Effect of Crude Oil Pollution on Some Geotechnical Properties of Disturbed Sandy Soil

Abir Ahmed Elazzabi
abirelazabi@gmail.com

Department of Civil Engineering, Collage of Engineering, Tripoli

ABSTRACT: Recently, the effects of soil pollution with crude oil have received much attention from many researchers. Most of the results showed contradictions in their results because of adding crude oil to the soil. Some of the results showed an increase in the maximum dry density while other results indicated a decrease as well as for the shear resistance. The present study seeks further research to evaluate the physical and mechanical properties of loose sandy soils contaminated with crude oil obtained from the Nalut region in southwestern Libya.
The soil samples used in this research were classified according to the Unified Soil Classification System (USCS) as poor graded sandy soil (SP.) And were classified (A-3) according to the American Association of Highway and Transportation Officials for Classifying Soil System (AASHTO).
The contaminated material is crude oil from Abu Al-Tifl field located in Gallo city. The soil was polluted in a laboratory by manually mixing the soil with the pollutant material in percentages (10, 7, 4) of the dry soil weight after the soil was well mixed with the pollutant and after confirming the uniformity of the distribution The pollutant was in the soil and left for three days in closed containers to study the effect of crude oil on the physical and mechanical properties of the soil by conducting conventional tests to measure these properties and through the results of laboratory tests showed that crude oil has a great effect on some properties and little effect on other properties.
As the increase in the pollutant percentage in the soil led to a slight effect on the specific gravity, while there is a significant effect on the permeability coefficient as it decreased with the increase in the percentage of pollutant, the optimum water content also decreased and the maximum dry density increased with the increase in the percentage of pollutant, while the value of the California Bearing Ratio (CBR) increased at 4% and then starts to decrease as the crude oil increases.

KEY WORDS:
Crude Oil Specific Gravity Permeability Shear Strength Maximum Dry Density

1. INTRODUCTION:

The correct design of any engineering facility requires adequate knowledge of the engineering properties of the soil and its effect on the surrounding conditions in addition to knowledge of its impact on the materials presented to it from different sources, which is very important in determining the change that occurs to its engineering properties and among the most likely of these materials to seep into the soil and penetrate it is Crude oil and its derivatives and their high percentages of hydrocarbons, as hydrocarbon leakage and spillage has become a major concern in most oil-producing countries in the world, as oil pollution of the soil is responsible for the majority of soil pollution with hydrocarbons [1].
The impact of these leaks and spills on the environment cannot be overlooked, as they are considered a geo-environmental problem that negatively hinders the quality of soil, groundwater and the atmosphere. Crude oil, or one of its products, when it seeps into the soil through the unsaturated area under the influence of the forces of gravity and capillary property, and through

the pores, a part of it is kept there where it adheres to the soil particles, while the remaining part reaches the groundwater level, causing water pollution. The evaporation of the remainder in the atmosphere pollutes the air, vegetation, etc. [2, 3].
Soil pollution above a certain level causes the loss of some geotechnical soil properties, so the problem is complicated by the arrival of the effects of pollution to the soil supporting the foundations and working to weaken it, i.e. losing some of the bearing capacity of the soil and its effect appears in the form of deformations in parts of the structures and sometimes leads to collapse as a result of cavities in the event of neglect and lack of control. Therefore, it is important to determine the effects of soil pollution based on existing structures. This change also has a far-reaching impact on the proposed structures that the polluted soil must support. It can lead to structural or functional collapse of existing structures, especially when pollution causes a significant increase in soil plasticity; Loss of bearing capacity; increasing subsidence, and / or preventing drainage of water or other fluids.
For the proposed structures, this could cause abandonment of the site with the contaminated soil, a decrease in the project potential, or an increase in the project cost. This cost is represented in geotechnical and chemical analyzes of the soil to determine the extent of its contamination, and the deterministic choice of the most stable type of structural foundation or the cost of applying techniques Soil remediation or stabilization. However, the use of some previously verified wastes as soil stabilizers - marble powder [4], steel slag [5,6], modified asphalt pavement (reclaimed asphalt pavement) [7]- May reduce the percentage increase in project cost for proposed facilities on contaminated soil.
In most cases, petroleum hydrocarbons are accidentally caused by an oil spill during transport as a leak from pipelines and storage tanks, or during oil drilling operations, so an oil spill can be considered an inevitable consequence. And the lack of static electrical systems that would protect the tank structures and pipelines from corrosion, and if any, they may not receive follow-up and periodic tests to ensure their efficiency is one of the biggest causes of oil spillage or one of its derivatives into the soil, an example of this is the pipeline transporting oil derivatives linking the Zawiya oil depot.(Which feeds from the Zawiya refinery for oil refining) and the Tripoli oil depot, the airport road of the Brega Oil Marketing Company, where a leakage of this pipeline occurred in the Ghiran area, Janzour, in front of the General Water Authority building, as it negatively affected the water wells in the area and some drops occurred in some unpaved places from here The idea of research came, in addition to the fact that all the oil fields in Libya are located in the center and south of the country and the export ports are on the Libyan coast in the north of the country, which makes the pipelines to transport crude oil from the far south to the far north and it is known that the northern region of the country has 80% of the population. It makes it capable of reconstruction and construction in the future. From here came the idea of studying the effect of studying crude oil on the soil to avoid any future problems in the foundations.
In order for the treatment of the leakage problem to be based on scientific foundations, it is necessary to first study the effect of these fluids on the engineering properties of the soil in preparation for proposing treatment and fixing methods.

2. REVIW OF LITERATURE:

Researchers have reported that the engineering properties of oil-polluted soils are radically altered and make them unsuitable to support engineering facilities, while others have pointed to the idea that soil pollution with an appropriate proportion of crude oil or its products will modify some geotechnical properties of soil.

During a study conducted in India that pollutant containing percentages of petroleum derivatives lead to reducing soil resistance. Also stabilizing this soil by using a number of stabilizers, including cement, in addition to a mixture of other compositions, and the soil showed a remarkable improvement in its properties [8].

It is investigated the effects of four types of pollutants on the geotechnical properties of clay soils. Pollutants are kerosene, ammonium nitrate, copper and lead. Then each one of them was mixed with the soil at rates of 10% and 25%. The results showed various effects of these pollutants on the geotechnical characteristics of clay soil [9].

The effect of diesel oil on the geotechnical properties of soil has been studied. The results of this study showed that the addition of diesel oil has an effect on the geotechnical properties of the studied soil samples [10]. The effects of petroleum hydrocarbons on the geotechnical properties of clay soil samples were investigated, and the results showed several effects on the geotechnical properties of soil samples [11].

Also, some oil derivatives such as emulsified asphalt and containing large quantities of solvents such as (gasoline and kerosene) have studied its effect on the soil and proved the possibility of using it as an improved (proven) substance for some engineering properties, where it was found that the cohesion value of soil increases with increasing percentage The asphalt emulsion then decreases with the increase in the ratio from its optimum value, and the internal angle of friction was found to decrease because these materials work to reduce the friction between the particles) [12,13].

A presentation was made on the use of industrial water containing petroleum products in road layering, as it was used as an additive for well-graded sandy soil, and the study showed improvement in most of the engineering properties of soil [14].

The effect of three types of petroleum derivatives ranging from 0% to 6% on sand has been studied. It was found that the bearing capacity is greatly affected as a result of the shear effect. Soil parameters [15].

The amount of increase in the concentration of benzene in the soil as a result of leakage from the oil pipelines has been studied. It was found that the concentration of benzene increased by about 800 to 5000 times the amount of concentration before the leakage, and that this increase was the cause of many construction problems as a result of the differential decrease. In the foundations [16].

The effect of crude oil contamination on compacting sand properties has been studied and it is concluded that when using crude oil as a porous liquid, the maximum unit weight of dry sand was about 6 percent higher compared to water as a porous liquid. The explanation for this is that the oil is more effective in reducing the friction between soil particles resulting in reduced spacing between soil particles; Thus increasing the dry unit weight at a certain compaction effort. The maximum shear strength, internal friction angle, is found to decrease with increasing oil saturation. They concluded by increasing the relative density of sand with the increase in the viscosity of the petroleum pollutant [17].

The effect of crude oil on the geotechnical properties of Kuwaiti sand has been studied, and it has been concluded that the compressibility of sand as a result of adding crude oil was improved by adding oil by up to 4% by weight. The permeability coefficient decreased by 20% and the internal friction angle decreased when the oil was added [18].

The effect of residual basalt soil pollution with motor oil on the geotechnical properties of soil has been studied[19]. The effect of diesel oil pollution on the microstructural changes of clay soil has also been studied [20].

The effect of contamination of clay soil with methanol, ethanol, isopropyl alcohol, and acetic acid on plasticity, consolidation, and shear resistance has been investigated. [21] Laboratory studies were conducted to determine the effect of crude oil contamination on laterite soils on shear resistance [22].

The effect of crude oil contamination has been studied on the plasticity and compression properties and other of geotechnical properties of loose soils, but their results were different, making it difficult to obtain a general description of the effect of crude oil contamination on clay soils [23].

3. MATERIALS:

3.1 WATER: Distilled water was used in this research, except for the compaction test, which used regular water.

3.2 SOIL The soil used in this study was Collected from depth of 50cm below natural ground surface from the Nalut region in southwestern Libya It is a sandy soil that has been classified according to the Unified Soil Classification System (USCS) as (PS) and (A-3) according to the American Association of Highway and Transportation Officials of Soil System (AASHTO), table 1 shows the natural properties of the soil. And Figure 1 shows the results of the sieve analysis test for soil free of contamination.

Table 1: Physical and engineering properties of tested soil

Properties of soil	Values	Specification
Physical Properties		
M.C (%)	1.5%	(ASTMD-2216)
G.S	2.645	(ASTM C 127).
Classification of soil (AASHTO)	A-3	AASHTO T99-01
Classification of soil (USCS)	SP	(ASTMD-2487)
Engineering Properties		
Unsoked CBR (%)	17%	(ASTM D1883-16)
K (cm/sec)	0.043	(ASTM D 2434-68).
Max Dry Density (gm/cm^3)	1.84	(ASTM D698-12).
C(KN/m2), Ø	0KN/m^2, 31.09°	(ASTM D3080).

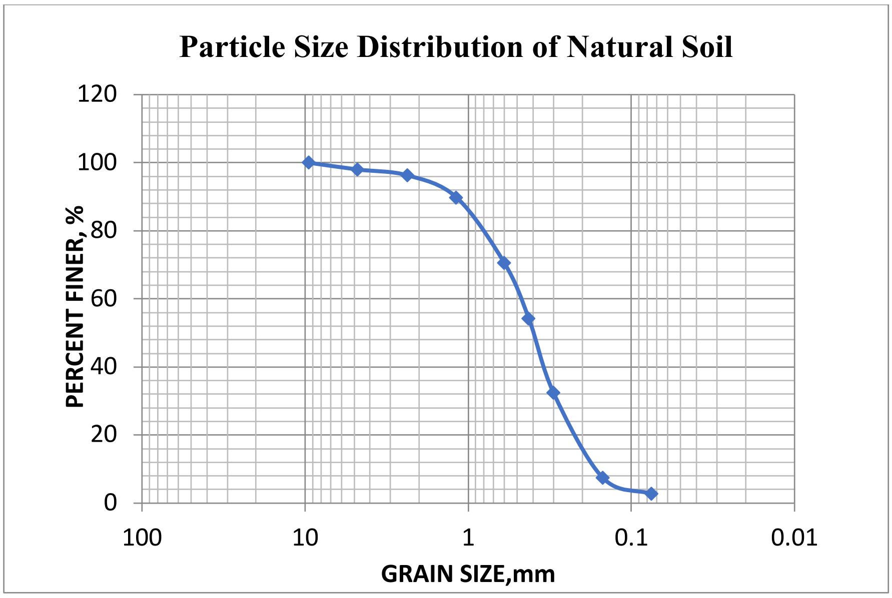

Figure 1: Grain size distribution for the tested soil

3.3 CRUDE OIL (ADDITIVE SUBSTANCE)

Some properties of Crude Oil of Buattifel field are shown in Table2. The analysis of Buattifel crude oil sample was carried out using well recognized standard procedures given in ASTM .IP and UOP methods.

Table2: Physical and chemical properties of Buattifel crude oil:

DESCRIPTION	VALUES	METHOD
Density @ 15C° , g/ml	0.8121	ASTM D-4052
Specific gravity@60/60 15F°	0.8129	Calculation
API gravity	42.6	Calculation
Kinematic viscosity @210 F°	2.1512	ASTM D-445

4. METHODOLOGY:

The soil sample was divided into four parts. Crude oil added to each of the parts in 0%, 4%, 7%, and 10% proportions by dry weight of the soil sample, respectively. The soil-crude oil mixtures were thoroughly mixed manually and stored in closed containers for three days to ensure full absorption of contaminants into the soil. A set of laboratory tests carried out on the uncontaminated (0% crude oil content) soil sample and contaminated (4%, 7%, and 10% crude oil contents) soil samples. The procedures for laboratory tests were according to the specifications of the American Society for Testing and Materials (ASTM), the following tests are:

Soil Physical Tests

These included specific gravity test, and Sieve analysis test.

Soil Engineering Tests

These included standard compaction test, direct shear test, unsoaked California bearing ratio test, and permeability test.

5. RESULTS AND DISCUTIONS:

We have conducted a set of laboratory tests on both natural and polluted sandy soil samples by adding crude oil in different proportions (4%, 7%, 10%), and the results as shown in table3:

Table 3: The characteristics of the soils contaminated with crude oil

Property		Max Dry Density	Gs	O.M.C	CBR	K	Ø	C
		gm/cm^3	-	%	%	cm/sec	°	KN/m^2
specification		(ASTM D698-12).	(ASTM- C127).	(ASTM D698-12).	(ASTM D1883-16)	(ASTM D 2434-68).	(ASTM D3080 -11)	(ASTM D3080 -11).
Pollution percentage	0%	1.83	2.645	12.93	17	0.0426	31.09°	0
	4%	1.855	2.279	11.1	19.74	0.0298	26.09°	17.28
	7%	1.86	2.288	8.3	13	0.0087	27.75°	1.84
	10%	1.863	2.184	8.5	10.15	0.0074	4.00°	8.09

5.1 RESULTS OF SPECIFIC GRAVITY TEST:

A graphical illustration of the results of specific gravity tests on the soil admixed with varying percentages of crude oil content is presented in Figure 2. The specific gravities of the contaminated soil samples were found to be lower than that of the uncontaminated soil sample. As the crude oil content in the soil increased, the specific gravity of the contaminated soil progressively decreased. This is attributed to the lower specific gravity of the crude oil**.**

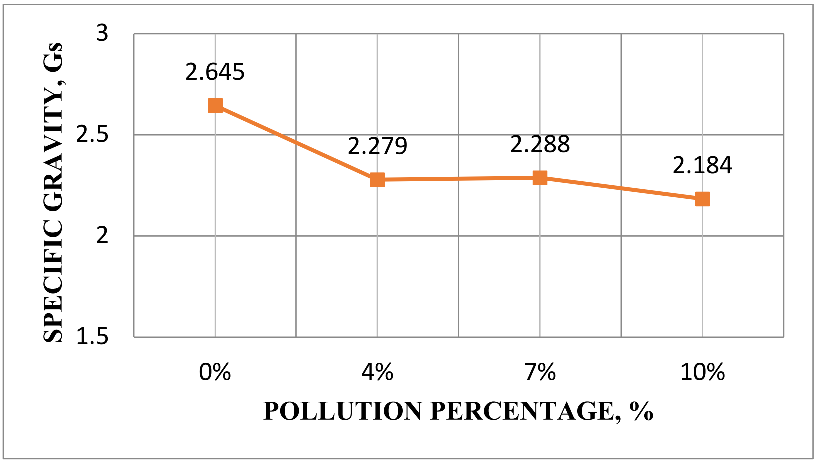

Figure 2: Variation of specific gravity with oil content

5.2 RESULTS OF STANDARD COMPACTION TEST:

The results of the standard compaction test on the soil samples are presented in Figure 3. As crude oil content in the contaminated soil increased, the optimum moisture content (OMC) of the soil decreased and the maximum dry density of the soil increased. The explanation for this is that the oil is more effective in reducing the friction between soil particles resulting in reduced spacing between soil particles; Thus increasing the dry density at a certain compaction effort.

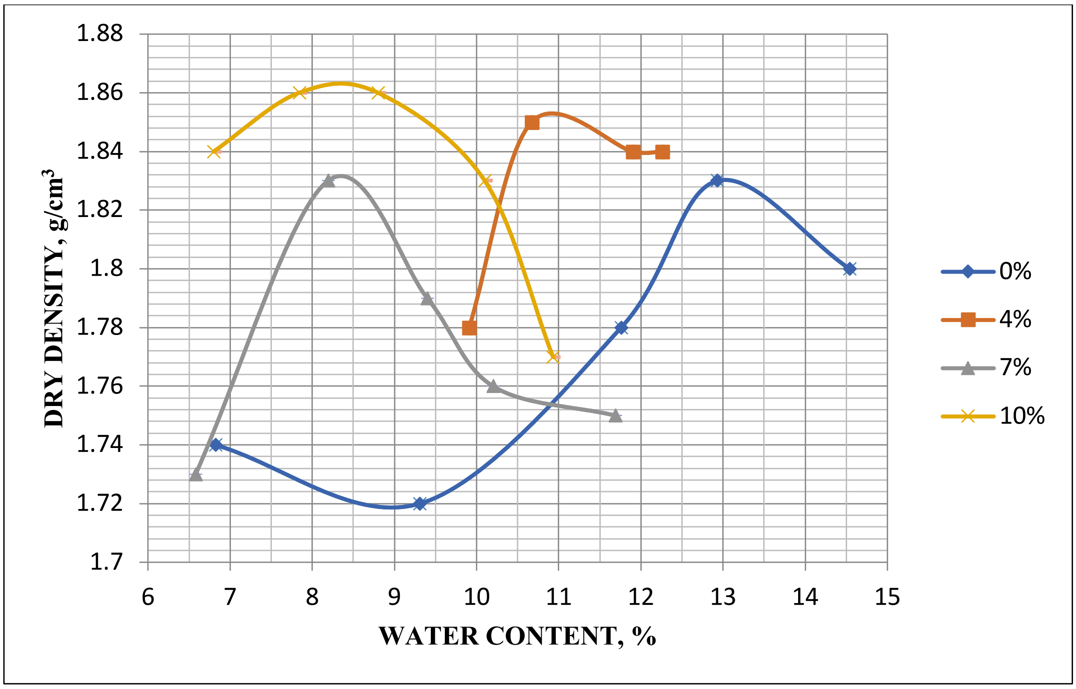

Figure 3: Variation of optimum moisture content and maximum dry density with oil content

5.3 RESULTS OF DIRECT SHEAR TEST:

The results of the Direct shear test for all proportions of contaminated and free of contamination soils are shown in table 4.When studying the table, it was found that the highest value of the internal friction angle when contaminated was 0%, reaching 31.09º), and the lowest value of the internal friction angle was 10%, which is (24.0º). And the highest value for soil cohesion when contaminated was 4%, reaching (17.28KN/m²), and the lowest for soil cohesion by 0%, reaching (0 KN/m²).

Table 4: Results of the direct shear test with oil content

Property					
Normal stress, σ KN/m²		Shear stress, τ KN/m²			
		Pollution percentage			
		0%	4%	7%	10%
136.25		**61.78**	**86.060**	**66.200**	**69.51**
272.5		161.09	152.261	163.294	133.504
408.75		226.18	219.564	208.53	189.774
parameters	C, **KN/m²**	0	17.28	1.84	8.09
	Φ	31.09	26	27.75	24

5.4 RESULTS OF CALIFORNIA BEARING RATIO TEST:

The differences in unsoaked CBR values for soil with the addition of varying percentages of crude oil are graphically illustrated in Figure 4 and illustrated as a percentage of crude oil in soil, the unsoaked CBR increased slightly and subsequently decreased. The slight increase in the proportion of unsoaked CBR in contaminated soil is thought to have resulted from agglomeration of sand particles facilitated by crude oil, which may have caused an increase in the shear resistance between particles of the soil. The decrease in the non-soaked CBR after adding 4% crude oil indicates that the addition of 4% crude oil is to reduce the increase in the shear strength between the particles. In addition to adding 4% of the crude oil, the lubricating effect of the oil is thought to cause easy soil particles to slide over each other, which represents the decrease in the unsoaked CBR.

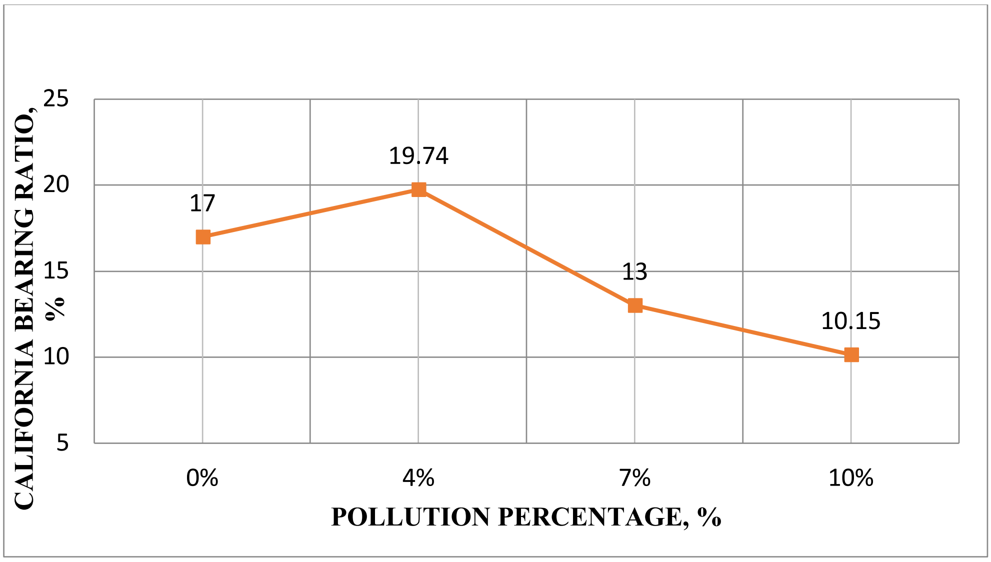

Figure 4: Variation of unsoaked CBR with oil content

5.5 RESULTS OF PERMEABILITY TEST:

A graphical illustration of the results of the permeability tests on the soil admixed with varying percentages of crude oil content is presented in Figure 5. As the crude oil content increased, the permeability of the contaminated soil decreased. Crude oil becomes entrapped in the pore spaces that forms the pathway for water within the contaminated soil and consequently, reduced the pore sizes. The decrease in the permeability of the contaminated soil is attributed to the reduction in the pore space.

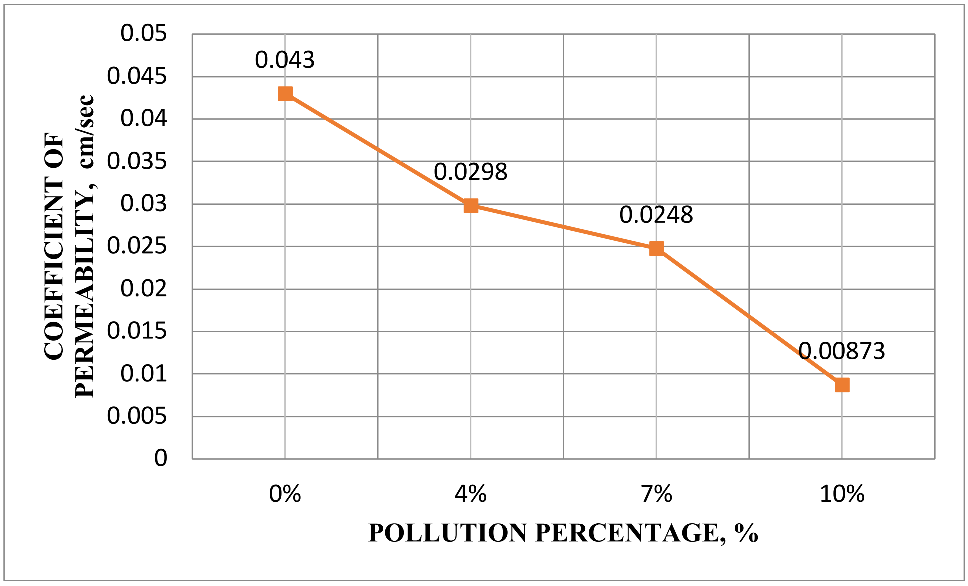

Figure 5: Variation of permeability with oil content

6. CONCLUSIONS AND RECOMENDATIONS:

6.1 CONCLUSIONS:

As a result of the test program that was conducted in this study and the discussions, the following can be concluded:

1. Oil contamination of soil affects the physical properties of soil, as its specific gravity decreased with an increase in the percentage of contamination by crude oil.
2. The compaction tests showed that the increase in the oil content led to an increase in the maximum dry density and a decrease in the optimum water content. The explanation increased the maximum dry density is that the oil is more effective in reducing the friction between soil particles resulting in reduced spacing between soil particles; Thus increasing the dry density at a certain compaction effort.
3. The unsoaked CBR of the soil increases to a certain extent, so its highest value is at 4% of the pollutant. After that, a decrease occurs with an increase in the percentage of crude oil in the soil.
4. A similar behavior was also observed on cohesion (C)) when crude oil was increased to a certain limit, so the highest value was at 4% of pollution, and the lowest value was at 0% of pollution. While the internal friction angle (Ø) decreases with the increase in the proportion of crude oil.
5. Adding crude oil to the soil reduced its permeability, which is due to the confinement of crude oil inside the soil pores. The highest permeability value was when the soil was free of pollution and the lowest value was obtained at 10% of pollution.

6.2 RECOMMENDATIONS:

1. To obtain an effective soil treatment with positive results, it is preferable to start working on soil improvement immediately after stopping the leakage.
2. Since the viscosity of oil and some of its other properties varies according to the different places of exploration and exploration, from field to field and from one region to another according to the materials that the oil is made of over hundreds of years, the change in viscosity may have different effects on the properties of the polluted soil.
3. Construction is not recommended on untreated polluted soils due to the change in its properties.

7. ACKNOWLEDGMENT:

We thank Al-Alya Engineering and Technical Consulting Company for the assistance of sample preparation and soil testing.

6. REFERENCES:

[1] American Petroleum Institute, Sampling and analysis of gasoline range organics in soils. American Petroleum Institute Publication, No. 45 16, 1991.1.5

[2] Hinchee, R.E. and Olfenbuttel, R.F. Butterworth-Heinemann, in Situ Bioreclamation: Application and Investigations for Hydrocarbon and Contaminated Site Remediation. Ed. by. London. pp. 125-142.

[3] Dineen. D., Slater, J.P., Jicks, P. and Holland, In situ biological remediation of petroleum hydrocarbons in unsaturated soils, Hydrocarbon Contaminated Soil and Ground Water: Analysis, Fate, Environmental and Public Health Effects, Remediation. Ed by Kostecki, P.T. and Calabrese, E.J. Vol. 1. Lewis Publishers, Chelsea, Mich., pp. 177-187, 1990.

[4]Okagbue, C. O., and Onyeobi, T. U. S. 1999. Potential of marble dust to stabilise red tropical soils for road construction. Engineering Geology, 53, 371-380. DOI:10.1016/S0013-7952(99)00036-8

[5] Akinwumi, I. I., Adeyeri, J. B., Ejohwomu, O. A. 2012. Effects of steel slag addition on the plasticity, strength and permeability of a lateritic soil. Proceedings of Second International Conference on Sustainable Design, Engineering and Construction, ASCE, Texas, pp.457-464. DOI:10.1061/9780784412688.055

[6] Akinwumi, I. I. 2012. Utilization of steel slag for stabilization of a lateritic soil. M.Eng. Dissertation, Covenant University, Ota.
[7] Akinwumi, I. I. 2014. Plasticity, strength and permeability of reclaimed asphalt pavement and lateritic soil blends. International Journal of Scientific and Engineering Research, 5(6), pp.631-636.
[8] Sanjay J.Shah, Shroff A.V, Jignesh v., Tiwari K.C. & Ramakrishnan D.(2002)"Stabilization of Fuel Oil Contaminated Soil"Journal of Geotechnical &Geological Engineering,Vol.21,No.4.
[9] Karkush, M. O, Zaboon, A. T. and Hussien, H. M., 2013, Studying the effects of contamination on the geotechnical properties of clayey soil, Coupled Phenomena in Environmental Geotechnics, Taylor & Francis Group, London, pp. 599-607.
[10] George, S., EA, A., Sabu, B., NP, K. and George, M., 2015, Effect of diesel oil on the geotechnical properties of soil, International Journal of Civil and Structural Engineering Research, Vol. 2, No. 2, PP. 113-117.
[11] Al-Harbawy, A.F.Q (2002)"The effect of Emulsified Asphalt on Some Engineering Properties for Expansive Soil" M.Sc. Thesis, Department of Civil Engineering, College of Engineering, Mosul University Iraq..
[12] Ingles O. G. & Matcalf J.B. (1972)"Soil Stabilization Principle & Practice).
[13] Ramzi Taha, Amer Al-Rawas, Salim Al-Oraimi, Hossom Hassan& Mohammed Al-Aghbari (2005)"The Use of Brackish &Oil Contaminated Water in Road Construction" Environmental &Engineering Geoscience, Vol.11,No.2.
[14] Das. B.M & Eun chal shin (2001)"Bearing Capacity of(- 111 - (Unsaturated Oil-Contaminated Sand" International Journal of Off share &Polar Engineering ,Vol.11, No.3.
[15] Yong R.N ,Taheri E. ,Khodadai a.(2007)"Evaluation of Remediation Methods for Soil Contaminated with Benzo" International Journal of environmental research ,Vol.1,No.4.
[16] Purj, V.K., B.M. Das, E.C. Cook and E.C. Shin, "Geotechnical Properties of Crude Oil- Contaminated Sand". ASTM Special Technical Publication, 1221, 7 Y 5-88, 1994.
[17] H. Al-Sanad, W.K. Eid, and N.F. Ismael, "Geotechnical Properties of Oil- Contaminated Kuwait Sand", Journal of Geotechnical Engineering, No. 5, Vol. 121, pp. 407-412, May 1995.
[18] Rahman, Z. A., Hamzah, U., and Taha, M. R., 2010, Influence of oil contamination on geotechnical properties of basaltic residual soil, American Journal of Applied Sciences, Vol. 7, No. 7, PP. 954–961.
[19] Izdebska-Mucha, D., and Trzcinski, J. 2008. Effects of petroleum pollution on clay soil microstructure. Geologija,50 Supplement P),S68-S74. DOI: 10.2478/V10056 -008-0027-0
[20] Olgun, M., and Yildiz, M. 2010. Effect of organic fluids on the geotechnical behavior of a highly plastic clayey soil. Applied Clay Science, DOI: 10.1016/clay .2010.03.015.
[21] Oyegbile, O. B., and Ayininuola, G. M. 2013. Laboratory studies on the influence of crude oil spillage on lateritic soil shear strength: A case study of Niger Delta Area of Nigeria. Journal of Earth Science and Geotechnical Engineering, 3(2), pp.73-83.
[22] Khamehchiyan, M., Charkhabi, A. M., and Tajik, M., 2007, Effects of crude oil contamination on geotechnical properties of clayey and sandy soils, Engineering Geology, Vol. 89, PP. 220-229.
[23].Kermani, M., and Ebadi, T. 2012. The effect of oil contamination on the geotechnical properties of fine-grained soils. Soil and Sediment Contamination, DOI:10.1080/15320383.2012.672486.
[24] "Chemical and Physical Properties of Crude Oils", www.nap.edu, Retrieved 28-9-2018. Edited.
[25] Anne Marie (2018-3-23)، " Chemical Composition of Petroleum. Thoughtco Retrieved 2018-7-14. Edited.