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Evaluation the Geotechnical Properties of Oil-Polluted Soil from Two Selected Areas in Thi-Qar Governorate-Iraq

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Abstract

Oil pollution of the soil due to a leakage in oil tubes, transportation of products, or during oil excavations can change the soil physical and mechanical, chemical, and biological properties. Consequently, the soil may or may not be eligible for engineering construction projects and it may need a significant treatment. Therefore, it is required to have a better understanding of the general behavior and the corresponding geotechnical properties upon pollution particularly for those areas associated with oil explorations and industry like Thi-Qar Governorate. Fine and coarse soils from two sites at the University of Thi-Qar are artificially contaminated with oil products ranging from 0% to 10% of their dry weight. Testing programs have been performed on both soils included conventional tests such as grading, Atterberg limit, vane shear and direct shear tests. To achieve a fair comparison, the outcomes are directly compared to those of the original uncontaminated soil. The final results of this study indicated the variations in the soil properties for the studied soils upon contamination and addressed the concept behind such behavior.

Keywords: Soil pollution, oil-polluted soil, geotechnical properties, Shear Strength.

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تقييم الخواص الجيوتكنيكية للترب الملوثة بالنفط من منطقتين مختارتين في محافظة ذي قار/العراق

الملخص:-
يمكن للتلوث النفطي في الترب الناتج عن تسرب في أنابيب النفط ، أو عن نقل المنتجات النفطية، أو أثناء التنقيب عن النفط أن يغير خصائص التربة الفيزيائية والميكانيكية والكيميائية والبيولوجية. وبالتالي ، قد تكون التربة أو قد لا تكون مؤهلة لمشاريع البناء الهندسية ، وربما تحتاج إلى علاج كبير. لذلك ، يجب أن يكون هناك فهم أفضل للسلوك العام والخصائص الجيوتقنية لتلك التربة عند التلوث خاصة لتلك المناطق المرتبطة باستكشافات النفط والصناعة النفطية مثل منطقة محافظة ذي قار.في هذه الدراسة تم اخذ نموذجين من التربة الناعمةوالخشنة من موقعين مختلفين في جامعة ذي قار وتم تلويثهما اصطناعيا بمنتجات نفطية وبنسب تتراوح من صفر٪ إلى 10٪ من وزنها الجاف. وقد أجريت برامج الاختبار على كلا النموذجين وقدشملت الاختبارات التقليدية مثل التدرج الحبيبي ، وحدود اتيربيرك اختبار قص الريشة، واختبار القص المباشر. ومن اجل تحقيق مقارنة عادلة ، فقد تمت مقارنة نتائج التربة الملوثة مباشرة بتلك الخاصة بالتربة الأصلية غير الملوثة. أشارت النتائج النهائية لهذه الدراسة إلى الاختلافات الملحوظة في خصائص التربةالمدروسة قبل وبعد التلوث ، وتناولت المفهوم الكامن وراء هذا السلوك.

الكلمات المفتاحية: تلوث التربة ، التربة الملوثة بالنفط ، الخصائص الجيوتقنية ، وقوة القص.

1. Introduction

Subsurface pollution with oil may occur due to the leakage in the oil tube-lines and underground storage tanks of fuel or gas stations, Nevertheless oil spills during transportation on the land or during oil drilling processes happen by accidents in most cases [1]. Globally, many researchers have measured the soil features of the polluted cohesive and non-cohesive soil to have a better understanding of the behaviour of the soil upon pollution [2-5]. Locally, the study of physical, chemical, and mechanical properties of soils within Thi-Qar region in south of Iraq is a key of significance for many decades.

Recently, many investigator were interested in this soil such as [6], [7] and [8]. However, the number of the research dedicated on the analysis of petroleum product impact on this soil composition and properties is still limited from practical point of view. Although Thi-Qar area has a high potential of pollution with oil, because of its consideration as an oily governorate possessing many oil fields and wells, there are no data on the impact of petroleum products on geotechnical properties of Thi-Qar region soil. So, the need to explore its influence by oil is crucial for both construction projects and oil excavations carried out in this area. For very few examples in this topic, [9] employed a modification direct simple shear apparatus to investigate the behaviour of oil-polluted sand and steel interfaces friction. Parameters investigated include oil content, sand relative density, surface roughness and normal stress level. The main conclusion was that increasing the oil content in the soil sample caused to a noticeable decreasing in shear strength parameters at any relative density value and for both roughness cases of the interfaces friction. The mobilized shear strength associated with displacement along the interface of a soil and structure is a major factor governing the stability analysis for geotechnical eng- ineering design [10]. Karkush and Altaher, [11] estimated the risk of soil pollution resulting from the industrial wastewater discharged from Thi-Qar oil refinery plant. More recently, [12] presented remediation of contaminated soil of Thi-Qar Oil Refinery Plant by applying the enhanced electro kinetic method, which is considered as an efficient method for treating low-permeability polluted soils.

To sum up, in the Iraqi literature much research has been done to date to investigate Thi-Qar soils. However, little research focused on effect of oil contamination on such soil. Taking that lack in study into consideration and highlighting the gap of knowledge within this field, the current study examines the impacts of petroleum products on composition, physical and mechanical characteristics of soils in two sites at Thi-Qar area through a series of conventional tests conducted on both intact and artificially contaminated samples.

2. Materials and Methods

The study was performed at the laboratories of Civil Engineering Department in College of Engineering at the University of Thi-Qar. The soil samples were collected from two locations at the University of Thi-Qar site. The soil from the first location (location 1) was named Soil A while that from the second location (location2) was named Soil B. The satellite map shown in Figure 1 demonstrate both locations within the red circles.

Figure 1: The satellite map of the investigated soil

Figure 2 shows the grain-size distribution curves for both soils. Soil A have been obtained from sedimentation test while that of Soil B have been obtained from the sieve analysis test. Table 1 summarizes the physical properties of both soils. Crude oil and engine oil have been brought from Al-Refai Oil Field at Thi-Qar governorate, crude oil was added to Soil A at different percentages ranging from 0 to 10% of the sample dry weight while engine oil was added within the same range to Soil B; their corresponding typical properties are listed in Table 2. Sedimentation, Atterberg limits, vane shear tests have been conducted upon contamination of Soil A while direct shear test has been performed for the contaminated Soil B.

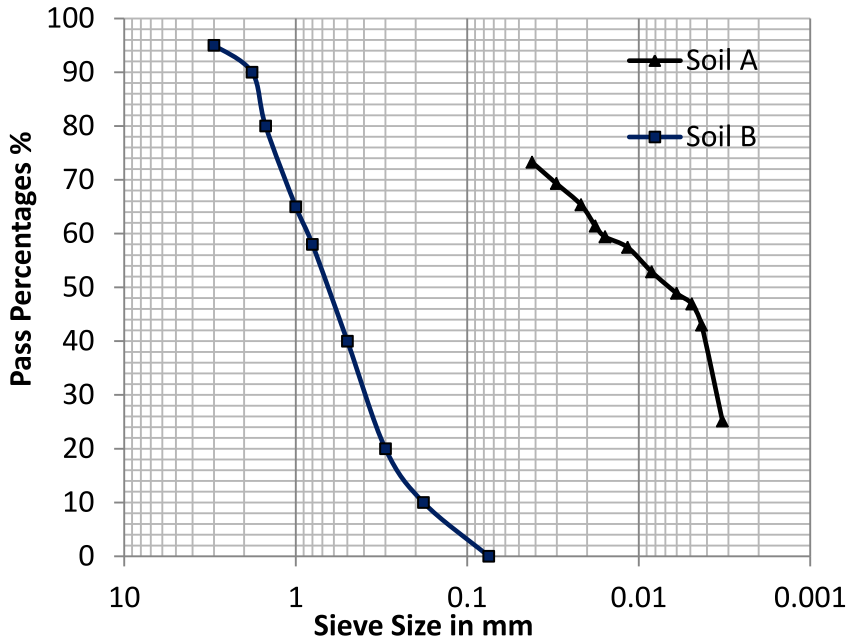

Figure 1: Grain Size Distribution of Soil A and Soil B

Table 1: Properties of used soils

Soil	Description	Properties	Value
Soil A	Clayey Silty Soil (Fine grained soil)	Liquid limit L.L	37
		Plastic limit P.L	25
		Plasticity index	12
		Maximum dry unit weight, γ_{max} (g/cm^3)	1.65
		Optimum moisture content w_c	17
		Specific gravity Gs	2.7

Soil B	Gap graded Sandy Soil (Coarse grained Soil)	Effective size, D10 (mm)	0.17
		Mean grain size, D50 (mm)	0.60
		Uniformity coefficient, Cu	5.2
		Coefficient of gradation, Cc	0.8
		Maximum dry unit weight, γ_{max} (kN/m^3)	16.7
		Minimum dry unit weight, γ_{min} (kN/m^3)	14.8
		Specific gravity Gs	2.65

Table 2: Typical properties of the used oils

Properties	**Crude oil**	**Engine oil**
Density (gm/cm^3), 30°C	0.884	0.836-0.850
Kinematic viscosity	9.8	4.5
Flash point,°C	317	174
Pour point, °C	-27	+15

The first test series has performed on Soil A, the soil mixed with the target percentage of crude oil (described in Table 2) thoroughly and left for 7 days in sealed plastic bag to reach equilibrium and ensure a uniform distribution to the petroleum product over the soil sample. Afterward, the sample was tested according to the standard specifications and the experiments were repeated as recommended in the associated specifications. Three tests (sedimentation, Atterberg limits, and vane shear test) have been carried out for this soil type and the associated results were as follows in the next sections (3.1.1 to 3.1.3). During the sedimentation test, Soil A has been washed on Sieve No.200 (75 micron) and after noticing there was no soil remained on that sieve. It was decided to condu ct the sedimentation test using hydrometer only. The sedimentation analysis has been performed according to ASTM D422 for uncontaminated and contaminated samples after mixing with the crude oil. The samples of different artificial mixtures were kept sealed for the period mentioned above in this section. In this study, the Atterberg limits of Soil A at different fractions of crude oil were tested using Casgrande device and rolling method according to ASTM 4318. The undrained shear strength characteristics of Soil A have been investigated, First the sealed contaminated specimens is brought to the laboratory as shown in the photo in Figure 2, then each time the investigated percentage of the polluted soil has been transferred to a cylinder container of 4.0 cm diameter and 8.0 cm height and the soil is compacted at 16.5 kN/m^3 within three layers. Afterwards, the hand shear vane tester was used and the corresponding reading was recorded, from which the value of undrained shear strength is obtained, see Photo in the Figure 3.

Figure 2: The sealed contaminated soil samples

Figure 3: Hand vane shear tester

The second test series has performed on Soil B, the sand specimens (Soil B) were first dried in oven for 24 hours. Then, they were prepared and mixed thoroughly with engine oil described in Table 2 of fractions 0%, 3.5%, 6.5% and 10% by weight of the dry soil samples. To achieve homogeneity, uniformity and the required relative density, the specimens were compacted by means of tamping in three layers and put in small direct shear box, then the test was carried out at rate of strain of 1 mm/min under normal stresses of 20, 55 and 100 kPa. The related results and conclusions are discussed in Section 3.2.

3. Result and Discussion

3.1 Result and Discussion (Soil A)

3.1.1 Sedimentation Results

Figure 4 demonstrates the variations in soil particle size of all tested samples. In comparison to intact samples, an increase in oil content indicated a shifting to the grain size distribution curve from finer to coarser ranges. Those results of artificial mixture fit very well with the previous work which was done for soil abroad such as [13]. Authors attributed such performance to the formation of soft oily soil clods upon petroleum contamination [4].

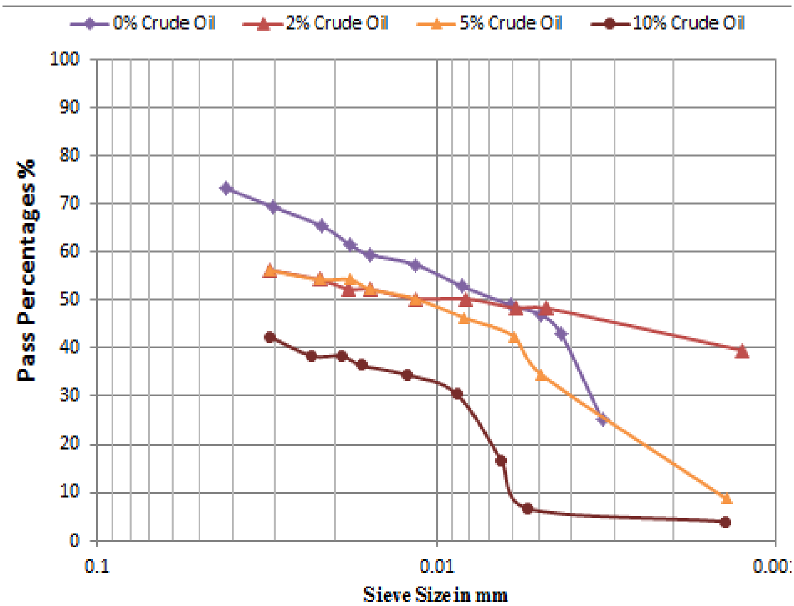

Figure 4: The grain size distribution curves (hydrometer tests) of Soil A at different concentration of crude oil

3.1.2 Atterberg Limit Results

The findings of Atterberg limits tests showed that the liquid limit, plastic limit, and plasticity index increases markedly of the contaminated samples in comparison to non-contaminated ones. However, increasing the oil percentages in contaminated sample itself shows a slight increase in liquid limit and plastic limit and indicates almost constant value of plasticity index (23-24) as shown in the Table 3.

Table 3: variations in Atterberg limits of Soil A upon contamination

Percentages of crude oil %	Liquid Limit (L.L)	Plastic Limit (P.L)	Plasticity Index (PI)
0	36	24	12
2	48	25	23
5	51	27	24
10	52	29	23

The findings seem to be reasonable because resulting more consistency to the soil due to oil effect and that was matching the results produced by to [15] who investigated the geotechnical behavior of oil contaminated to high plasticity clay.

3.1.3 Vane Shear Test Results

The results are shown in Figure 5 which can reflect increasing in shear strength with increasing the oil content except small percentage of 2% which indicates decreasing of the value. That increase of undrained shear strength could be as a result to the increase in particle bonding of soil.

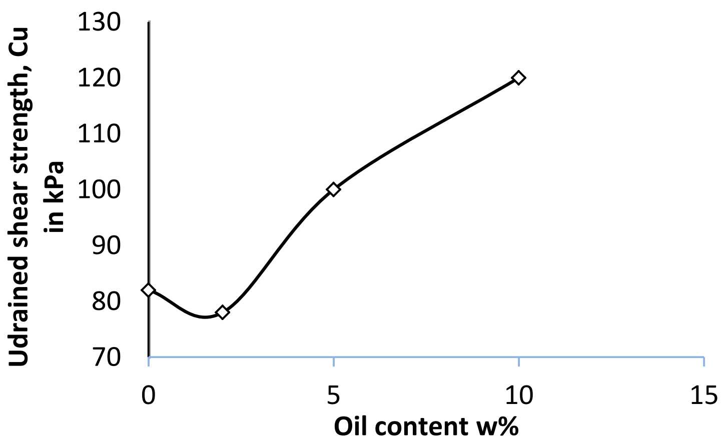

Figure 5: Undrained shear strength of soil A form vane shear test at different contamination percentage

3.2 Discussion of Results (Soil B)

From the results of the direct shear test as shown in Figure 6, it can be deduced that the shear stress of sandy soil increases with decreasing oil content because upon contamination sand particles tend to be more lubricated and easy to slide, while the strength of the soil specimens will decrease. On other hand, it was observed that the angle of internal friction was decreased upon oil contamination. This finding agree with the conclusions of the previous studies (see, [15]; [16]; [17]; and [2].

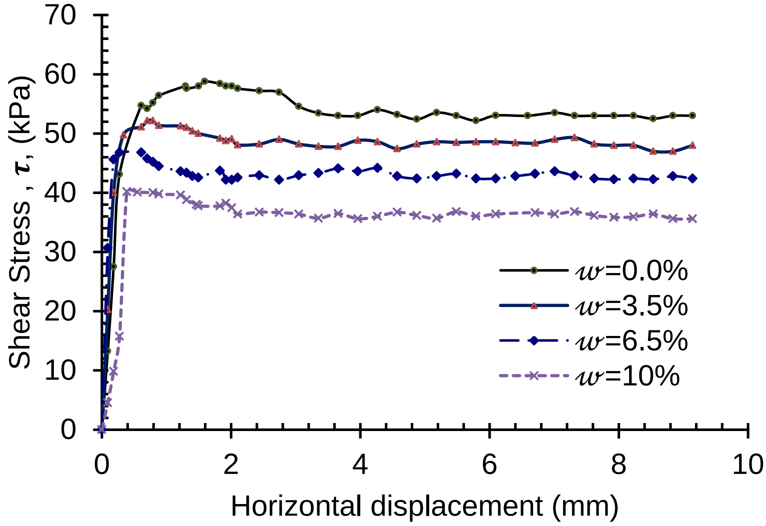

Figure 6: Relationship between shear stress versus horizontal displacement at (σn) =100 kPa

Figure 7 shows the relationship between internal friction angle values with different percentages oil contents. The results show reduction in internal friction angle due to the increasing of oil contents of sand soil. In fact, the soil grains are coated with oil which causes the decrease of soil internal friction. In additional, the increase in oil viscosity causes the decrease in friction angle. Similar results were observed by [18]. According to [17], soil particles were coated with oil which resulted in friction reduction when soil particles slipped and skidded over another. The friction angles for sandy soil are about 32^{o}. It can be seen that the friction angle may be reduced by about 23.5^o when the oil contents increased from 0% to 10%. There is an apparent reduction in internal friction angle as oil content increases in sandy soil.

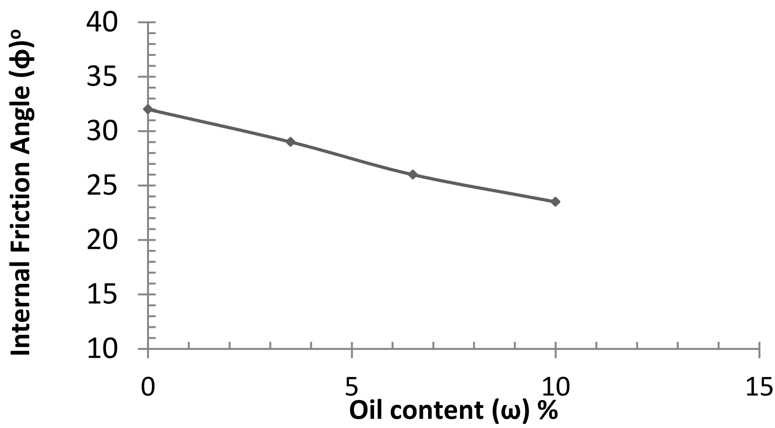

Figure 7: Influence of oil content on internal friction angle of soil at (σ_n) =100 kPa

4. Conclusions

Two series of conventional laboratory testing was conducted to evaluate the increasing in oil concentration on the geotechnical properties of fine and coarse soils samples at sites located within Thi-Qar Governorate area. The study reveals that there is a major influence of crude and engine oil contamination on engineering behavior of clayey silty and sandy soils. The following main conclusions can be drawn:

1. The increase in oil content causes shifting the grain size distribution curve from finer to coarser ranges.
2. The liquid limit, plastic limit, and plasticity index increases significantly of the contaminated samples in comparison to non-contaminated samples.
3. The rise in oil content of fine soil (Soil A) causes an increase in the undrained shear strength because the possible increase of particle bonding of soil.

4. The increase in oil content for sandy samples causes a reduction in shear stress because the potential of soil inter-particle slippage for such soil which would increase with increasing the oil content, and eventually decreases the shear strength of soil
5. The angle of internal friction of the sandy soil decreased upon pollution with the petroleum product.

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