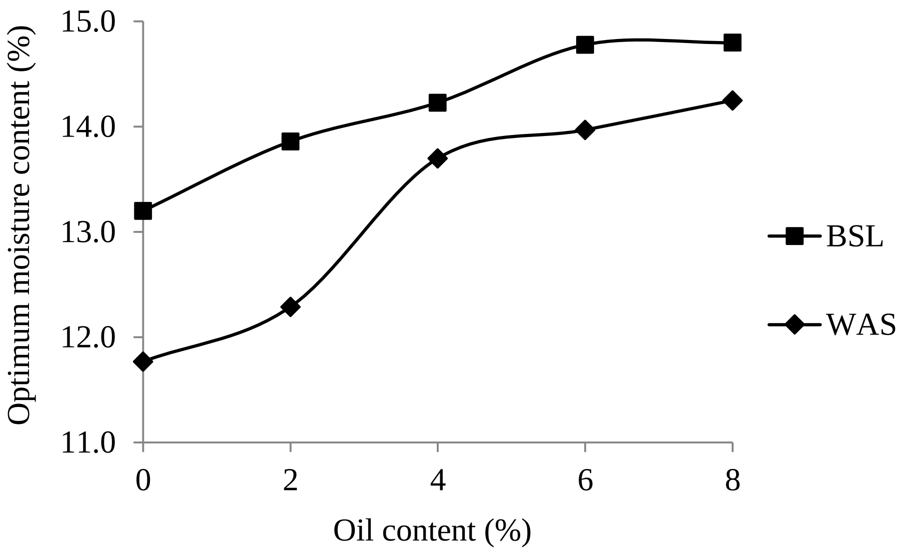

Figure 4(d). Variation of optimum moisture content with varying oil contents

The results agree with Vipulanandan and Elesvwarapu (2008) and Rahman et al., (2010a). The reduction in the MDD could be attributed to the slipperiness of the soil particles over one another, which reduces interparticle bonding due to the lubricating nature as the oil content increases. It might also result from the alteration of the morphological state of the clay minerals which act as the binding medium in the soil. The soil structure becomes dispersed in the presence of polar organic liquids which consequently reduce the MDD (Meegoda et al., 1998). Although a polar inorganic substance was used as moulding agent, the presence of oil which differs in and of high viscosity as a lubricant compared to water mask the effect of water with the insulation effect of the oil film around the soil particles as the oil content increases such that the soil particles could not bond together to produce aggregates of higher density.

3.4 Strength characteristics

The unconfined compressive strength of the samples started increasing with increase in oil content up till 2% after which it began to decrease with further oil content increment as shown in Figure 5 below for both compactive efforts used in this study. The increase in strength at the onsets of the trend could result from the agglomeration of the soil particles bonded together by oil film to form a larger but weakly bonded soil matrix which initially resisted the impact of the loading but thereafter failed with increase in oil content which has weaken the interstitial force of cohesion between the particles of the soil., Al-Sanad et al., (1995); Khamehchiyan et al., (2007); Ijimdiya, (2007, 2013) and Mashalah et al., (2006) acknowledge the same trend of results in their various studies. Zulfahmi, Umar and Mohd, (2010) also found that hydrocarbon contaminated soil give a lower unconfined compressive strength than that of uncontaminated except that no peak strength is gained with the increase in oil content as it was observed with 2 % in this study. This might be due to the differences in the morphological characteristics of the studied soils. In the same vein, Ratnaweera and Meegoda (2006) attributed the observed reduction in shear strength and stress-strain behaviour of low plastic and high plastic clays to a combination of two mechanisms: (i) reduction in frictional properties at particle contacts resulting from changes in mineral-pore fluid-mineral interaction which might be due to the lubrication occurring at particle contacts leading to a reduction in maximum past consolidation pressure. This can be quantified as a function of pore fluid viscosity, (ii) changes in the physicochemical interaction which results from changes in the dielectric constant of the pore fluid.

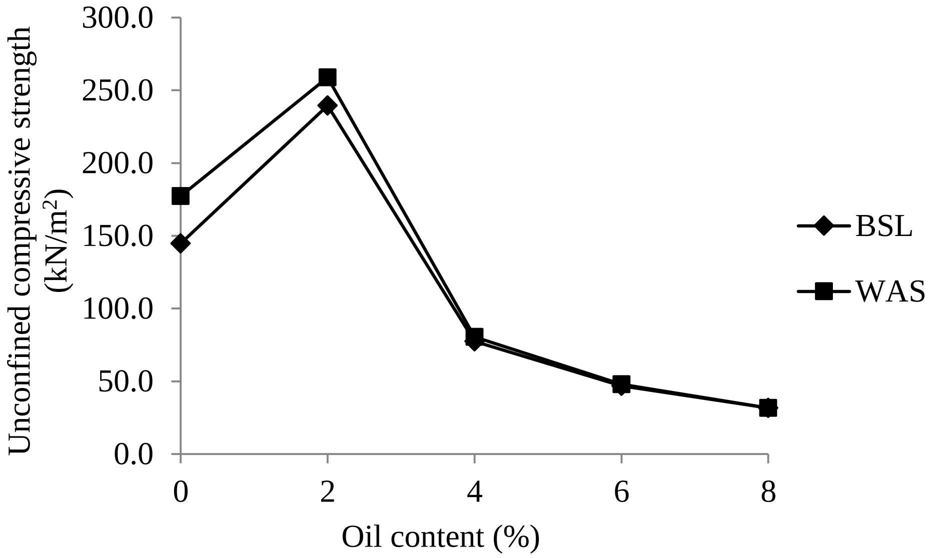

Figure 5. Variation of unconfined compressive strength with oil content

4.0 CONCLUSION

As observed from the results of this study, although the consistency index of the soil was improved by the addition of the oil as contaminant especially at 2% contamination, the dry density of the soil samples were drastically reduced due to loss of potency for strong bond within soil matrix. This also results in the reduction in the strength parameter of the soil especially UCS. It is apparent that presence of crude oil or any of its fractionally distilled products exceeding 2% of the total soil mass has a negative impact on the geotechnical properties and consequently limits its usage as civil engineering construction material.

REFERENCES

Abbawi, Z. W., Al-Soudany, K. Y. & Al-Recaby, M. K. (2013). Assessment of bearing capacity of subbase contaminated with kerosene. *Engineering and Technology Journal.* 31, Part (A), (19): 159-172.

Al-Baoey, T. A. A. (2011). Effect of crude oil contamination on geotechnical properties of fine grained soil, (Unpublised M.Sc. Thesis). Building and Construction Department, University of Technology, Iraq.

Al-Mashhidani, H. A. A. (1999). Effect of petroleum products on permeability of clayey soils of normal and high swelling potential, (Unpublised M.Sc. Thesis). College of Engineering, University of Baghdad, Iraq.

Al-Sanad, H. A. & Ismael N. F. (1997). Aging effect on oil-contaminated Kuwait sand. *Journal Geotechnical and Geoenvironmental Engineering.* 123 (3): 290 – 293.

Al-Sanad, H. A., Eid, W. K. & Ismael N. F. (1995). geotechnical properties of oil-contaminated Kuwait sand. *Journal Geotechnical Engineering,* 121 (5): 407 – 412.

BS 1377 (1990). *Method of testing soils for civil engineering purpose*. British Standard Institute, BSI, London.

BS 1924 (1990). *Method of test for stabilized soils.* British Standard Institute BSI London.

Ebong, G. A., Etuk, H. S. & Johnson, A. S. (2007). Heavy metals accumulation by talinum.triangulare grown on waste dumpsites in Uyo metropolis Akwa Ibom state." *Nigerian Journal of Applied Sciences.* 7 (10): 1404 –1409.

Eja, M.E., Ogri, O. R. A. & Rikpo, G. E. (2003). bioconcentration of heavy metals in surface sediments from the Great Kwa River Estuary, Calabar, Southern Nigeria. *Journal of Nigerian Environmental Society.* 1: 247–256.

General Electric Company Corporate Research and Development (1992). *Final Report* on 1991 In situ Hudson river research study: a field study on biodegradation of pcbs in Hudson river sediments: Abramowictz, D. A., Harkness, M. R., McDermott, J. B., & Salvo, J. J.

Habib, U. R., Abduljauwad, S. N. & Akram, T. (2007). Geotechnical behaviour of oil-contaminated fine grained soils. Journal of Electrical and Geology Engineering. 12. Retrieved from http://www.ejge.com/2007/JourTOC12A.htm.

Head, K. H. (1980). *Manual of soil laboratory testing.* Vol. 1: Soil classification and compaction., London Plymouth, Pentech Press.

Ifeadi, C.N. & Nwankwo, J.N. (1987), Critical analysis of oil spill incidents in Nigerian petroleum industry. Seminar Proceedings of Petroleum Industry and the Nigerian Environment. FMNH and NNPC, Lagos. 104–114.

Ijimdiya, T.S. (2007). Effect of oil contamination on soil properties. 5th Nigerian Material Congress, NIMACON 2007, November, Ile-Ife, Osun State.

Ijimdiya, T.S. (2013). The effects of oil contamination on the consolidation properties of lateritic soil. *Development and Applications of Oceanic Engineering (DAOE)* 2 (2): 53-59.

Jardin**,** X. (2010). More oil spilled in Nigeria every year than has been lost in the Gulf of Mexico. Retrived from http://boingboing.net/2010/06/14/more-oil-spilled-in.html.

Khamehchiyan, H. M., Hossein, A. A. & Tajik, R. A, (2007). Effect of crude oil contamination on geotechnical properties of clayey and sandy soils. *Journal of Engineering Geology,* 89 (3-4): 220-229.

Mashalah K., Amir H. C.& Majid, T. (2006). The effects of crude oil contamination on geotechnical properties of Bushehr coastal soils in Iran. *The Geological Society of London. IAEG2006 Paper number 214.*

Meegoda, N. J., Huang, D. R., DeBose, B., & Mueller, R. T. (1992). Use of Petroleum Contaminated Soils in Asphalt Concrete, In: Kostecki, P. T. Calabrese, E. J. and Bonazountas, M. (Eds.) *Hydrocarbon Contaminated Soils*. CRC Press.

Meegoda, N.J. & Ratnaweera P. (1994). Compressibility of contaminated fine grained soils. *Geotechnical Testing Journal,* 17 (1): 101 – 112.

Meegoda, N.J., Chen, B., Gunasekara, S.D. & Pederson, P. (1998). Compaction characteristics of contaminated soils – Reuse as a road base material. *Recycled Materials in Geotechnical Applications*, GSP 79, ASCE, 195-209.

Ndiokwere, C. C.& Ezehe, C. (1990). The occurrence of heavy metals in the vicinity of industrial complexes in Nigeria. *Environmental International,* 16: 291-295.

Okpowasili, G. C. (1996). Microbial degradation of petroleum hydrocarbon by brackish water isolates in Nigeria wetlands. In: Akpata, T.V.I.& Aven Okoli (Ed.), *The Nigeria Man and the Biosphere.* (M.AB-5) National Committee, 138 – 146.

Oluremi, J. R.& Osuolale, O. M. (2014). Oil contaminated soil as potential applicable material in civil engineering construction. *Journal of Environment and Earth Science,* (4) 10: 87 – 99.

Onifade, A. K., Abubakar, F. A.& Ekundayo, F. O. (2007). Bioremediation of crude oil polluted soil in the Niger Delta area of Nigeria using enhanced natural attenuation. *Research Journal of Applied Science,* 2 (4): 498 – 504.

Osinubi, K. J. (2006). Influence of compactive efforts on lime-slag treated tropical black clay *Journal of Materials in Civil Engineering, ASCE.* 18, (2): 175-181.

Pamukcu, S. & Hijazi, H., 1992. Grouting, soil improvement and geosynthetics. *Geotechnical Special Publication,* New York, 345.

Rahman, A. Z., Hamzah, U., Taha, M. R., Ithnain, N. S. & Ahmad, N. (2010a). Influence of oil contamination on geotechnical properties of basaltic residual soil. *American Journal of Applied Sciences* 7 (7): 954-961.

Rahman, A. Z., Umar, H., & Ahmed, N., (2010b). Geotechnical characteristics of oil contaminated granitic and metasedimentary soils. *Asian Journal of Applied Science,* 3: 273-249.

Rasool, H. A. (1999). Some geotechnical properties of oil contaminated soil. (Unpublished M.Sc. Thesis). College of Engineering, University of Baghdad, Iraq.

Ratnaweera P. & Meegoda, N. J. (2006). Shear strength and stress- strain behaviour of contaminated soils. *Geotechnical Testing Journal,* 29 (2): 133 – 140.

Usman, O. A., Shu'aibu, U. A. & Ayodele J. T. (2002). Bioaccumulation of four heavy metals in leaves of clotropis procera. *Journal of Chemical Society of Nigeria,* 27: 26-27.

Vidal, J. (2011) Niger delta oil spills clean-up will take 30 years, says UN. The Guardian Newspaper Retrieved from http://www.theguardian.com/environment/2011/aug/04/niger-delta-oil-spill-clean-up-un**.**

Vipulanandan, C. & Elesvwarapu, P. (2008). Index Properties and Compaction Characteristics of Contaminated Clayed Soil *Proceeding of GeoCongress: Geotechnics of Waste Management and Remediation.*

Zauyah, S. B., Julian, R., Noorhafizh, Fauzih, C. I. & Rosemani, B. (2004). "Concentration and speciation of heavy metals in some cultivated and uncultivated utisols and inceptisls in peninsular Malaysia supersoil." *3rd Australian New Zealand Soils Conference,* University of Sydney, Australia.

Zulfahmi, A. R., Umar, H. & Mohd, R. T. (2010). Influence of oil contaminated on Geotechnical properties of basaltic residual soil. *American Journal of Applied Science,* 7: 954-961.