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Investigation of Clayey and Sandy Soil Characteristics Polluted with Crude Oil

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ABSTRACT

The focusing in this study was on the contaminated-uncontaminated soils' properties which studied by performing experimental tests included, Atterberg's limit, specific gravity, compaction, unconfined compression, and direct shear tests. Different % of crude oil was used in the contaminated soils which are performed by mixing the soils using different percent of were oil of 3 %, 6 % and 9 % by dry weight. The main effect of oil contamination causes a reduction in the liquid and plastic limit values for clayey soil. Besides oil contamination gives a reduction in the maximum dry unit weight as well as a decreasing the optimum water content with comparison to original soil (clayey and sandy soil). The angle of internal friction is decreased for sand while it increases for clay is one of oil contamination results.

1- Introduction

The main causes of soil contamination are due to damaged pipelines, transportation's facilities of petroleum, the tankers' incidents, during drillers operations, the container's rust, and during leak process. This urged to study and determines the oil contamination affecting on structures. A laboratory testing was performed by [1]. on the cohesive and cohesionless soils (clay and sand) from the Persian Gulf to investigate how soil properties have been affected by oil contamination. The testing program included liquid and plastic limit, compaction, direct shear, uniaxial compression, and permeability by use a same density of cleanly and polluted soil samples.

Reference [2]. their study focuses on the main effect of oil contamination on the soils properties on weathered basaltic soils. They found that the Atterberg's limits of polluted soils were less that the native soils. The increasing of oil content reduces the maximum dry density and optimum water content. The coefficient of permeability and the strength of soils were reduced in weathered soils. A reducing in undrained shear strength "Cu" was noticed in basaltic soils as oil contamination percentage increased to 4%.

A similar study carried out on the soil (soft clay) of the "Niger Delta region of Nigeria" has been examined by [3] according to the laboratory study by comparing the physical properties of the native and contaminated soft clays. The results revealed that crude oil causes a 17.9% increase in the Liquid limit and 6.9% causes an increase in Plastic limit "PL" so consequently "Plasticity index" PI increases by 37.5%. The crude oil contamination of soft clay leads to a remarkable increasing in the maximum dry density and a lowering in the optimum water content.

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Reference [4] used fine-grand soils in the study and they found that the properties have effected by crude oil, friction angle, maximum dry density, compression index, and Atterberg limits increased while there is a reducing in the optimum water content as the contamination content increasing.

Reference [5]used kaolinite polluted by gas oil. The samples were prepared by mixing the soils with crude oil using different percentages corresponding 2%, 4%, 8%, 12%, and 16% by dry weight. The main finding that there is an increasing in the coherence and a decreasing in friction angle, the compressibility of kaolinitic soils as the contamination percentage increased.

Also, they find that there is a reduction in the strength, maximum dry density, optimum water content, permeability, and Atterberg's limits.

Reference [6] use different gradation size of soil to study how the geotechnical and soil physical properties have effected by oil pollution. The Authors used three types of soils (SP, CL, ML) poorly graded sand, clay with low plastic material and silt with low plasticity. The main conclusion was drawn that as the gas oil ratio increased, the recorded indicated coherence increased, whiles decreasing in the angle of friction. In addition, can be noticed that the maximum dry density and optimum water content reduced. Gas oil increasing has a direct impact on increasing of liquid and plastic limits of clay and silt soils.

Reference [7] used fine, coarse-grained soil and evaluated the alteration of the properties including "Specific Gravity, Liquid Limit, Plastic Limit, and Shrinkage Limit". This behavior is due to the structure of the soil's particles and high permeability of coarse-grained soil leads to the seepage of oil at a higher rate compared to that of clayey soil which has low permeability and thus is less affected by the crude oil. So as the rate of seepage increases the penetration of crude oil increase this increment causes the deterioration of the soils 'properties for both clayey and sandy soils.

2- Materials and Methods

2-1 Soil's Properties

Two types of soils were used in this study; the first soil used was brought from Al- Nahrawan city (23 km) east of Baghdad city. The soil consists of 2% sand, 38% silt and 60% clay. The properties for clayey and sandy soils are listed in Tables 1 and 2. Distributions of the grain size with percentage passing of used soils are shown in Figure 1.

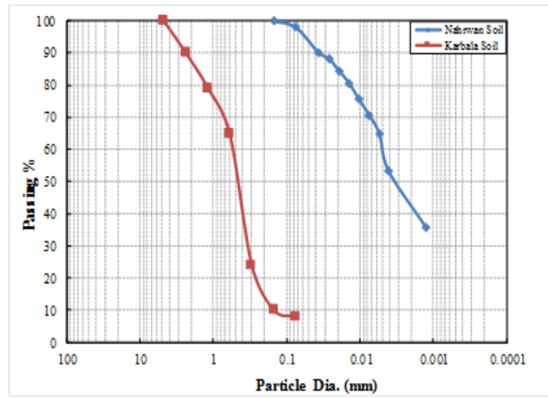


Figure 1. Distribution of size.

Table 1. The physical and chemical properties of natural clayey soils.

`	Index property	Index Value	Specification
Atterberg limits	Liquid limit, L.L (%)	43	ASTM D [8]
	Plastic limit, P.L (%)	22	
	Shrinkage limit, S.L (%)	27	
	Plasticity index, P.I (%)	21	
Grain size analysis	% sand (0.075-2) mm	2	ASTM D [9]
	% silt (0.005-0.06) mm	38	
	% clay (< 0.005) mm	60	
Activity	-	0.45	ASTM D [8]
Specific gravity	Gs	2.69	ASTM [10]
Compaction test	Max. dry unit weight (kN/m^3)	17.1	ASTM D [11]
	Optimum water content, (%)	17	

Table 2. Sand properties

Index property	Index Value	Specification
Specific gravity	2.65	ASTM D [10]
D10(mm)	0.148	ASTM D [9]

D30(mm)	0.35	ASTM D [12]
D60(mm)	0.58	
Uniformity Coefficient (Cu)	3.91	
Curvature Coefficient (Cc)	1.42	
The maximum Void ratio	0.7	
The minimum Void ratio	0.4	
The maximum dry unit weight (kN/m³)	18.9	ASTM D[13]
The minimum dry unit weight (kN/m³)	15.56	ASTM D[14]
Soil classification(USCS)	SP	

2-2 Properties of the crude oil

The oil is obtained from Al-Samawa depot. Table 3 shows the properties of the crude oil which were performed by the Ministry of Oil.

Table 3. The properties of Crude oil (strategy line-Basra)

Index Properties	Value
API @60ºF	28-32.4
Density @ 15º C gm/cm³	0.879-0.859
Density @ 50º C gm/cm³	0.868
Water & Sediment Vol %	0.1-0.05
RVP kg/cm³	0.4-0.34
Specific Gravity @ 60ºF and 15.6ºC	0.832
Viscosity @ 10ºC	24.1
Viscosity @ 21ºC	18.2
Viscosity @ 50ºC	7.8

2-3 Sample preparation

The sample dried by an oven and mixed manually with crude oil using "0, 3, 6 and 9%" according to dry soil weight. The samples had been put in container and locked for 14 days foragaing and equilibrium.

2-4 Control tests

To calculate the actual moisture content of the contaminated samples, the percentage losses of crude oil at 105 ºC must be determined. To do this, samples were put in an oven (105 ºC – 110 ºC) and by daily checked the percentages of losses. This process was continued until the sample's weight became constant. These results are shown clearly in Figure 2.

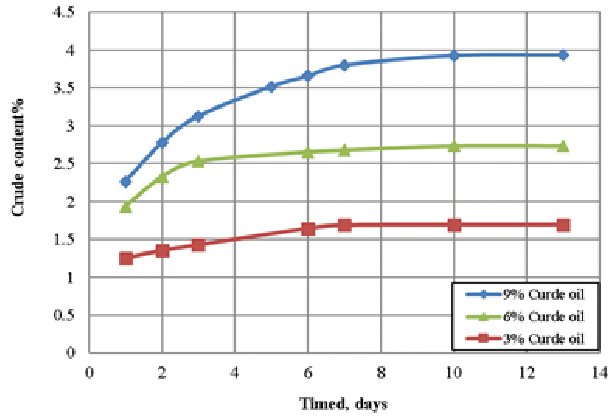
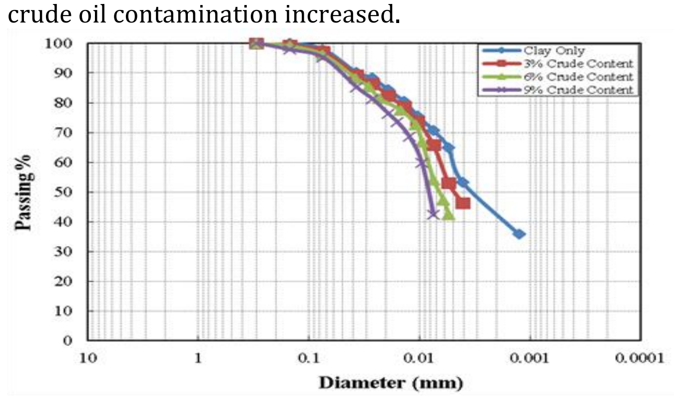


Figure 2. Time of drying versus crude oil losses.

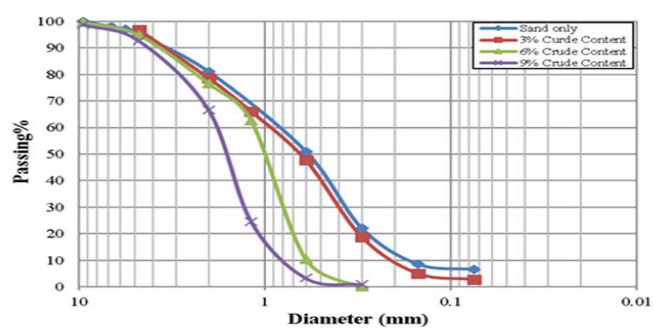
3- Results and Discussion

3-1 Distribution of grain size

As shown in the figure 3 the distributions of grain size before and after contamination. There was alteration in soil's particles gradation with increasing in crude oil as revealed in results. The clayey and sandy soils become courses as % of crude oil contamination increased.



a) Clay soil



b) Sand soil

Figure 3. Grain size distribution curves for contaminated and clean soil.

3-2 Specific gravity

Reference [10] was used to find the specific gravity of clean and contaminated soils. Figure 4 shows the variation of specific gravity of clayey and sandy soil and contaminated soil sample, The results indicated that as the contamination percentage increased from 0 to 9%, the specific gravity reduced from 2.69 to 2.64 for clayey soil and from 2.65 to 2.57 for sandy soil. This behavior is as a result of low values of specific gravity of crude oil.

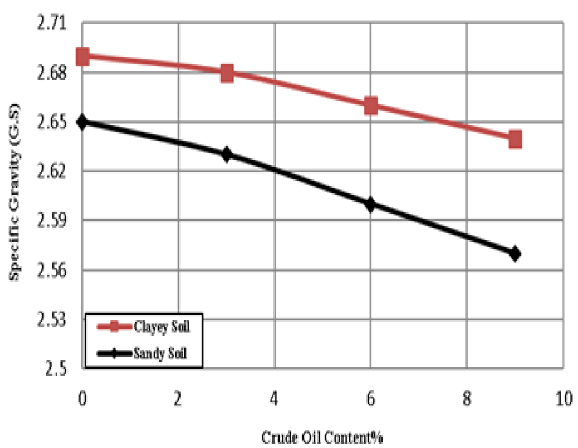


Figure 4. Specific gravity of soil versus crude oil content.

3-3 Atterberg's limits

The Atterberg's limits of the contaminated soil with different % of crude oil (3%, 6%, and 9%) were conducted to study the effect of contamination % on the plasticity characteristic of clayey soil. Figures 5-7 show the change L.L. (Liquid limit), P.L.(plastic limit) and PI (plasticity index)with contamination % in the clayey soil.

It is seen that as the crude oil contamination increased from increased from 0 to 9% the L.L.(Liquid Limit) , P.L.(Plastic Limit) and PI (Plasticity Index) decreased by 26.4%, 24%, and 31.2% respectively. This is clearly shown in Figure 6. This behavior is in general because of crude oil contamination which causes a decrement in the moisture content of L.L. and P.L. The presence of water around the charged clay particles lessen as no polarized liquid of oil occupies the soil. The results are compatible with experimental results by [1] who mentions, that a decrease in the liquid limit , plastic limit, and plasticity index occurs as oil contamination increase in clay with low plasticity (CL).

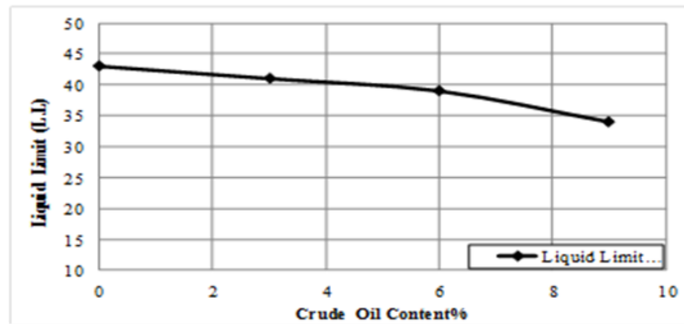


Figure 5. Liquid limit of clayey soil versus crude oil content.

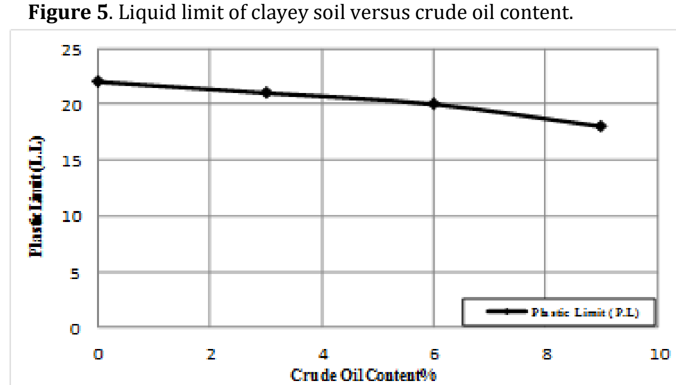


Figure 6. Plastic limit of clayey soil versus crude oil content.

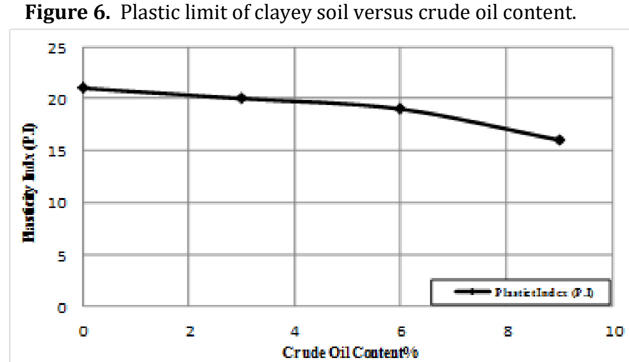


Figure 7. Plasticity index of clayey soil versus crude oil content.

3-4 Compaction test

Procter compaction (standard) test was performed on the contaminated clean clayey and sandy soil according to 11. The results are shown in Figures 8 and 9. It can be noticed that the contaminated compaction curve moved to left the unpolluted curve as crude oil percentages increased. Figures 10 and 11 show the effect of crude oil on the maximum dry unit weight and optimum moisture content respectively. The dry unit weight decreased from 17.6 to 17.02 as the contamination of soils increased from 0 to 9%, while the optimum water content decreases from 17 % to 13.8% for clayey soil and the maximum dry unit weight decreased from 19.13 to 18.6 kN/m^3 and the moisture content decreases from 10.2 % to 8.2% for sandy soil. It's indicated that the soil structure tends to be in a dispersed structure, this dispersed structure causes a reduction in the dry unit weight of soil. These results are compatible with the results reported by [2], that to achieved maximum dry unit weight, the moisture content reduced as oil content increased in contaminated soil.

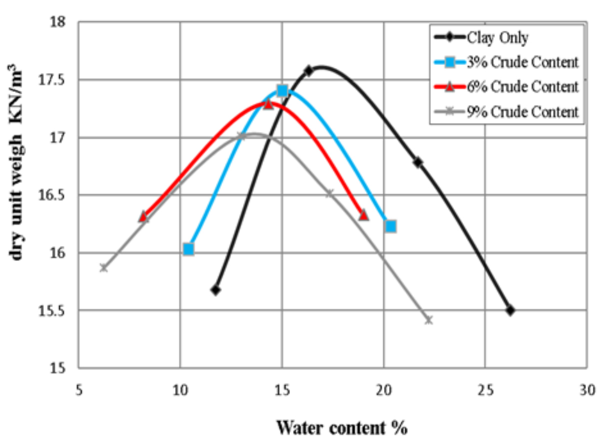


Figure 8. Dry unit weight versus dry unit weight.

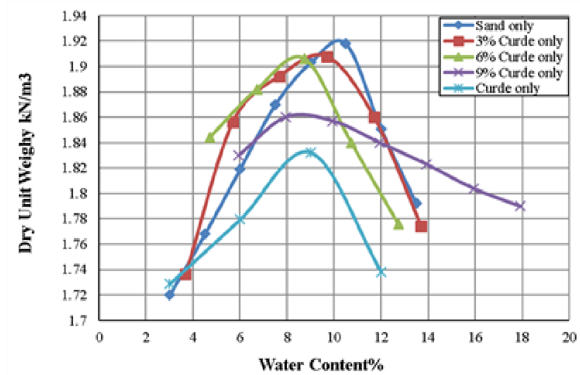


Figure 9. Dry unit weight versus water content %.

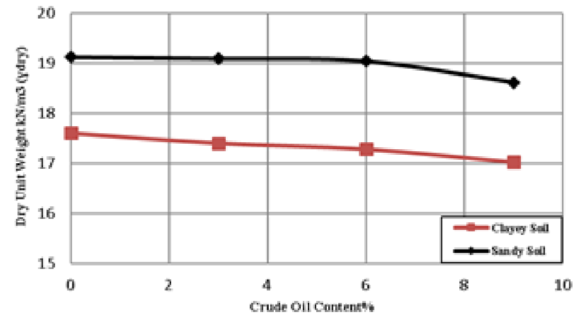


Figure 10. Maximum dry unit weigh versus crude oil content in clayey and sandy soils.

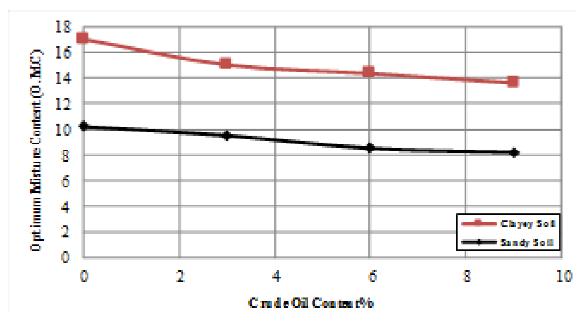
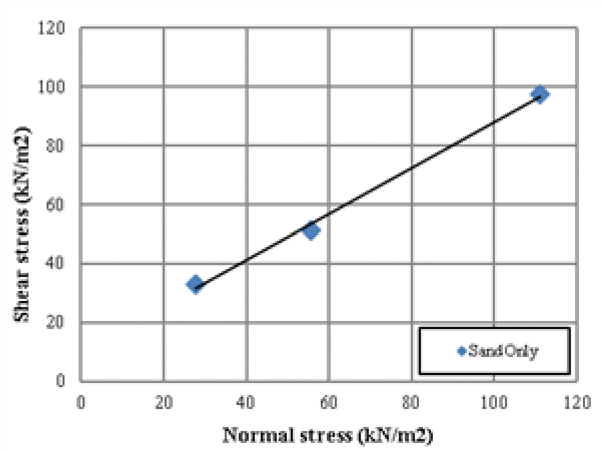
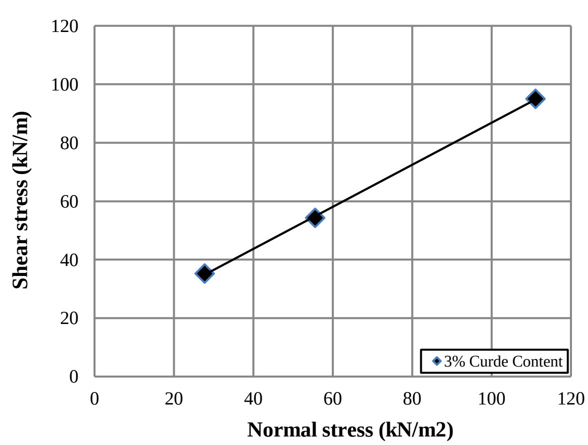


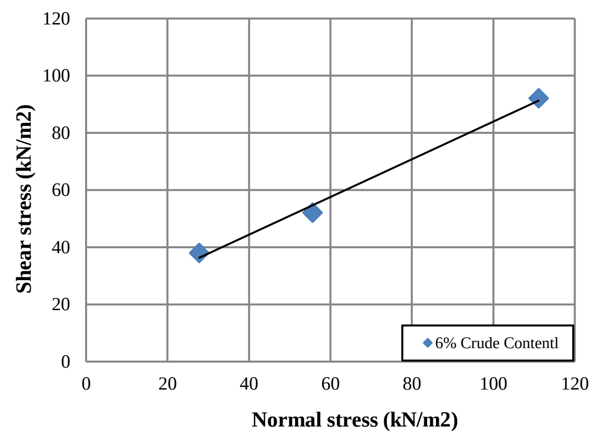
Figure 11. The optimum moisture versus crude oil content in clayey and sandy soils.

3-5 Shear strength

According to [15], the direct shear test was performed on clean and contaminated soils. Figures 12 and 13 show the angle of internal friction and soil cohesion of sandy soil. The effect of crude content on unconfined compressive strength for clayey soil is shown in Figure 14. The tests conducted according to [16]. In general, there is an increase in the friction angle and a decrease in the cohesion of contaminated soil as the % of crude oil increased for clayey soil and inferred that the contaminated soil will be more resistant than the clean soil. This is due to the products of crude oil which increase inters particle slippage, thus reducing the cohesion of contaminated soil. Further increases in crude oil content indicated cause a smaller change in soil cohesion. This can be devoted to that the presence of oil with a higher viscosity than water might blanket the soil particles. The results are in good agreement with [4]. Figure 15 shows the effect of crude oil on the Cohesion of clayey and sandy soil and internal friction (ø) can be seen in Figure 16.







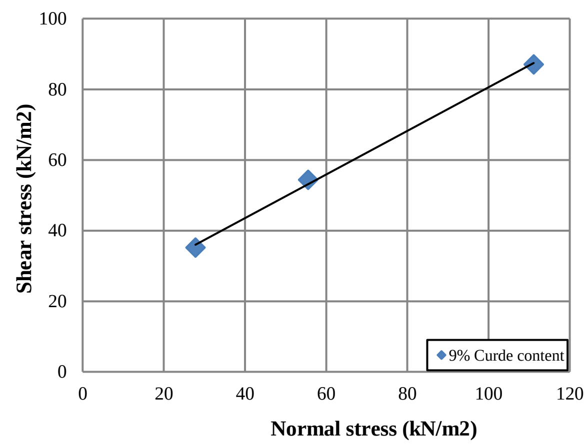
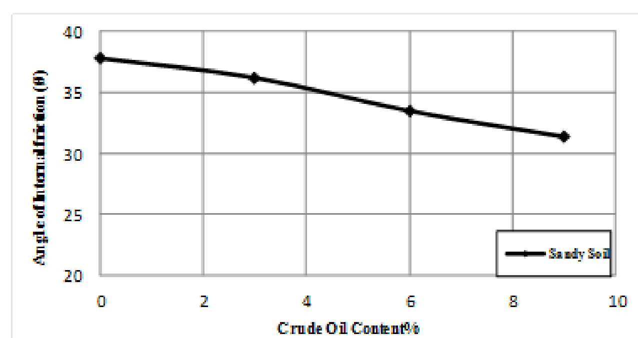
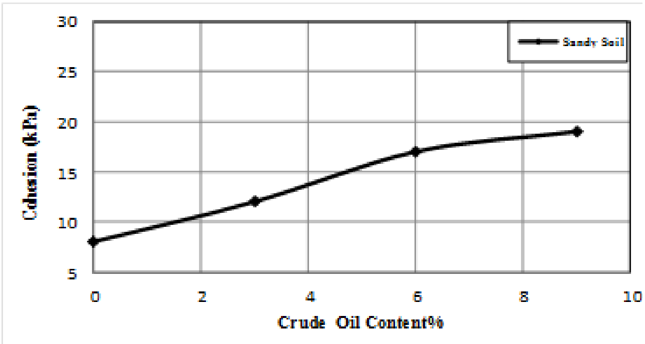


Figure 12. Relationship between shear – normal stress for sandy soil.

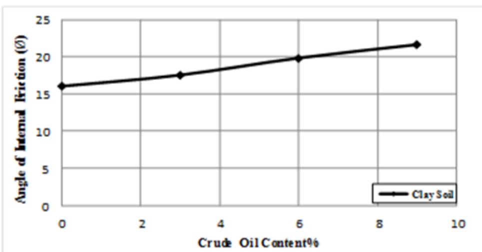


a) Angle of internal friction (ø)

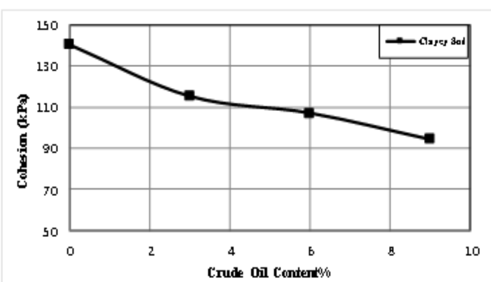


b)-Cohesion (kPa)

Figure 13. Shear strength parameters (Direct shear) for sandy soil versus crude oil content.



a. Angle of internal friction (ø)



b.Cohesion (kPa)

Figure 14. Shear strength parameters (Unconfined shear strength) versus crude oil content for clay soil.

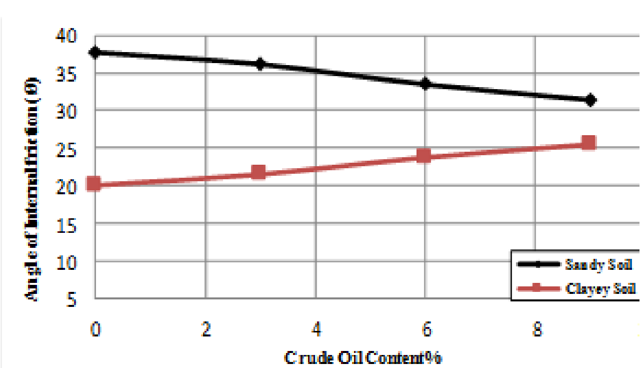


Figure 15. Friction angle of soil versus crude oil content in clayey and sandy soils.

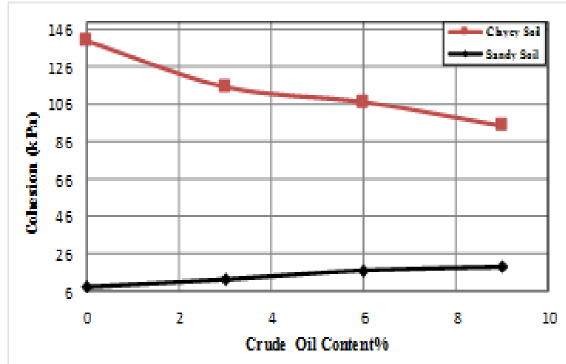


Figure 16. Cohesion of soil versus crude oil content in clayey and sandy soils.

4- Conclusions

The main conclusions drawn from this study can be listed as follows:

I. Increasing crude oil pollution % in clay soil lead to a reduction in specific gravity.

II. Atterberg's limits decrease with an increase in crude oil % in clayey soils. This behavior is indicated the nature of water in the clay minerals structure.

III. As crude oil % increases, the compaction curves of contaminated soil go down and shift to the left of the uncontaminated soils curve.

IV. An increase in crude oil percentage (%) causes an increase in the angle of internal friction and a decrease in cohesion.

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