Tikrit Journal of Engineering Sciences (2022) 29 (3): 59-69
DOI: http://doi.org/10.25130/tjes.29.3.7

IRAQI Academic Scientific Journals

College of Engineering

ISSN: 1813-162X (Print); 2312-7589 (Online)

Tikrit Journal of Engineering Sciences

available online at: http://www.tj-es.com

TJES Tikrit Journal of Engineering Sciences

A Comparative Study for the Effect of Some Petroleum Products on the Engineering Properties of Gypseous Soils

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Keywords:

Gypseous soil; Engine oil; Fuel oil; Kerosene; Direct shear; Collapse potential

A R T I C L E I N F O

Article history:

Received	30 Aug. 2021
Accepted	23 Sep. 2022
Available online	15 Oct. 2022

Citation: Hamad AM, Jassam MG. A Comparative Study for the Effect of Some Petroleum Products on the Engineering Properties of Gypseous Soils. Tikrit Journal of Engineering Sciences 2022; 29(3): 59- 69.
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A B S T R A C T

Gypseous soils are considered problematic soils because the soil cavities happen during receiving the water or this type of soil and solving gypsum materials and contract in a soil volume. In this study, three types of gypseous soils are used; soil1, soil2, and soil3 with gypsum content (28.71%, 43.6%, and 54.88%) respectively, petroleum products (engine oil, fuel oil, and kerosene) are added to the soils with percentages (3%, 6%, 9%, and 12%) for each product. The result showed that specific gravity, liquid limit, optimum moisture content (O.M.C), and maximum dry density decreased with an increased percentage of product for all types of products. The direct shear (dry and soaked case) results show that increasing the (angle of internal friction and the soil cohesion) for soil1, soil2, and soil3 by adding engine oil and fuel oil. Still, when the soils were treated with kerosene, the angle of internal friction increased while cohesion decreased. The collapse potential for the treated soils increases with increasing gypsum content for all petroleum products. The collapse potential (CP) for (soil1) decreased by 47% when using 6% of the engine oil, 48.8% when using 9% of the fuel oil, and 55% when using 9% of the kerosene. The same percentage of the petroleum products (engine oil, fuel oil, and kerosene) decrease the collapse potential for (soil2), (47%, 46%, and 50%) respectively and decrease the collapse potential for (soil 3), (51%, 47.7%, and 52%) respectively. In the unconfined compressive test applied on (soil1) using maximum density, the results show that the soil strength increased (26% and 10%) when using 6% and engine oil and fuel oil, respectively, while the soil strength decreased by 29% when treated with 9% of kerosene.

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دراسة مقارنة لتأثير بعض المنتجات النفطية على الخواص الهندسية للترب الجبسية

عسل محمود حمد قسم الهندسة المدنية / كلية الهندسة / جامعة تكريت / العراق.
محمود غازي جسام قسم الهندسة المدنية / كلية الهندسة / جامعة تكريت / العراق.

الخلاصة

تعتبر التربة الجبسية من التربة المسببة للمشاكل، لأن التجاويف التي تحدث في التربة أثناء استقبال الماء لهذا النوع من التربة تحلل مواد الجبس وتقلل من حجم التربة. في هذه الدراسة تم استخدام ثلاثة أنواع من الترب الجبسية. تربة 1، تربة 2 وتربة 3 ذوات محتوى جبسي، (28.71٪، 43.6٪، 54.88٪) على التوالي، المنتجات البترولية (زيت المحرك، زيت الوقود، النفط الابيض) اضيفت الى الترب بنسب (3٪، 6٪، 9٪، 12٪) لكل منتج .أظهرت النتائج أن الوزن النوعي وحد السيوله ومحتوى الرطوبة الأمثل (O.M.C) والكثافة الجافة العظمى انخفضت مع زيادة نسبة المنتج النفطي لجميع انواع المنتجات. أظهرت نتائج القص المباشر (الحالة الجافه والمغمورة) زيادة زاوية الاحتكاك الداخلي والتماسك عند اضافة زيت المحرك وزيت الوقود ولكن عند معالجة الترب بالنفط الابيض لوحظ زيادة زاوية الاحتكاك الداخلي بينما انخفضت قيمة التماسك. مؤشر الانهيار CP)) لـ (التربة 1) انخفض بنسبة 47٪ عند استخدام 6٪ من زيت المحرك، 48.8٪ عند استخدام 9٪ من زيت الوقود و55٪ عند استخدام 9٪ من الكيروسين. تعمل نفس النسبة من المنتجات البترولية (زيت المحرك، زيت الوقود، الكيروسين) على تقليل احتمالية الانهيار (للتربة 2)، بنسب (47٪، 46٪، 50٪) على التوالي وتقليل احتمال الانهيار لـ (التربة 3)، (51٪، 47.7٪ و52٪) على التوالي. تزداد إمكانية الانهيار للتربة المعالجة مع زيادة محتوى الجبس لجميع المنتجات البترولية .فحص الانضغاط غير المحصور اجري على (التربة 1) باستخدام الكثافة العظمى، وأظهرت النتائج أن قوة التربة زادت (26٪ و10٪) عند استخدام 6٪ من زيت المحرك و9٪ زيت الوقود على التوالي بينما تنخفض قوة التربة 29 ٪ عند معالجتها بـ 9٪ من الكيروسين.

الكلمات الدالة: تربة جبسية، زيت محرك، زيت وقود، نفط ابيض، القص المباشر، احتمالية الانهيار.

1. INTRODUCTION

The gypseous soil is considered one of the challenges that civil engineering must be prepared with carefully because gypsum mineral ($CaSO_4$) dissolves in the water, changes the soil mass underneath the structure, and makes cavitation in the soil, so it must protect the particles of this soil from the water. Most gypseous soil is in arid and semi-arid areas [1]. Gypseous soils have behavior in the laboratory significantly different from the field because the laboratory behavior depends on the soil weather. Also, the initial water content, gypsum content, the initial void ratio, and over-consolidation pressure all control the behavior of the gypseous soils in the laboratory and field [2]. The engine oil's effect on gypseous soil permeability was studied using two types of soils (26% gypsum content, and 51% gypsum content). The results show that the soil permeability decreases with the increase in engine oil percentage [3]. conducted a triaxial test on soil treated with fuel oil. The results show that increasing the angle of internal friction and decreasing the soil cohesion is conducted by increasing fuel oil percentage [4]. Used petroleum production as an addition to the soil properties. The results show that the soil cohesion value increases with an increase in asphalt percentage until reaching the optimum value of asphalt after decreasing the soil cohesion with increasing the asphalt percentage. The angle of internal friction decreased with increased asphalt content because the asphalt reduces the friction between the soil particles [5]. Performed anon-confined compressive strength test with a direct shear test to find the cohesion and angle of internal friction for the soil and conducted with untreated and treated soils with different percentages of Cut-Back asphalt (Rc-70) with the dry and wet conditions [6]. The results showed that the maximum density decreases and the optimum moisture content increase with an increase in liquid asphalt percentage. Also, the unconfined test for the soil increase (33%) at the optimum value of the liquid asphalt percentage is equal to (6%). The soil cohesion increases to (70%) percent at the (6%) percent of the liquid asphalt, then decrease with the rise of the liquid asphalt, and the angle of internal friction is not affected by the liquid asphalt. When the soil is flooded with water, it is found that the soil strength for the unconfined pressure and soil cohesion decreases by about (50%) and (38%) respectively. Used the fuel oil taken from AL-Dura Refinery has (9.3 kN/m^3) density, to treat the gypseous soils (51.6%and26.55% gypsum content) that brought from the AL-Tharthar region, the results showed improved (cohesion, permeability, and collapsibility) of soils with increase the fuel oil percentage [7]. They used two percentages (10% and 20%) of fuel oil studies on the effect of petroleum on clay soil properties. The results showed various effects of this material on the soil properties, such as decreasing the soil strength [8].

2. EXPERIMENTAL PROGRAM

2.1. The gypseous soils

The samples were brought from the Tikrit University site in Salah Al-Dean Governorate at a depth of 1.5 meters below ground level. Three gypseous soils with different gypsum content; Soil 1 (28.71%), Soil 2 (43.6%), and Soil 3 (54.88%), are used in this research to study the effect of some petroleum products with different percentages on their physical and engineering properties.

2.2. Engine oil

Engine oil is one of the crude oil products used to improve the three gypseous soils because it is available in Iraq at a cheap cost compared to other materials used for soil improvement.

2.3. Fuel oil

It is also one of the crude oil products available in Iraq at a cheap cost compared with other improvement materials.

2.4. Kerosene

It is one of the most common types of oil products and is used in heating. It was chosen to conduct laboratory tests on the three types of gypseous soils mentioned above. It is available, cheap. The petroleum products' engineering properties (density, Specific gravity, and viscosity) are shown in Table 1.

Table 1 The physical properties of petroleum products.

PRODUCTS PROPERTIES	ENGINE OIL	FUEL OIL	KEROSENE
DENSITY (kN/m³)	8.9	8.5	7.9
SPECIFIC GRAVITY	0.873	0.833	0.785
VISCOSITY (POISE)	12.5	5.6	1.02

3. RESULTS AND DISCUSSION

The tests in this search are divided into (physical, chemical, and engineering) tests conducted on three types of soils; soil 1 (28.71% gypsum content), soil 2 (43.6% gypsum content), and soil 3 (54.88% gypsum content), physical and engineering tests also divided into two groups of soil, the first group including the natural soil and the second group including the gypseous soils that treated by the petroleum products (engine oil, fuel oil, and kerosene) with the percentage of (3%, 6%, 9%, and 12%). The engineering tests include shear strength tests such as a direct shear test for the soaked and dry conditions, unconfined compressive tests, and collapsibility tests for three types of gypseous soils.

3.1. Physical tests

3.1.1. Particle size distribution

According to (ASTM D422), particle-size distribution is conducted on the three types of soils (28.71% gypsum content, 43.6% gypsum content, and 54.88% gypsum content) using dry sieving. The samples were passed on sieve No. 4 after drying the soil in the oven under 45°C for 24 hours to avoid burning the gypsum material. The results showed that the soil is classified as poorly graded sand according to the unified soil classification system (USCS); particle size distribution results are shown in Fig. 1.

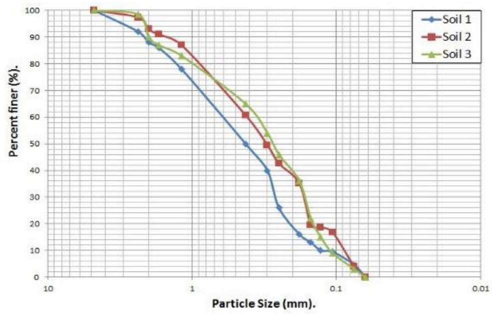


Fig. 1. Particle size distribution for the used soils.

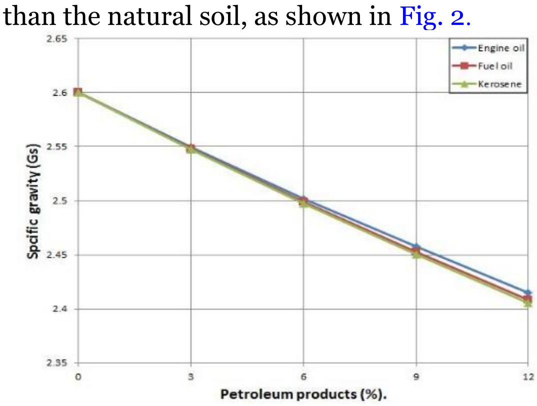
The results of the physical properties of the naturally used soils are summarized in Table 2.

Table 2 Physical properties of the used gypseous soils.

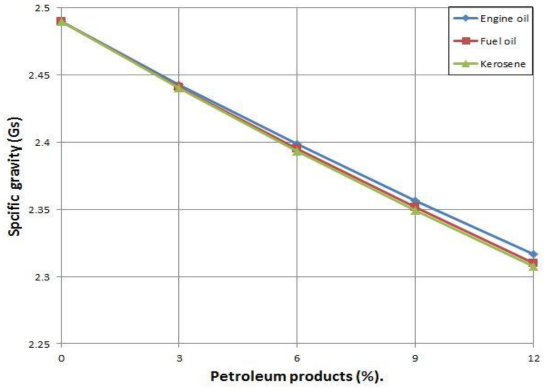
PROPERTIES	SOIL 1 (28.71% G.C.)	SOIL 2 (43.6% G.C.)	SOIL 3 (54.88% G.C.)
MOISTURE CONTENT (%)	10.2	9.6	9.8
SPECIFIC GRAVITY (Gs)	2.6	2.56	2.49
UNIFIED SOIL CLASSIFICATION	SP	SP	SP
LIQUID LIMIT (L.L)%	23.6%	22.6%	21.7%
PLASTIC LIMIT (P.L)%	N.P	N.P	NP
FIELD UNIT WEIGHT (KN/M³)	14.26	14.1	13.77
MAXIMUM DRY UNIT WEIGHT (KN/M³)	17.7	17.1	16.7
OPTIMUM MOISTURE CONTENT % (O.M.C)	15.5	15	14

3.1.2. Specific gravity (Gs)

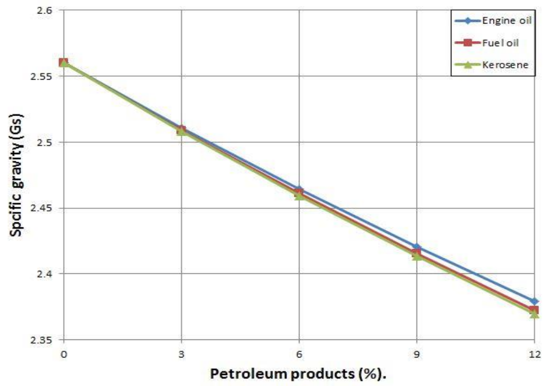
This test is conducted on the soil according to the (ASTM D854). In this test, kerosene was used instead of water to avoid the gypsum solution in the water (Head, 1982). The results showed that the specific gravity for all soil decreased with the added petroleum products because the density of the petroleum products (engine oil, fuel oil, and kerosene) are low compared to soil density. The specific gravity for petroleum productions are less than the specific gravity for the soil, and the density of the soil mixed with oil products will become less than the natural soil, as shown in Fig. 2.



(Soil1)



(Soil2)

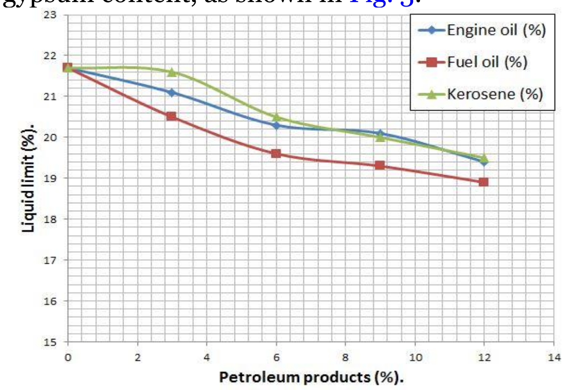


(Soil3)

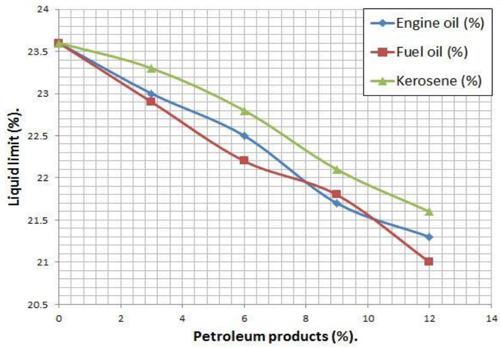
Fig.2. Change in specific gravity with petroleum products

3.1.3. Atterberg Limit

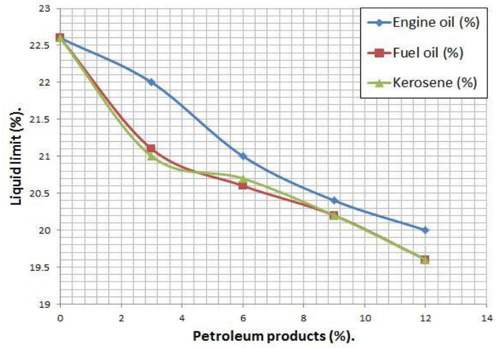
Atterberg limit tests are conducted according to the specification **(ASTM D4318).** All the samples passing through sieve No. 40 before using in the test, the Atterberg limit is considered very important because the soil classification depends on the Atterberg limit, so any change in the Atterberg limit (liquid limit and plastic limit) leads to a change the soil classification**.** The results showed that the liquid limit decreases with increasing the percentage of petroleum products (engine oil, fuel oil, and kerosene) with ratios. Also, the liquid limit decreases with increasing the gypsum content, as shown in Fig. 3.



(Soil1)



(Soil2)



(Soil3)

Fig.3. Effect of petroleum products on the liquid limit of gypseous soils

3.1.4. Field density

The sand cone method is used to find the field density and the water content according to **ASTM D1556;** the soil sample putting in a plastic bag to prevent water evaporation from the soil during the transportation operation of the soil samples to the laboratory. The results showed that the field density decreases with increasing gypsum content, as shown in Fig. 4 because the density of the gypsum material is less than the natural soil.

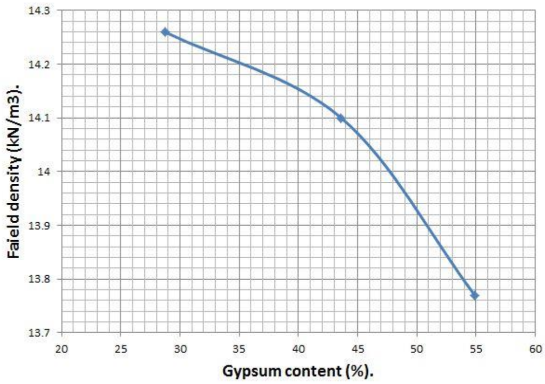
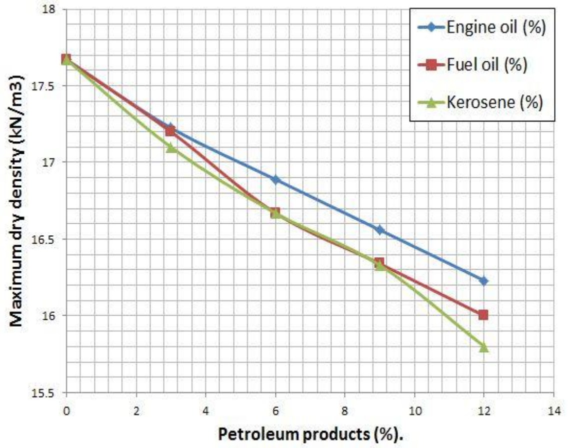


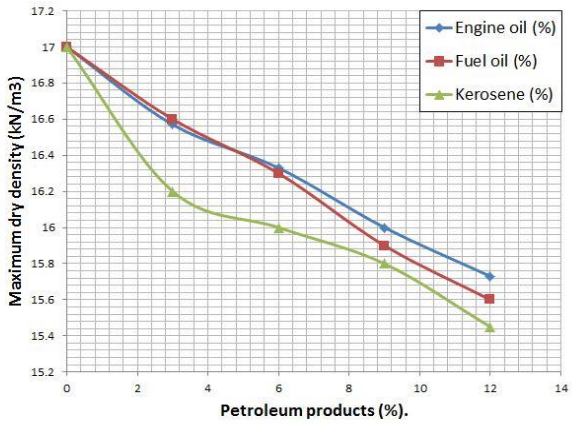
Fig.4. The relationship between the gypsum content and field density (y-axis, kN/m3 change to kN/m3)

3.1.5. Standard proctor compaction

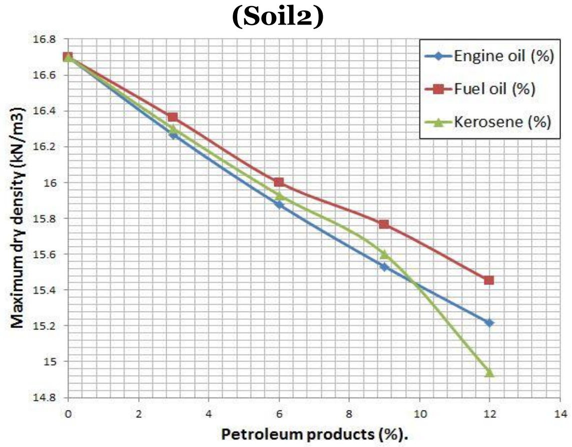
To find the maximum density and the optimum moisture content by using the standard Procter compaction method according to specification **(ASTM D698-91),** the samples of soils passed through sieve No.4 before using in the test; the results showed a clear decrease in the value of maximum dry density and the optimum moisture content with increasing the percentage of the petroleum products because the density for the petroleum productions are less than the soil density, some of the voids in the soil will be occupied by the oil products which will reduce the water content required to reaching the soil to the optimum water content. The variation of maximum dry density with petroleum products is shown in Fig. 5.



(Soil1)



(Soil2)



(Soil3)

Fig.5. Effect of petroleum products on the maximum dry density of gypseous soils

3.2. Chemical tests

The chemical tests are conducted on the sample in the laboratory for the Chemical Engineering Department at Tikrit University; the results are summarized in Table 3.

TYPE OF SOIL	SOIL 1	SOIL 2	SOIL 3
GYPSUM CONTENT(%)	28.71%	43.6%	54.88%
TOTAL SULFATE CONTENT(T.D.S) %	31.49%	49.08%	67.33%
P_H VALUE	7.89	7.83	8.01
ORGANIC	0.94%	0.68%	0.97%

Table 3 Chemical composition of the used gypseous soils.

3.3. Engineering tests

3.3.1. Direct shear test

The results of the direct shear tests for the soils used in this study are according to the specification **(ASTM D3080-72)** for the two conditions (soaked and dry) cases for three types of soils (28.71% gypsum content, 43.6% gypsum content, and 54.88% gypsum content).

3.3.1.1. Soil 1 (Dry case)

The results showed that the angle of internal friction for the soil that has gypsum content of 28.71% increased from (33.42°) for the natural soil to the (34.6°) when the adding ratio is (6%) of the engine oil, the angle of internal friction decreases with increasing the engine oil percentage. The soil cohesion increases from (8.8) kPa for the natural soil to (11) kPa with an increasing the engine oil percentage to receive (6%). When the fuel oil was used as an improvement material, an increase in the angle of internal friction from (33.42°) for the natural soil to the (34.7°) is observed when adding (9%) of fuel oil to the soil; The soil cohesion increased from (8.8) kPa to (10) kPa with increasing the fuel oil percentage to reach (9%). The optimum value of the fuel oil used to improve soil 1 (28.71% gypsum content) is (9%). The effect of the kerosene is significant on the angle of internal friction of the soil that has (28.71% gypsum content), which increases the angle of internal friction from 33.42° for the natural soil to (36.87°) when adding (9%) of the kerosene to the soil, The soil cohesion decreases from (8.8) kPa to (6.3) kPa with increasing the kerosene percentage to reach (9%). The reduction in the cohesion of soil and a significant increase in the angle of internal friction because the kerosene increases the angles sharpening of the soil particles and conglomerates the soil particles so increasing the angle of internal friction, also solving the physical bonds between the grains of this soil and decreeing the soil cohesion. The results are shown in Fig. 6.

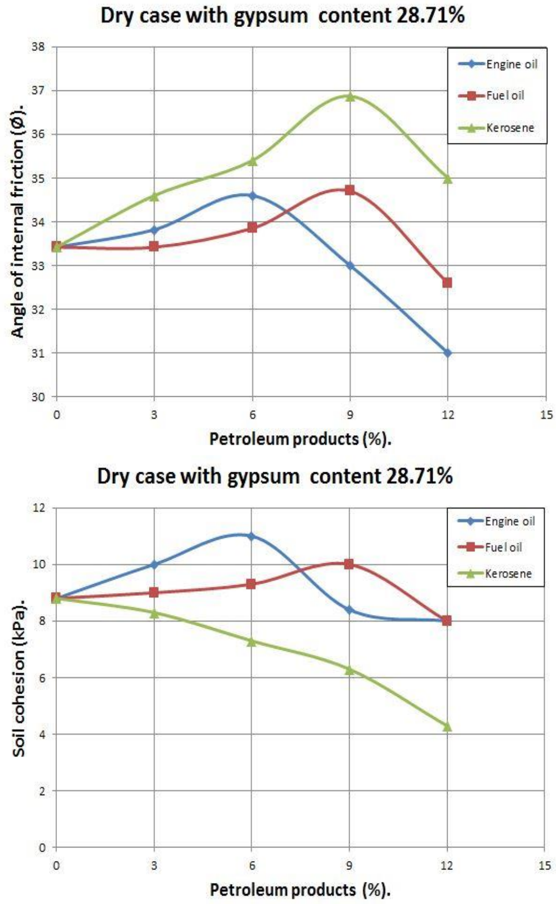
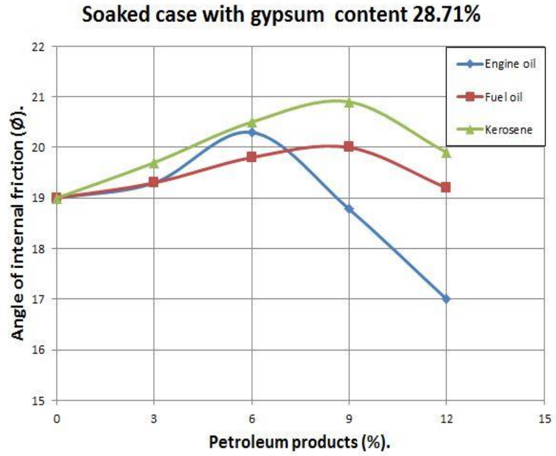


Fig. 6. The relationship between the (angle of internal friction - cohesion) and petroleum products for soil 1 (dry case).

3.3.1.2. Soil 1 (Soaked case)

The results showed that the angle of internal friction for the soil that has gypsum content of 28.71% increased from (19^o) for the natural soil to the (20.3^o) when the adding ratio is (6%) of the engine oil to the soil, the angle of internal friction decreases with increasing the engine oil percentage. The soil cohesion increased from (5) kPa for the natural soil to (8.8) kPa with increasing the engine oil percentage to (6%). Fuel oil is an improvement material that increases the angle of internal friction from (19^o) for the natural soil to the (20.5^o) when adding (9%) of fuel oil to the soil, after this value, the angle of internal friction decrease with increasing fuel oil percentage; the soil cohesion increases from (5) kPa to (8.7) kPa with increasing the fuel oil percentage to (9%). The effect of the kerosene is significant on the angle of internal friction of the soil that has (28.71%) gypsum content, which increases the angle of internal friction from (19^o) for the natural soil to (21.8^o) when adding (9%) of the kerosene to the soil, after this value, the angle of internal friction decreases with increasing kerosene. The results are shown in Fig. 7. The soil cohesion decreased from (5) kPa to (3.34) kPa with increasing the kerosene percentage to reach (9%).



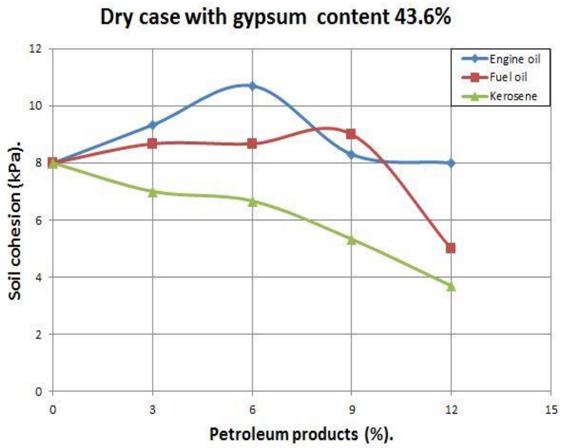


Fig. 7. The relationship between the (angle of internal friction - cohesion) and petroleum products for soil 1 (soaked case)

3.3.1.3. Soil 2 (Dry case)

The direct shear test was conducted on the soil samples with 43.6% gypsum content, using the field density (14.1 kN/m3). The results showed that the angle of internal friction for the soil has a gypsum content of 43.6% increased from (33^o) for the natural soil to the (34.5^o) when the adding ratio is (6%) of the engine oil and the soil cohesion increases from (8) kPa for the natural soil to (10.7) kPa with increasing engine oil percentage to (6%). When used fuel oil, the angle of internal friction increases from (33^o) for the natural soil to the (34.6^o) when adding (9%) of fuel oil to the soil due to the conglomerate of the soil particles, beyond this value, the angle of internal friction decrease with increasing fuel oil percentage, and soil cohesion increase from (8) kPa to(9) kPa with increasing the fuel oil percentage to (9%), results were also showed that the effect of the fuel oil on the soil cohesion is less than that of the engine oil on the same parameter. The effect of the kerosene is significant on the angle of internal friction of the soil that has (43.6%) gypsum content, which increases the angle of internal friction from (33^o) for the natural soil to (35.6^o), when adding (9%) of the kerosene to the soil, after this value, the angle of internal friction decrease with increasing kerosene; the soil cohesion decreases from (8) kPa to (5.33) kPa with increasing the kerosene percentage to (9%). The results are shown in Fig. 8. The optimum value of the kerosene used to improve the soil with (43.6%) gypsum content is (9%).

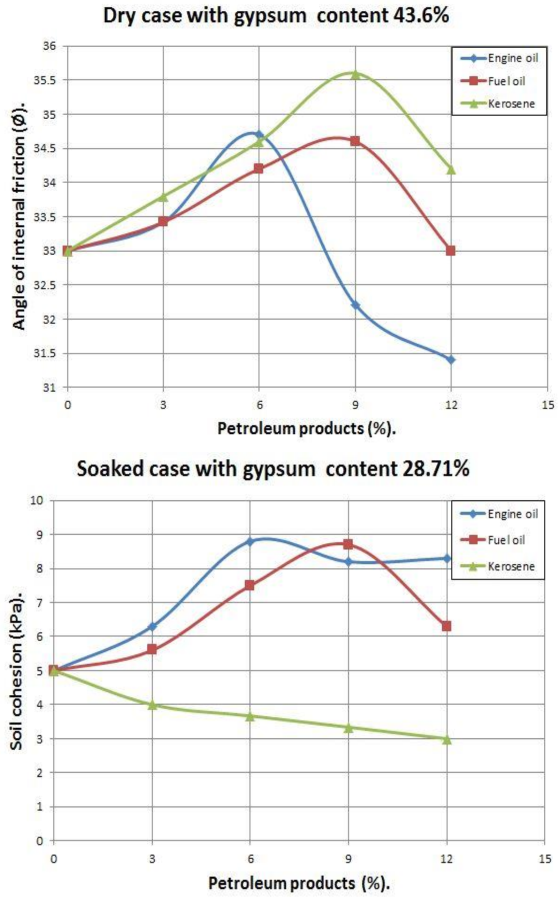


Fig. 8. The relationship between the (angle of internal friction- soil cohesion) and petroleum products for soil 2 (dry case)

3.3.1.4. Soil 2 (Soaked case)

Direct shear results showed that the angle of internal friction for soil 2 (43.6% gypsum content) increased from (18.5^o) for the natural soil to (19.8^o) when the adding ratio is (6%) of the engine oil. After this value, the angle of internal friction decreases with increasing the percentage of engine oil. Soil cohesion increased from (4) kPa for the natural soil to (7.3) kPa with increasing the engine oil percentage to (6%). The optimum value of the engine oil to improve the gypseous soil that has 43.6% gypsum content is (6%), which increases the angle of internal friction. improvement in the soil cohesion is also more significant than the improvement in the angle of internal friction due to the viscosity of the engine oil. The angle of internal friction increased from (18.5^o) for the natural soil to the (20^o) when adding (9%) fuel oil to the soil, the angle of internal friction decreases with increasing fuel oil percentage. The soil cohesion increases from (4) kPa to (6.67) kPa with increasing the fuel oil percentage to (9%. The effect of the kerosene is significant on the angle of internal friction of the soil that has (43.6%) gypsum content, which increases the angle of internal friction from (18.5^o) for the natural soil to (21.3^o) when adding (9%) of the kerosene to the soil, after this value the angle of internal friction decrease with increasing kerosene. Soil cohesion decreased from (4) kPa to (3.3) kPa with increasing the kerosene percentage to reach (9%). The results are shown in Fig. 9.

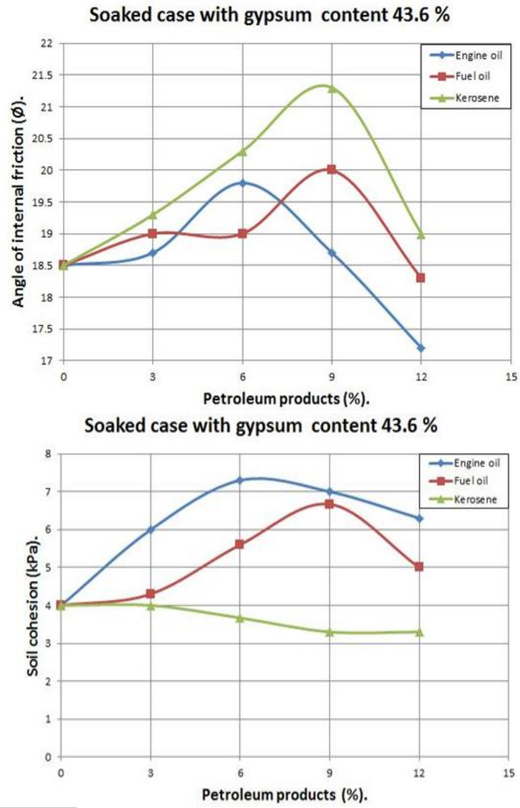


Fig.9. The relationship between the (angle of internal friction- soil cohesion) and petroleum products for soil 2 (soaked case).

3.3.1.5. Soil 3 (Dry case)

The direct shear test was conducted on the soil samples that have 54.88% gypsum content, by using the field density (13.77 kN/m3) with adding the petroleum products (engine oil, fuel oil, and kerosene) with a different percentage value. The results showed that the angle of internal friction for the soil increased from (32.62^o) for the natural soil to the (34.2^o) when the adding ratio is (6%) of the engine oil, after that the angle of internal friction decrease with increasing the engine oil percentage. The soil cohesion increases from (7.5) kPa for the natural soil to (9) kPa with increasing the engine oil percentage to (6%). When used fuel oil, the angle of internal friction increases from (32.62^o) for the natural soil to the (34.2^o) when adding (9%) of fuel oil to the soil, beyond this value the angle of internal friction decreases with increasing fuel oil percentage. Soil cohesion increases from (7.5) kPa to (8.2) kPa with increasing the fuel oil percentage to (9%). The results showed that the soil cohesion decreased with increasing gypsum content in the soil because of the cohesion between the soil particle greater than the adhesion between the soil practical and gypsum. The effect of the kerosene is significant on the angle of internal friction of the soil that has (54.88%) gypsum content, which increases the angle of internal friction from (32.62^o) for the natural soil to (36.5^o), when adding (9%) of the kerosene, then the angle of internal friction value decrease with increasing kerosene. The soil cohesion is decreased from (7.5) kPa to (5) kPa by increasing the kerosene percentage to (9%). The result showed that the kerosene improves the angle of internal friction of the gypseous soil greater than the fuel oil and engine oil because it conglomerates the soil particles more than engine oil and fuel oil, viscosity in the kerosene is less than the viscosity of the fuel oil and engine oil which increase the slip of the soil particles on others on reciprocal. The results are shown in Fig. 10.

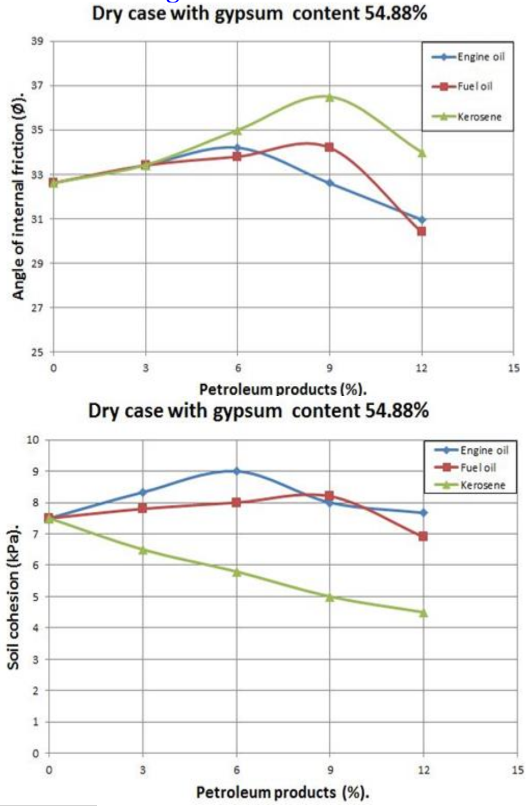


Fig. 10. The relationship between the (angle of internal friction- soil cohesion) and petroleum products for soil 3 (dry case).

3.3.1.6. Soil 3 (Soaked case)

The results showed that the angle of internal friction for the soil that has gypsum content of 54.88% increased from (17.74^o) for the natural soil to the (19.3^o) when the adding ratio is (6%) of the engine oil to the soil. The soil cohesion increases from (4) kPa for the natural soil to (7) kPa with increasing the engine oil percentage to (6%). When used fuel oil as an improvement material, the angle of internal friction increased from (17.74^o) for the natural soil to the (20^o) when adding (9%) of fuel oil to the soil, then the angle of internal friction value decrease with increasing fuel oil percentage. The soil cohesion increases from (4) kPa to (6.6) kPa with increasing the fuel oil percentage to (9%). The effect of the kerosene is significant on the angle of internal friction of the soil that has (54.88%) gypsum content, which increases the angle of internal friction from (17.74^o) for the natural soil to (20.8^o), when adding (9%) of the kerosene to the soil, after this value the angle of internal friction decreases with increasing kerosene. The soil cohesion decreases from (4) kPa to (3) kPa with increasing the kerosene percentage to (9%). The results are shown in Fig. 11.

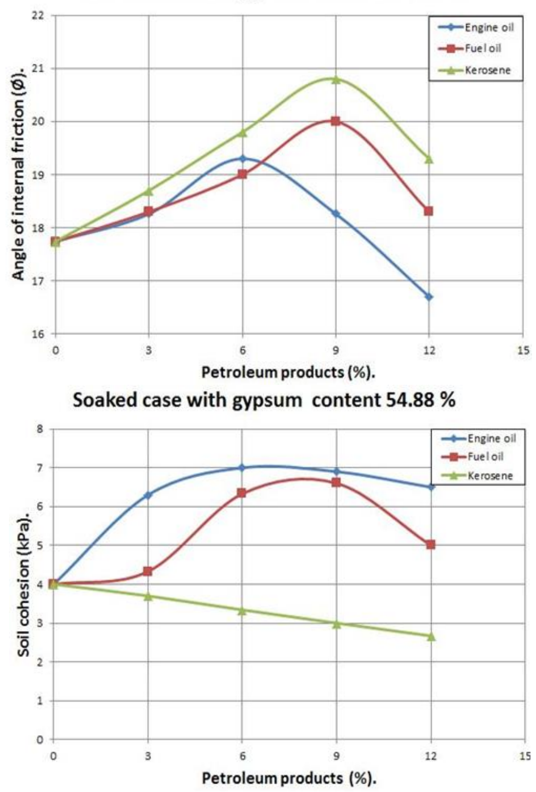


Fig.11. The relationship between the (angle of internal friction- soil cohesion) and petroleum products for soil. 3 (soaked case).

3.3.2. Collapsibility characteristics

Double odometer test depends on **(ASTM D5333-92)** used to find collapse potential (CP) for natural soils. The values of collapse potential are (10.05, 10.5, and 11.75) for soil 1, soil 2, and soil 3, respectively which means that these soils are severe trouble soils according to [8]; therefore, it is important to treat these soils to reduce its compressibility characteristics.

3.3.2.1. Soil 1 (28.71% gypsum content)

A double oedometer test was conducted on natural and treated soil 1 (28.71 gypsum content). The soil density used in this test is the natural density, which is equal to (14.26 kN/m^3) and the initial void ratio (e_o = 0.998) with the natural moisture content. The results showed that the collapse potential decreased from 10.05% in the natural soil to (5.25%) in the soil treated with (6%) engine oil, after that the collapse potential begin to increase with the increase in the engine oil. When using the fuel oil, the collapse potential decrease to (5.15%) at the percentage of the fuel oil (9%), after this value the collapse potential increase with the increase of the fuel oil. When using the kerosene, the collapse potential decreased to (4.5%) at (9%) percentage of kerosene, the percentage of kerosene (9%) consider is the ideal percentage which gave the smallest value of the collapse potential as shown in Fig. 12.

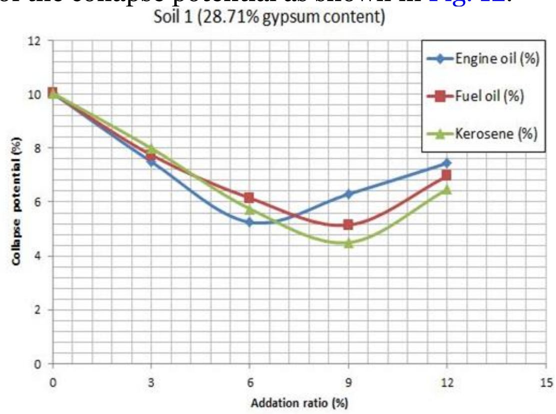


Fig.12. The relationship between the collapse potential and the petroleum products for the soil 1 (28.71% gypsum content)

3.3.2.2. Soil 2 (43.6% gypsum content)

Double odometer results show that the collapse potential decreased from 10.5% in the natural soil to (5.55%) in the soil treated with (6%) engine oil, after that the collapse potential begin to increase with the increase in the engine oil. When using the fuel oil, the collapse potential decrease to (5.65%) at the percentage of the fuel oil is (9%), after this value the collapse potential increase with the increase in the fuel oil. When using the kerosene the collapse potential decreased to (5.25%) at (9%) percentage of kerosene, percentage of kerosene (9%) consider is the ideal percentage which gave the smallest value of the collapse potential as shown in Fig. 13.

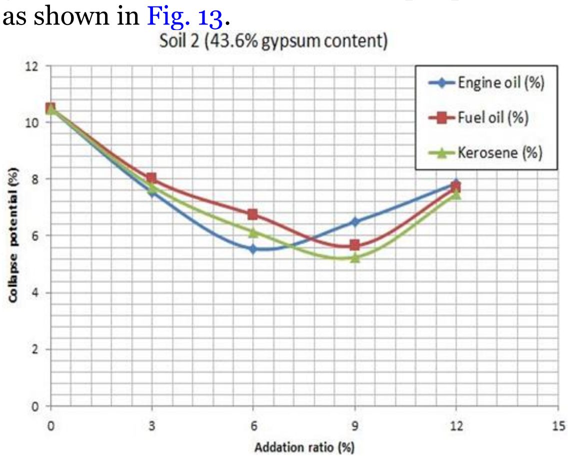


Fig. 13. The relationship between the collapse potential and the petroleum products for soil 2 (43.6% gypsum content).

3.3.2.3 Soil 3 (54.88% gypsum content)

The results showed that the collapse potential decreased from 11.75% in the natural soil to (5.75%) in the soil treated with (6%) engine oil, then the collapse potential begin to increase with the increase in the engine oil. When using the fuel oil, the collapse potential decrease to (6.15%) at the percentage of the fuel oil (9%), after this value the collapse potential increase with the increase in the fuel oil. When using the kerosene, the collapse potential decreased to (5.65%) at (9%) percentage of kerosene, the percentage of kerosene (9%) consider is the ideal percentage which gave the smallest value of the collapse potential as shown in Fig. 14.

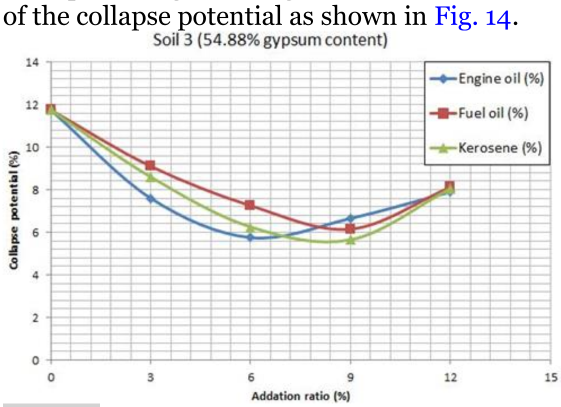


Fig. 14. The relationship between the collapse potential and the petroleum products for soil 3 (54.88% gypsum content).

3.3.3.Unconfined compressive test (UCS)

The unconfined compressive test is one of the important tests, which is give the relationship between stress and strain also called the stress-strain curve. This test cannot be applied to all types of soil in this study, because there is a challenge during soil molding for soils that have (43.6% gypsum content and 54.88% gypsum content), causing the samples to be destroyed during extruding from the mold. Only the soil that has 28.71% gypsum content can be remolded and tested. The results showed that soil strength increased by 26% with adding the engine oil until reached the percentage of (6%), so the optimum value of engine oil is (6%) which gives the maximum value of unconfined compressive strength. The optimum value of the fuel oil is (9%) at it the soil strength increased (10%). The results show that engine oil gives improvement for the gypseous soil greater than fuel oil. Kerosene is not gave any increase in the unconfined compressive strength, it decreased (UCS) by (29%) when reaching the kerosene ratio to (9%) because the kerosene dissolving the bond between the soil and gypsum material also made the soil close from brutal behavior, but the viscosity of the engine oil and fuel oil make the soil more elastic. The results are shown in Figs. (15-18).

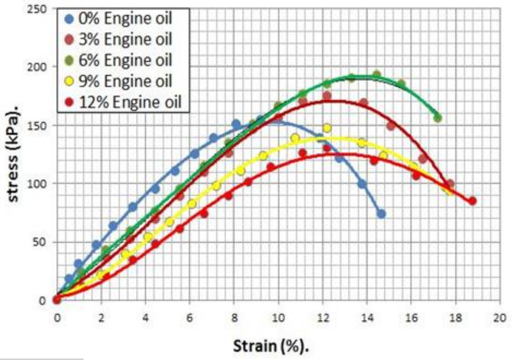


Fig.15. Unconfined compressive test results for soil1 (28.71% gypsum content) treated with engine oil.

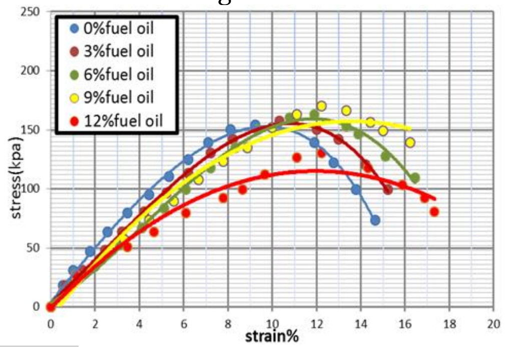


Fig.16. Unconfined compressive test results for soil1 (28.71% gypsum content) treated with fuel oil.

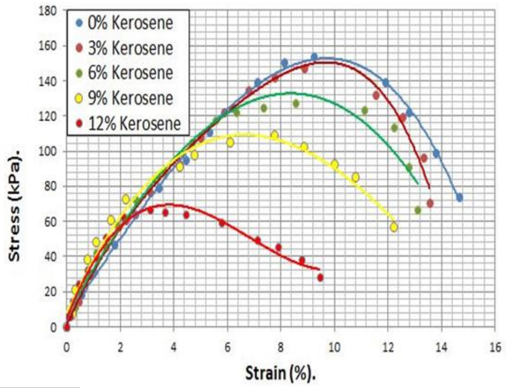


Fig.17. Unconfined compressive test results for soil1 (28.71% gypsum content) treated with kerosene.

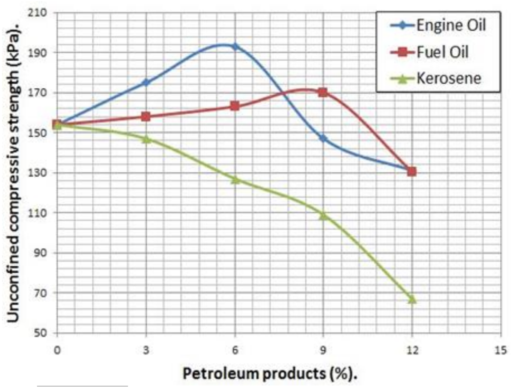


Fig.18. The relationship between the petroleum products and unconfined compressive strength for soil1(28.71% gypsum content)

4.CONCLUSIONS

The main conclusions of the present study could be summarized as follows:

- The specific gravity of gypseous soils decreased with increasing the percentage of petroleum products.
- Liquid limit is found to decrease with increasing the petroleum products additive.
- Maximum dry density and optimum moisture content of gypseous soils decreased by increasing the percentage of petroleum products.
- The petroleum products increase the shear strength of gypseous soils with different gypsum content. The optimum value for the engine oil is 6%, whereas the optimum value for the fuel oil and kerosene is 9%.
- Engine oil shows an increase in soil cohesion greater than fuel oil and kerosene.
- The effect of petroleum products on the cohesion of gypseous soils is greater than the effect on the angle of internal friction for the same soil.
- The collapse potential of gypseous soil is decreased with increasing the percentage of petroleum products.
- The shear strength in dry soil is greater than the shear strength in soaked soil for all types of gypseous soils.
- The efficiency of petroleum products for treating gypseous soils decreases with increasing gypsum content.

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