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STUDY THE EFFECT OF FUEL OIL LIQUID ON ENGINEERING PROPERTIES OF GYPSEOUS SOIL

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ABSTRACT: - One of the effected problems that the civil engineer faces it in construction of buildings is the presence of gypseous soils. Gypseous soil is highly dissolved when its water content increases. There are many treatments for such soils like soil replacement, earth reinforcement, compaction, addition of asphalt, lime, fuel oil and other.

In this study, the improvement properties of gypseous soils were investigated using fuel oil which is one of a little cost materials and because of the ability of this material to prevent the water action and to distribute in voids of soil. Gypseous soils used in this study, which contain (49.4%) gypsum content, were brought from Tikrit city, Salah-Aldeen governorate. The addition of fuel oil to gypseous soil, was with different percentages (0, 2, 4, 6, 8 and 10%) to get more observation about the study.

The results showed that the maximum dry density decreases while the optimum moisture content increases with increasing fuel oil content. Moreover, this study showed that as the fuel oil content increased to an optimum value (8%), the maximum unconfined compressive strength, the cohesion (c) and the angle of internal friction (φ) increased to about (34%), (52%), (15%) respectively, then decreased. When the treated and untreated samples soaked in water, the maximum unconfined compressive strength, the cohesion (c) and the angle of internal friction (φ) decreased to about (37%), (21%), (12%) respectively, at an optimum fuel oil content (8%). The initial void ratio (e_0) and collapse potential (C.p.) decreased to about (32%), (90%) respectively, as the fuel oil content increased to an optimum value (8%). The compression index decreased as the fuel oil content increased to an optimum value (8%) then increased.

The main results indicated that using fuel oil (8% fuel oil content) provides better solution for problems of gypseous soil. Using this material improving the engineering properties of the gypseous soils and reducing the collapsibility, especially when these soils faced the wet condition.
Key Words: Gypseous Soil, Fuel Oil, Collapsibility, Shear Strength

1. INTRODUCTION

gypseous soils usually stiff when they are dry, but these soils may be affected greatly when subjected to changes in water content due to human activities or any environmental conditions such as rising of water table, raining, changing the natural drainage and other which may dissolve gypsum causing pores, crack and producing cavities that lead to increase the permeability in gypseous soils. The problems results from these soils are very dangerous, therefore improving the gypseous soil before construction of buildings are very interesting. Gypseous soils occupy about 100 million ha (one million km^2) in the world across Algeria, Argentina, Australia, Iraq, Libya, Somalia, Spain, Sudan, Syria, the former USSR (Union of Soviet Socialist Republics) and other arid and semi aired countries with annual rainfall of less than (500) mm [1]**.** Several structures affected from gypseous soils and the following are some examples [2]:

1. Cracks in several houses in gayara refinery.
2. Samara hotel (crack and heel).
3. Storage water in Karbala (tip and tank).
4. The dam of the Mosul city (dissolved the gypseous rock).

The presence of gypsum in soil may cause many problems to the engineering structures that building on it and made it to exhibit unpredictable, associated with great loss of volume upon wetting with or without additional loading [3]. Many researchers studied the effect of addition some additives to improve the properties of these collapsibility soils like [4] studied the efficiency of adding cement, ceramic and mix of cement and ceramic for improvement. [5] used geomesh and addition of polycoat as an improvement characteristics of gypseous soils. [6] used clinker additive for improvement mechanical properties of gypseous soils. [7] used different percentages of (SM) and (ML) soils as a treatment material. Other researchers studied the effect of adding fuel oil as an improvement material like [8] studied improvement of gypsum soil by using fuel oil. [9] studied the effect of adding fuel - oil on some physical properties of soil. [10] studied the fuel oil effect on gypseous soils.

The main purpose of this study is to investigate improvement the engineering properties of gypseous soil by using fuel oil which is one of most little cost material [8].

2. MATERIALS

2.1 Fuel Oil: Brownish black liquid produced from petroleum refinement as a residue or a distillate with a relative density about (0.95) [11]. This production petroleum liquid is used in an engine for the generation of power or burned in a furnace or boiler for the generation of heat. Diesel is one type of fuel oil. Fuel oil is built up of long hydrocarbon series, particularly cycloalkanes, aromatics, and alkanes. The fuel oil from Al-Baiji Refinery, Salah-Aldeen governorate was used in this study.

2.2 Soil: The gypseous soil used in this study was taken from Tikrit city, (Al-Qadissia district), Salah-Aldeen governorate because its soils have highly gypsum content, from depth ranging (2.5-3.0) m which contain (49.4 %) gypsum content.

3. RESULTS AND DISCUSSIONS

Samples of gypseous soils remolded with different percents of fuel oil were used to examine the effect of fuel oil on the engineering characteristic of the gypseous soil. A homogenous soil dried by air was used. The required percent of water was added at room temperature and mixed for 2.5 minutes or when the water dispersed throughout the mixture. The required percent of fuel oil was taken as a percentage of total dry weight of gypseous soil.

3.1 Classification Test

Involving soil classification (grain size distribution, specific gravity, Atterberg limits, and relative density). Disturbed and undisturbed samples were obtained and carried out to the soil mechanics laboratory, Civil Engineering Department, College of Engineering at the University of Tikrit. All tests were carried out according to the ASTM specification [12] except the specific gravity which was conducted according to the British Standard [13] (white kerosene was used instead of distilled water) commended by U.S. Army Engineer waterways experiments station due to the solubility of gypsum in water [14]. The results of soil classification showed that the soil is poorly graded sand (SP) with gypsum content equals (49.4%). Figure (1), Table (1) and Table (2) summarized the grain size distribution, physical and chemical analyses respectively which were employed on soils study.

3.1.1 Specific Gravity

Figure (2) shows the specific gravity of treated soil with different fuel oil content (0, 2, 4, 6, 8 and 10%). It can be noticed that the specific gravity decreased as the fuel oil content increased. This behavior may be related to a little specific gravity of fuel oil as compared with that of soil.

3.2 Compaction Test

Untreated and treated moisture density relation of soil was obtained by the standard Procter compaction tests following the procedure of ASTM designated as D1557-79 [15]. Moisture content-dry unit weight of soil with different fuel oil content (0, 2, 4, 6, 8 and 10%) is considered as shown in Figure (3). Figure (4) represents the relation between the maximum dry density and fuel oil content. It can be noticed that as the fuel oil content increased, the dry density of gypseous soil decreased. The reason of this behavior may be related to the decreasing of specific gravity. Figure (5) shows the relation between the optimum moisture content and the fuel oil content, the optimum moisture content for treated soil is too close. This may be due to the resistance of the mixture to compaction offsets. The results of compaction tests were shown in Table (3)

3.3 Strength Test

3.3.1 Unconfined Compression Test

The unconfined compression test were carried out according to ASTM D2166-85 [14] using a constant strain compression machine with a rate of loading of (0.5mm/min). The effect of soaked of samples was also examined. The test continued until the sample reached its peak strength or (20%) axial strain.

Treated and untreated samples (which taken from the field) with different fuel oil content (0, 2, 4, 6, 8 and 10%) were tested. Two samples was prepared for each case. Unsoaked sample and sample soaked in water for (1 hour). Each of the tested samples had an optimum moisture content (O.M.C) related to its fuel oil content.

Typical unconfined compressive strength test results are listed in Table (4). Increase and decrease ratio are calculating according to Eq. (1) and (2). Figure (6) and (7) show the stress-strain relationships of undisturbed and disturbed (treated and untreated) samples with different percentage of fuel oil content for unsoaked and soaked case respectively. Fig. (8) shows the effect of fuel oil content on the maximum unconfined compressive strength.

$$\text{Increase Ratio} = \frac{q_u \text{ for treated soil}}{q_u \text{ for untreated soil with 0\% feul oil}} \quad \ldots\ldots\ldots\ldots\ldots(1)$$

$$\text{Decrease Ratio} = \frac{q_u \text{ soaked sample}}{q_u \text{ unsoaked sample}} \quad \ldots\ldots\ldots\ldots\ldots(2)$$

It can be noticed that, there were gradually increasing in compressive strength of treated samples with increasing fuel oil content until it reaches (8% fuel oil content) then decreased. The reason of this behavior may be related to the fuel oil content effect on the particles interlocking of treated soil.

Figure (7) represents the soaked case. It can be noticed that soaked samples had a little compressive strength as compared to the unsoaked samples. This behavior may be related to the failure of the cohesive bound between the fuel oil particles [16] . It can be noticed that for the unsoaked case, the unconfined strength increased as the fuel oil content reached (8%). The increasing of compressive strength with the addition of fuel oil is expected to be related to only the increasing in cohesion available by a continuous film of fuel oil surrounding the soil particles [16] and [17]. The reduction in compressive strength, when fuel oil content more than (8%) may be related to the contact between particles is prevented further. This causes a high reduction in friction , which in turn leads to a reduction in compressive strength. For soaked case in Fig. (8) it can observed that the fuel oil content has a small increasing effect on soaked strength due to the waterproofing action [16].

3.3.2 Direct Shear Tests

To determine the shear strength parameters, the cohesion (c) and the angle of internal friction (φ), direct shear test were conducted according to the ASTM (D3080-72), [14]. A calibrated proving ring at (2.5 kN) capacity and (2mm) precision dial gage, for vertical deformation (0.01mm) precision dial gage was used while for horizontal deformation a (0.01mm) dial gage was used. The rate of strain was (0.6mm/min).

The first set of tests was conducted without soaked for undisturbed samples and disturbed samples treated with (0,2,4,6,8 and 10%) fuel oil content. The second set of tests was conducted socked with water for undisturbed samples and disturbed samples treated with (0,2,4,6,8 and 10%) fuel oil content. Summary of the results are given in Table (5) .

Figures (9) and (10) show the relation between the cohesion (c) and the angle of internal friction (φ) with the fuel oil content respectively for unsoaked and soaked condition. For unsoaked case it can be noticed that the cohesion (c) and the angle of internal friction (φ**)** increased as fuel oil content increased to an optimum value (8% fuel oil content) then decreased. The reason of this behavior may be related to the cohesion of fuel oil that causes cohesion and interlocking between soil particles and increasing in (c) and (φ**)**. If the fuel oil content increased by optimum (8% fuel oil content), the thickness of the fuel oil films coating the particles increases the contact between particles is prevented and this causes a reduction in friction. For soaked case in Figures (9) and (10), it can be observed that the cohesion (c) and angle of internal friction (φ**)** reduced to a little value compared to the value for the unsoaked case. The reason of this reduction may be related to the cracking of antiparticles cementation bound in the particles system. Furthermore, there is an increasing in the value of cohesion (c) and angle of internal friction (φ**)** as fuel oil content increased. This increasing may be related to the waterproofing action of fuel oil.

3.4. Collapsibility Tests

A typical void ratio (e) – Applied load (log P) relation in semi log scale for treated and untreated samples were shown in Figures (11 a, b, c) [17]. The curves in these figures show trend of behavior where a reduction in void ratio as the applied load increase until a sadden compression observed upon submersion appears. Application of further loading gives a sharp slope comparison with unsubmerged stage. The results of collapse potential and initial void ratio were given in Table (6). Figure (12) collect all samples treated with different percentages of fuel oil content (0, 2, 4, 6, 8 and 10%), it can be noticed that the collapse potential and the void ratio decreased as the percent of the fuel oil content increased. The samples treated with fuel oil have compression index less than for the untreated soil. The optimum percent of fuel oil content which given minimum compression index is (8% fuel oil content). The effect of fuel oil content on collapse potential, initial void ratio and compression index were shown in Figures (13), (14) and (15). In Figure (13) the collapse potential decreased as the fuel oil content increased to an optimum value (8%), then it relatively increased as fuel oil content increased. This behavior may be related to the effect of water-proofing of fuel oil. When it coats the gypsum particles, this coating reduces the gypsum particle dissolution by the water and controls particulate system. Figure (14) shows that initial void ratio decreased as the fuel oil content increased until it reached minimum value at fuel oil content of (8%). This may be related to the fact that the lubrication effect of fuel oil is better than that of water, so the void ratio for the treated samples is less than that for untreated samples .

The coefficient of compression index (Cc) remain constant with fuel oil content increment for unsubmerged. When the soil submerged with water the value of compression index decreased as fuel oil content increased as shown in Figure (15).

3.5 The Effect of period of Soaked on Strength of Soil

The time of soaked acted on the shear strength parameter of soil. The shear stress and unconfined strength decreased as the time of soaking increased. Figure (16) shows the effect of period of soaking on (8% fuel oil content) treated samples. It can be noticed that the increment of period of soaking leads to decrease the unconfined strength and this behavior may be related to the cracking of antiparticles cementation bound (fuel oil and gypsum) in the particulate system. Figure (17) shows the maximum unconfined strength with period of soaking.

The effects of period of soaking on the shear strength parameters were shown in Figures (18) and (19) for cohesion (c) and angle of internal friction (φ) respectively. The cohesion (c) reduced as the soaking time increased while the period of soaking had little effect on the angle of internal friction (φ) .

CONCLUSION

The following points are drawn from this study :

1. The optimum moisture content increased and maximum dry density decreased as the fuel oil content increased.
2. For the treated soil without soaked in water, the unconfined compressive strength increased as the fuel oil content increased. The maximum increment for (8% fuel oil content) reached about (34%). For treated soil soaked in water, the unconfined compressive strength reduced to about (37%) as compared to the unsoaked but, it increased as the fuel oil content increased.
3. For unsoaked samples, the value of cohesion (c) and angle of internal friction (φ) increased as the fuel oil content increased to about (52%) and (15%) respectively, at fuel oil content (8%). For soaked samples the cohesion and angle of internal friction reduced to about (21%) and (12%) respectively, as compared to the unsoaked case. From direct shear tests it's found that the optimum percent of liquid fuel oil equal to (8%).
4. As the fuel oil content increased to (8%), the void ratio and collapse potential decreased to about (32%) and (90%) respectively, then increased. The compression index decreased as the fuel oil content increased to an optimum value (8%) then increased.
5. The value of the unconfined compressive strength and shear strength parameters affected by the period of soaking. As the period of time increased, the unconfined compressive strength and the shear strength decreased. (80%) of this reduction occurred after (2 days).

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Table (1) Results of Physical Tests

SOIL PROPERTIES	VALUE
Specific Gravity	2,663
Liquid Limit (%)	28
Plastic Limit (%)	----
Unified Soil Classification	SP
Maximum Dry Density (kN/m^3)	18,40
Field Density (kN/m^3)	14,80
Optimum Water Content(%)	15,40

Table (2) Results of Chemical Tests

TEST	VALUE
Gypsum Content (%)	49,4
Total Soulble Salts (T.S.S)%	21,0
Total Sulphate Content (SO3)%	28,0

Table (3) Results of specific gravity and compaction tests

Fuel oil content F.O%	Specific gravity Gs	Maximum dry density (kN/m^3)	Optimum Moisture content O.M.C.%
0%	2,663	18,4	15,4
2%	2,66	17,4	16,7
4%	2,60	16,3	17,3
6%	2,58	16,0	17,9
8%	2,575	15,7	18,2
10%	2,57	14,8	18,7

Table (4) Results of Unconfined Compressive Strength

F.O. %	qu Max. unsoaked (kPa)	qu Max. soaked (kPa)	Increase Ratio for unsoaked	Decrease Ratio for soaked
Undisturbed sample F.O. 0%	695	crumbled	-	-
Disturbed sample F.O. 0%	705	crumbled	1	-
2%	730	313	1,035	0,429
4%	804	330	1,140	0,410
6%	900	537	1,277	0,597
8%	945	600	1,340	0,635
10%	880	451	1,248	0,513

Table (5) Results of Direct Shear Tests

Type of test		Without Soaked		Sacked in Water	
Soil Property		c kPa	φ (degree)	c kPa	φ (degree)
Unconfined Samples		48,07	37,28	8,40	28,60
Disturbed Samples With F.O%	0%	47,50	38,30	10,00	30,70
	2%	53,40	40,20	28,50	32,80
	4%	60,70	42,50	35,60	34,70
	6%	68,20	43,20	46,00	35,80
	8%	72,00	44,00	57,00	38,60
	10%	69,00	43,30	50,00	37,00

Table (6). Results of Collapse Potential and Initial Void Ratio

Soil property		Initial Void Ratio (e_0)	Collapse Potential (C.p.)
Undisturbed Sample		0,9130	20,3870
Disturbed Sample With	0%Treated	0,8112	15,7820
	2%Treated	0,7842	10,0900
	4%Treated	0,7330	5,1930
	6%Treated	0,6852	3,5600
	8%Treated	0,6210	0,6170
	10%Treated	0,6911	2,6610

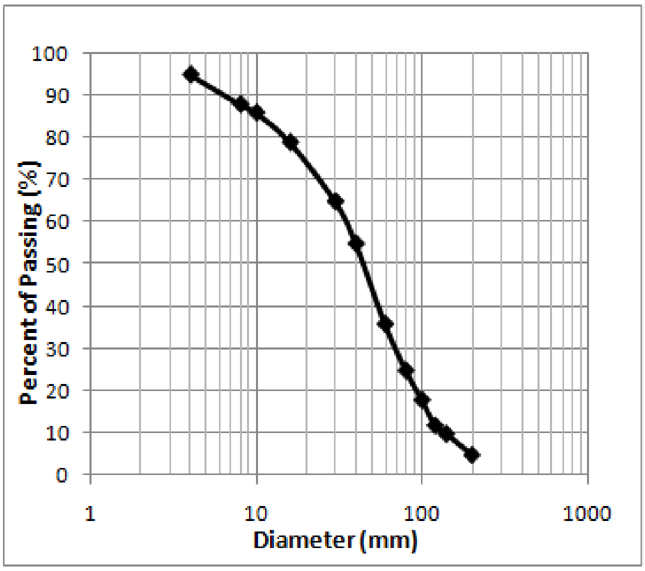

Figure (1) Grain size distribution

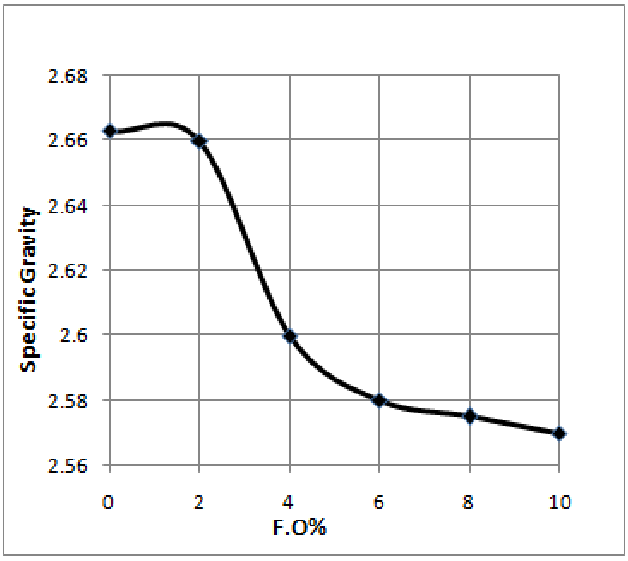

Figure (2) The effect of fuel oil content on specific gravity

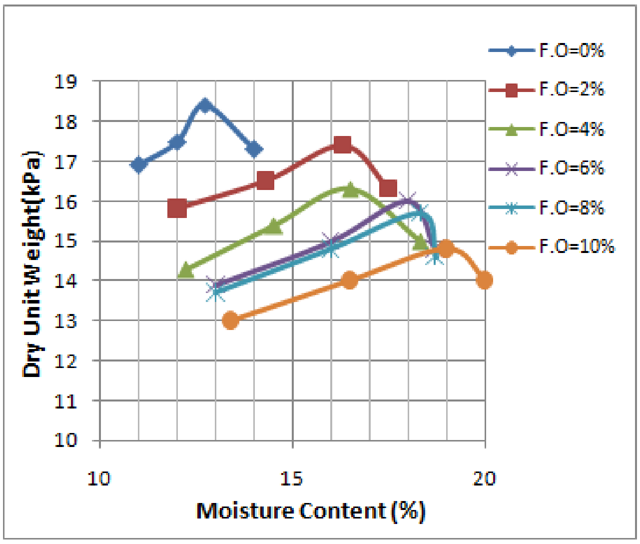

Figure (3) Moisture content-Dry unit weight relationship with different fuel oil content

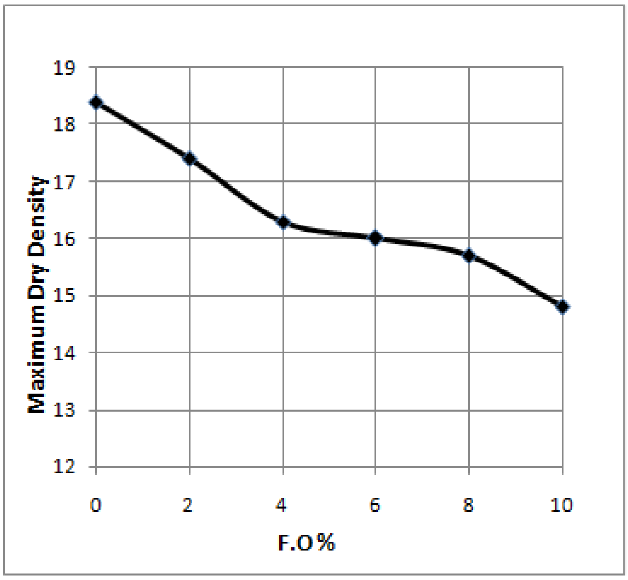

Figure (4) Variation of maximum dry density with different fuel oil content

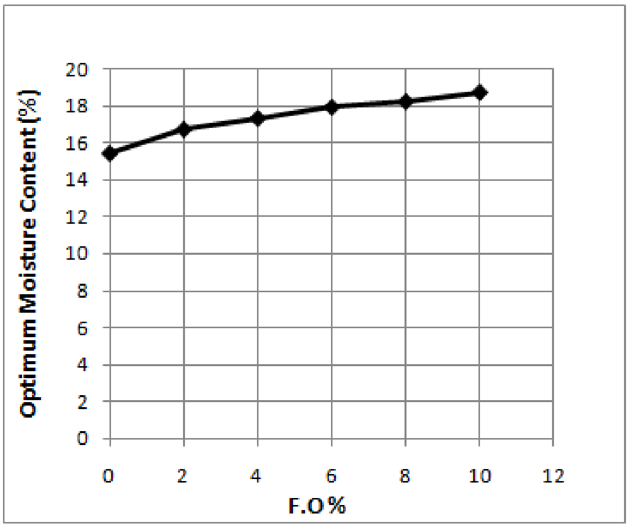

Figure (5) Variation of optimum moisture content with different fuel oil content

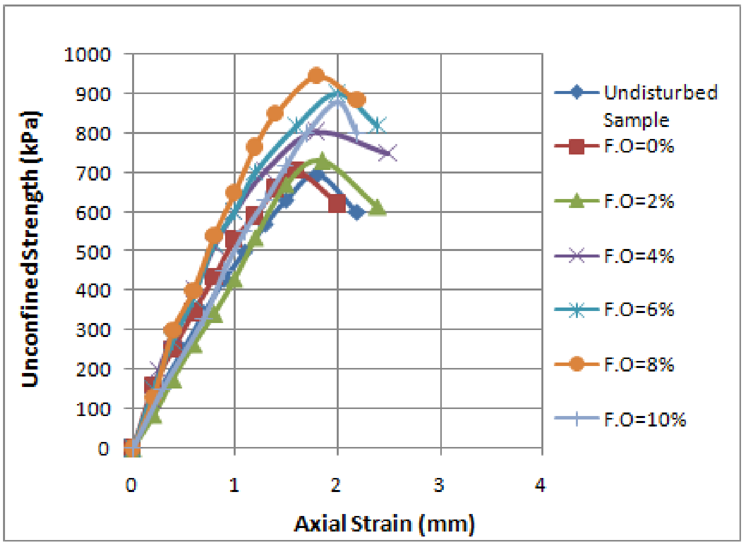

Figure (6) Stress-strain relationship for unconfined compression tests for unsoaked samples

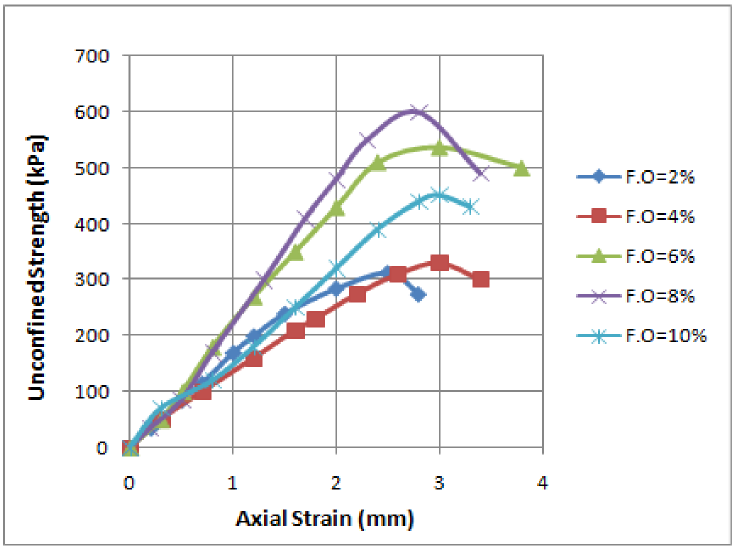

Figure (7) Stress-strain relationship for unconfined compression tests for soaked samples

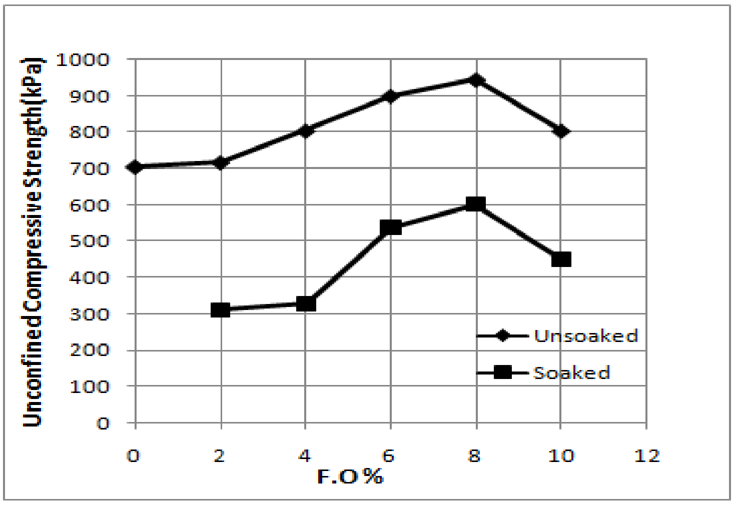

Figure (8) Effect of fuel oil content on the maximum unconfined compressive strength tests

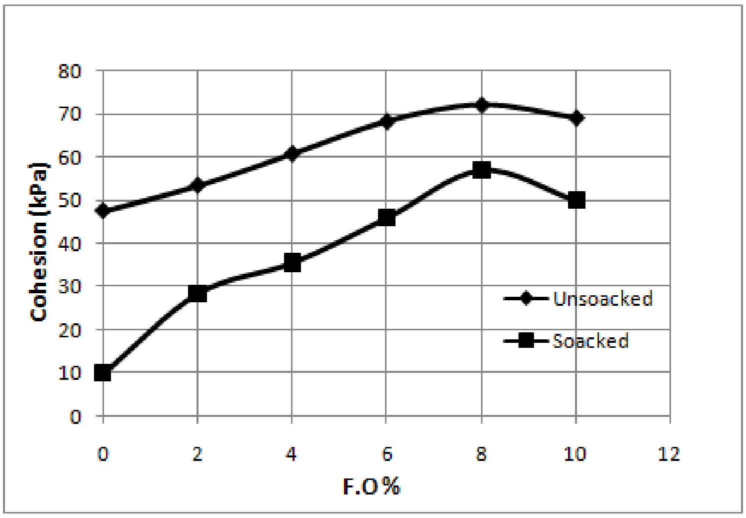

Figure (9) Effect of fuel oil content on the cohesion of samples (c)

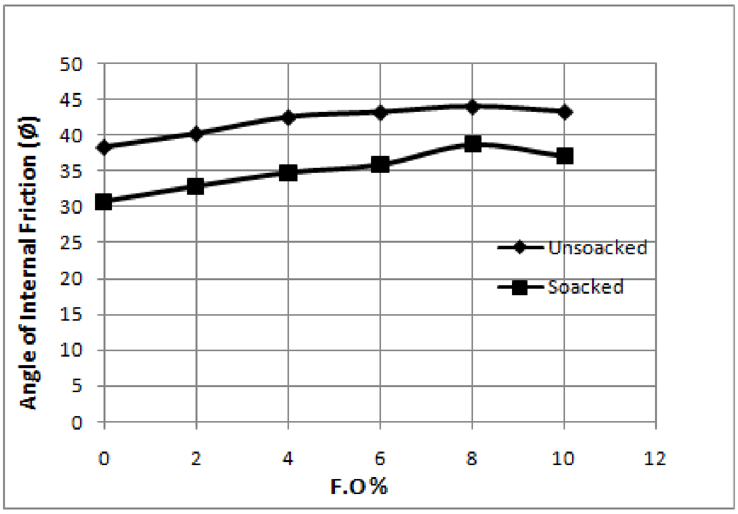

Figure (10) Effect of fuel oil content on the angle of internal friction (Ø)

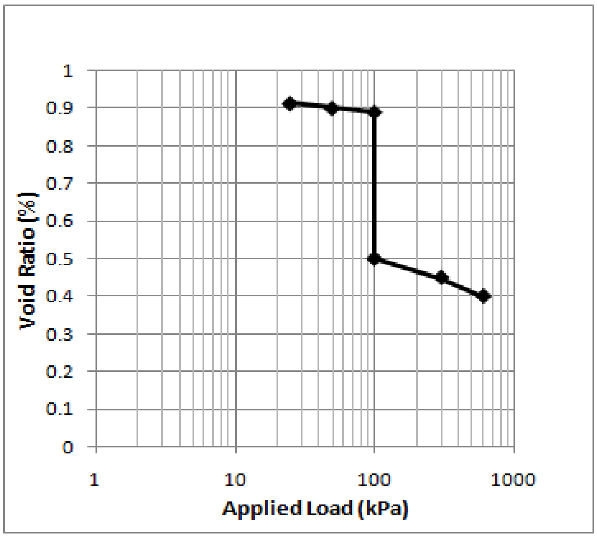

Figure (11, a) Applied load-void ratio relationship for undisturbed sample

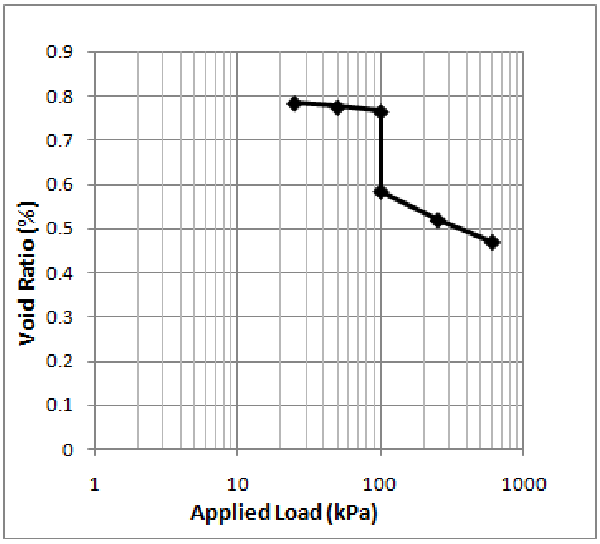

Figure (11, b) Applied load-void ratio relationship for disturbed sample (treated with 2% fuel oil)

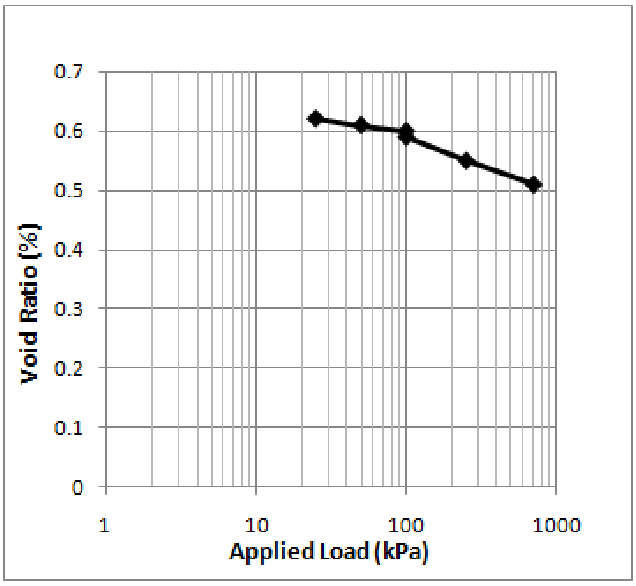

Figure (11, c) Applied load-void ratio relationship for disturbed sample (treated with 8% fuel oil)

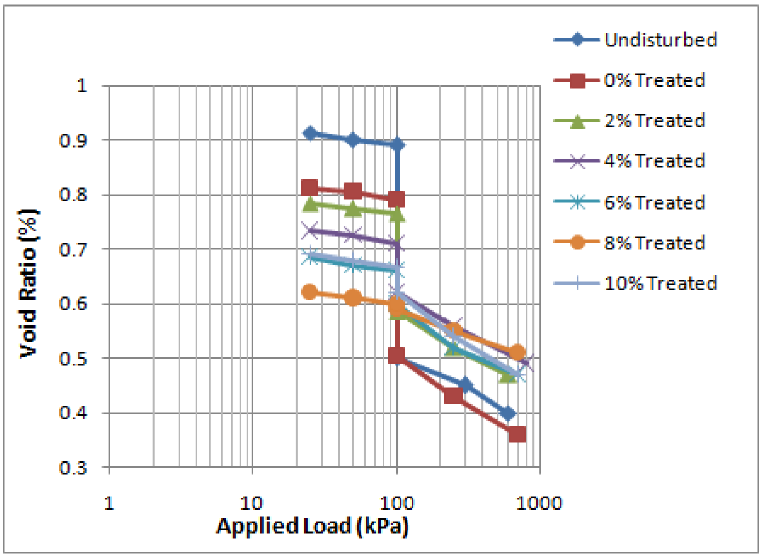

Figure (12) Applied load-void ratio relationship treated with different fuel oil content

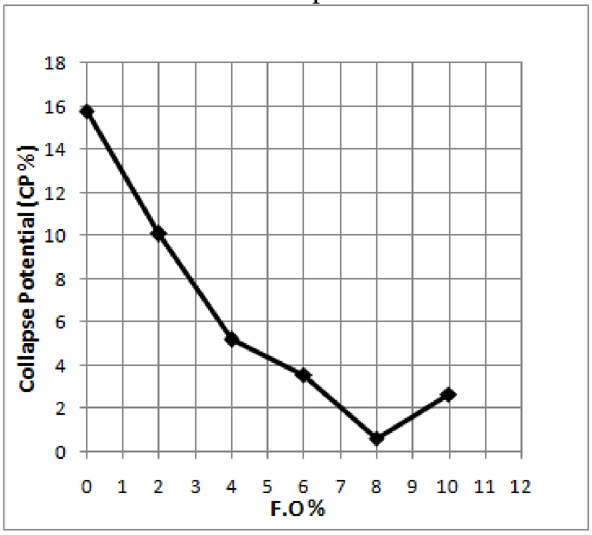

Figure (13) The effect of fuel oil content on collapse potential

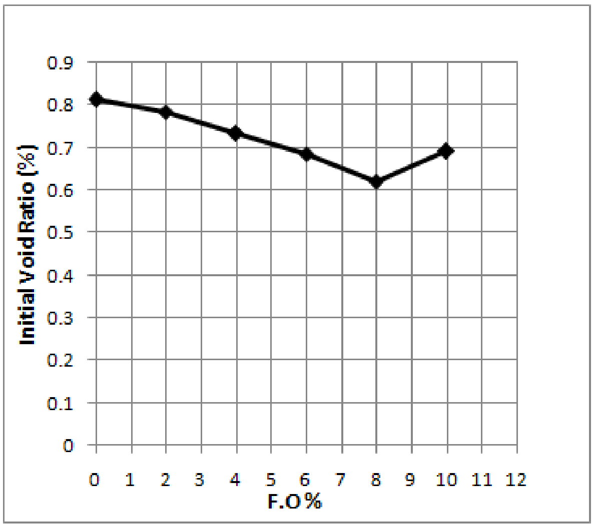

Figure (14) The effect of fuel oil content on initial void ratio

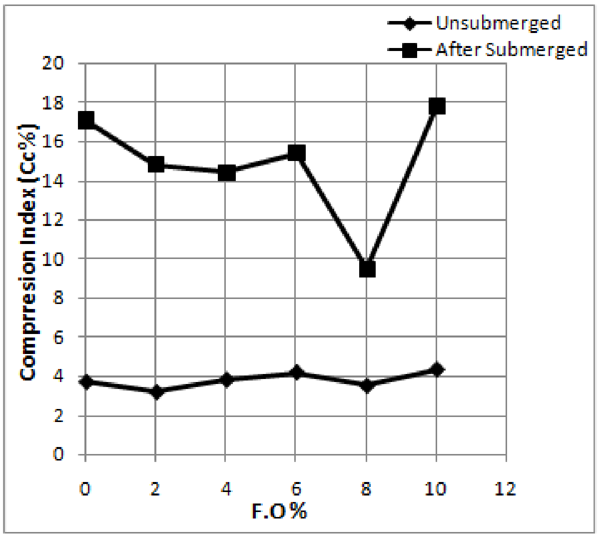

Figure (15) The effect of fuel oil content on compression index (Cc)

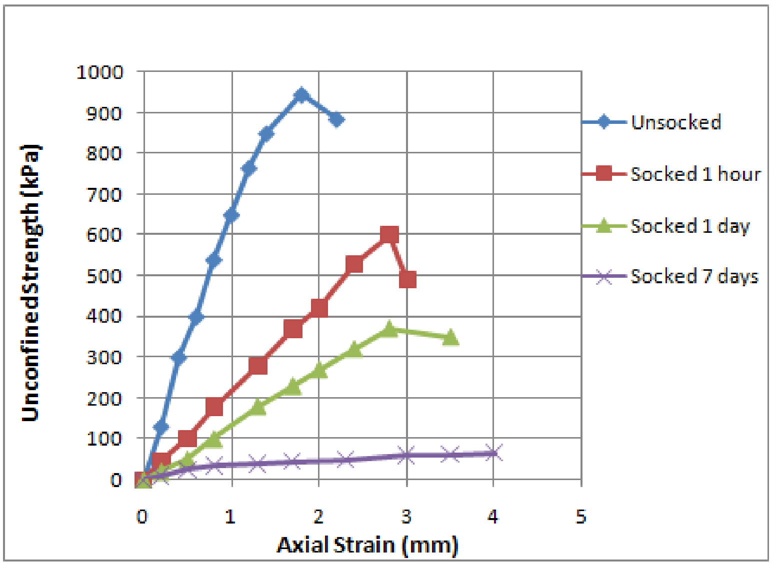

Figure (16) Axial strain-unconfined strength relationship for several period of soaking samples treated with 8% fuel oil content

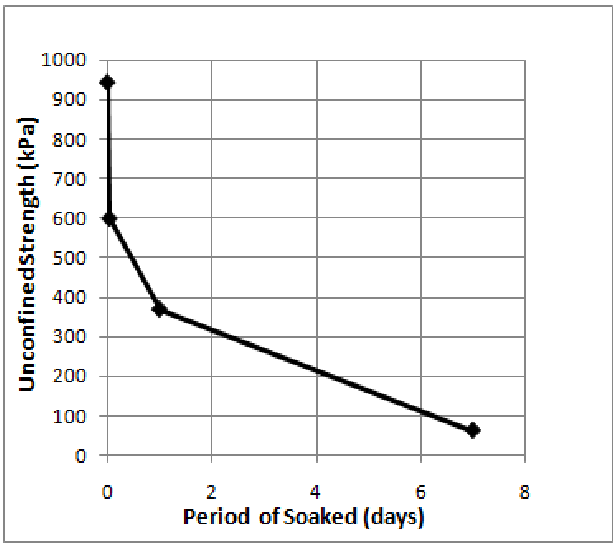

Figure (17) Effect of period of soaking on unconfined strength for 8% fuel oil content

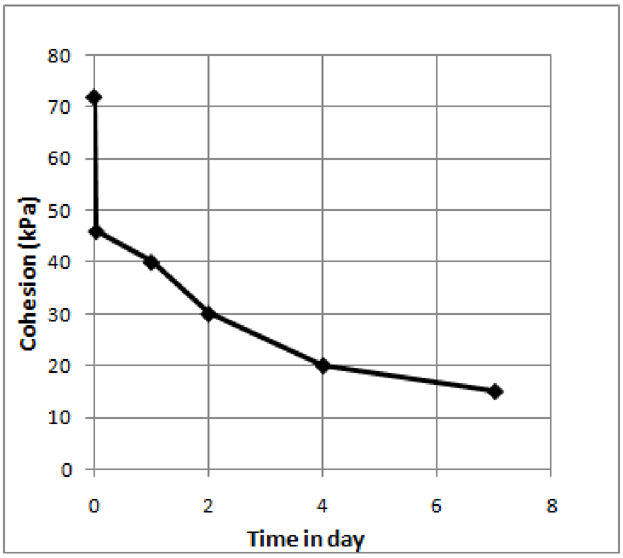

Figure (18) Effect of period of soaking on cohesion for 8% fuel oil content

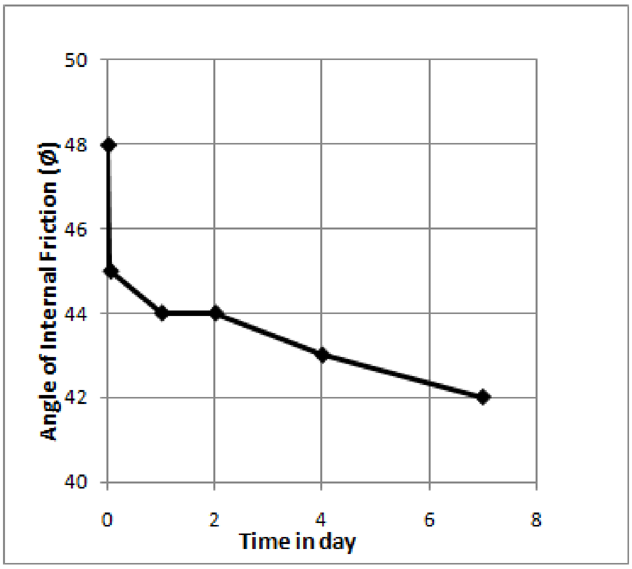

Figure (19) Effect of period of soaking on angle of internal friction for 8% fuel oil content

دراسة تأثير زيت الوقود السائل على الخصائص الهندسية للتربة الجبسية

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المقدمة

من المشاكل الهندسية التي تواجه المهندس المدني في أعمال إنشاء المباني هو وجود التربة الجبسية. والجبس من الأملاح السريعة الذوبان في الماء بزيادة المحتوى الرطوبي للتربة. هنالك العديد من المعالجات لهذه الترب منها استبدال التربة والتسليح والحدل و إضافة الاسفلت وألنوره وزيت الوقود وغيرها من الطرق الأخرى.

في هذه الدراسة سيتم دراسة إمكانية تحسين خصائص التربة الجبسية وذلك باستخدام تقنية إضافة زيت الوقود والمتوفر محليا وبكلفة منخفضة نسبيا إضافة إلى قدرته على تقليل تأثير الماء في التربة بنسب مختلفة (2, 4, 6, 8 و10%) للحصول على بيانات كافية.

أظهرت النتائج إن النسبة المثلى للمحتوى المائي تتزايد والكثافة العظمى تتناقص بزيادة نسبة زيت الوقود السائل. وكذلك مقاومة الانضغاط غير المحصور للتربة وتماسك التربة وزاوية الاحتكاك الداخلي تزداد قيمتها بحوالي (34%), (52%) و (15%) بالتتابع بزيادة نسبة زيت الوقود السائل عند النسبة المثلى للمعالجة وهي (8%) ثم تتناقص. وعندما تم غمر النماذج المعالجة والغير معالجة بالماء لوحظ تناقص قيم الانضغاط الغير محصور وتماسك التربة للتربة وزاوية الاحتكاك الداخلي بحوالي (37%), (21%) و (12%) بالتتابع. كما إن نسبة الفراغات الأولية للتربة ومعامل الانهيارية تتناقص قيمتها بحوالي (32%) و (90%) بالتتابع بزيادة محتوى زيت الوقود عند النسبة المثلى للمعالجة وهي (8%) ثم تزداد بزيادة محتوى زيت الوقود. أما معامل الانضغاطية فانه يتناقص بزيادة محتوى زيت الوقود السائل عند النسبة المثلى للمعالجة (8%) ثم يزداد بزيادته.

وأظهرت النتائج أن زيت الوقود هو مادة جيدة لتعديل الخصائص الأساسية للتربة الجبسية وان استخدام هذه المادة يساعد في تحسين الخصائص الهندسية للتربة الجبسية وتقليل انهياريتها وخصوصا بوجود الماء.

الكلمات المفتاحية: التربة الجبسية, زيت الوقود, الانهيارية, مقاومة القص