Journal of Engineering and Sustainable Development

Vol. 21, No. 5, September 2017
ISSN 2520-0917
www.jeasd.org

EFFECT OF USING PETROLEUM PRODUCTS ON THE CHARACTERISTICS OF EXPANSIVE SOIL

Dr. Adel H. Majeed [1], *Muhannd W. Majeed [2]

1) Asst. prof. Dr., Civil Engineering Department, Al-Esraa University, Baghdad, Iraq.
2) Asst. Lecturer, Civil Engineering Department, Al-Mustansiryah University, Baghdad, Iraq.

Abstract: Expansive soil is the soil that its volume changes according to the changing of moisture content included in it. When the soil absorbs water this will lead to increase its volume and vice-versa. The swelling of soil leads to structural damage such as kerbs swelling, cracking in borders and reinforced foundation and finally leads to deformation in floors and doors, these deformations may be light, moderate and heavey according to the value of swelling. In this research, the expansive soil "that is brought from Karkuke province" has initial plasticity index (P.I) is (98), Liquid limit (L.L) is (163), and plastic limit (P.L) is (65). In order to improve the properties of expansive soil, petroleum products have been added to the soil in different percentages (2%, 4%, 6%, 8% and 10%) by soil weight. These different products such as: Kerosene, Gasoil, and Cut-back asphalt (MC-30) are brought from AL-Durra Oil Refinery in Baghdad.. After done all the laboratory tests on this type of soil with different percentages of adding petroleum products, it will be noted that the addition of 10% by soil weight of kerosene reduces the liquid limit (L.L), plastic limit (P.L) and plasticity index (P.I). It also reduces the free swell and swelling pressure as shown in this research. For all petroleum products the increase of adding petroleum products leads to reduce volumetric changes.

Keywords: *expansive soil, petroleum products, swelling, plasticity index*

تأثير أستخدام مواد نفطية على خصائص التربة الانتفاخية

الخلاصة: الترب الانتفاخية هي الترب التي يتغير حجمها نتيجة تغير المحتوى المائي المحيط بها. فعندما تمتص التربة الماء يؤدي ذلك الى زيادة حجمها والعكس بالعكس. ان ظاهرة النتفاخ بالتربة تؤدي الى اضرار كبيرة في المنشات منها ظهور تشققات في الارضيات والسقوف والابواب وهذه التشققات ربما تكون قليلة او متوسطة او كبيرة بالاعتماد على قيمة الانتفاخ. في هذا البحث الترب الانتفاخية تم جلبها من مدينة كركوك وكانت نتائج الفحوصات الأولية لها كما يلي مؤشر اللدونة (98%) وفحص حد السيولة (163%) وحد اللدونة (65%). ولأجل تحسين الخواص للتربة النتفاخية تم أستخدام وأضافة منتجات نفطية وبنسب مختلفة (2%، 4%، 6%، 8%و 10%) من وزن التربة. والمنتجات النفطية المستخدمة هي النفط الابيض والكازأويل ومستحلب الاسفلت (أم سي 30) وهذه المنتجات جلبت من مصفى الدورة في بغداد . بعد اجراء كافة الفحوصات المختبرية وبأستخام نسب مختلفة من المنتجات النفطية وجد أن مادة النفط البيض وبنسبة 10% قد قللت نتائج حد السيولة وحد اللدونة ومؤشر اللدونة مقارنة بالمواد النفطية الاخرى، كما وانها قللت من قيمة الانتفاخ الحر وضغط الانتفاخ للنماذج وكما موضح بالبحث.

*Muhannd.w1981@gmail.com

1. Introduction

In view of the worldwide importance of expansive soil due to its responsibility for heave problems, numerous conferences, symposiums, and researches have been made to study its behavior under various conditions. The interest in expansive soil goes as far as it was considered as a new phase of soil mechanics. The wide extent of expansive soil around the world, plate (1), and the serious impacts that it creates to the structures (highway fills, highway subgrades, buildings foundations, canal linings, and other structures) oblige the world countries to take care by the method of its treatment to curb these negative impacts. Plate (1) is expansible map because new towns are constructed and small towns are expanded.

Chemical stabilization of soils is one of the available answers for the geotechnical engineering problems and it may be used to [1] :

1-Reduce the settlement of structures.

2-Improve the shear strength of soil and thus increase the bearing capacity of shallow foundation.

3-Increase the Factor of safety against possible slope failure of embankment and earth dams.

4-Reduce the shrinkage and swelling characteristics of soils.

Although it is known that the properties of expansive soils could be substantially altered by the addition of stabilizing agents, the chemical stabilization is still at its infancy.

In Iraq, many studies have been conducted to investigate the swelling characteristics of expansive soil in Iraq and maps have been performed for this purpose one of which that presented by the National Center for Construction Laboratories and Research (NCCLR) as shown in plate (2).

Plate (1) Distribution of reported instance of heaving [2]

Plate (2) Map of the expansive soil distribution in Baghdad City [3]

The object of the previous researches were therefore to determine free swell and swelling pressure that a soil may exhibit under an extreme condition of complete flooding. In the field, the condition of moisture change that may occur is cycles of wetting and drying leading to cycles of swelling and shrinkage of the soil. Soil stabilization has therefore grown widely in recent years, especially in developing countries, where the need for in expansive techniques to improve the engineering properties of soil is necessary [4].

Cement and Lime stabilization are of the most common methods of chemical stabilization [2] and [4] . The alteration of the properties of soil is achieved by the addition of an additive causing chemical reaction within the soil. This has been employed for the stabilization of clay soils in pavement work [5].

2. Objective of this paper

The main target of the present work is to demonstrate the influence of adding petroleum products such as (Kerosene, Gasoil and Cut-back asphalt MC-30) in different percent (2%, 4%, 6%, 8%, and 10%) by weight on the properties of expansive soil including consistency limits, compaction characteristics, shear strength, compressibility, free swelling and swelling pressure have been studied.

3. Research Significance

3.1. *Expansive soil*

The term expansive soils usually refers to those clay minerals which experience significant volume change upon wetting and drying. The amount of swell generally increases with the increases in plasticity index [6]. In addition to countries like, Jorden, India, Sudan, USA,etc,expansive soils are depressively spread in the middle and north of Iraq [7] and [8] .

Korn and Slossen [9] , as reported by Frdlund [10], stated that 7 billion dollars were spent each year in the United States as a result of damage to all types of structure built on swelling soils. Yong and Worknetin (1966), as reported by Subaa Rao and Stayadas (1987), stated that soil contaning montmorillonite show an almost high swelling and shrinkage characteristics where as a soil containing kaolinite or illite show an initial large volume decrease on drying with only limited swelling on rewetting.

Saxena [12] pointed out that the swelling pressure of clay minerals may be defined as the pressure required to consolidated back a swollen soil to its original volume and/or the pressure required to keep the initial volume of swollen soil constant. Sivapullaiah et al. [13] stated that the primary factors which affect the swelling of soil as: the initial water content, the type and amount of clay minerals, the initial dry density and the percentage of coarse-grained fraction. In addition, Komine and Ogata [14] reported that the ion concentration of pore water and the specific surface of clay particles significantly influence the swelling characteristics of the clay.

Swelling of soils occur in partially saturated plastic soils exposed to wetting during raining seasons or due to leakage of water pipes or rise of water table through the expansive soil layer. A measure of the ability and degree to which a soil might swell when its environment is to be changed is known as swell potential [15] , the free swell is defined as the percent of increase in volume of partially saturated sample of soil when exposed to wetting.

There have been numerous attempts to predict the nature of the swell potential, this depends on the free swell index [15] . Many factors affect the free swell of the soil, among these are the amount and type of minerals, density, loading conditions, soil structure, time, pore fluid and water content. The first of these factors is related indirectly to the index properties such as plasticity index, while the effect of the other factors is determined from direct free swell tests

4. Materials and experimental work

The clayey soil used in this study is a natural soil brought from the State Company of Geological Survey and Mining. It was supplied as a powder packed in 25 Kg bags, petroleum products used in this study are Kerosene, Gasoil and Cut-Back asphalt (MC-30)as shown in table (1). These products were brought from AL-Durra Oil Refinery in Baghdad and Distilled water is used throughout this study in all tests and specimens preparation. Some of the tests are conducted on the natural clayey soil, while the other are conducted on clayey soil mixed with different percentage (2%, 4%, 6%, 8% and 10%) by weight of the petroleum products [Kerosene, Gasoil and Cut-back asphalt (MC-30)]. Before mixing, the soil was dried in the oven at 105 ˚C for 24 hours. After mixing, the samples were left for 24 hours before any testing. Samples for free swell test, swelling pressure test, consolidation test, and direct shear test are prepared at [100%] of maximum dry density and at optimum moisture content.(soil source from kurkuk , north company oil).

Table (1) The Physical Properties of Petroleum products and water.

Materials / *Properties*	*Kerosene*	*Gasoil*	*Cut-back asphalt (MC-30)*	*Water*
Dielectric constant	1.8 at T 21.1˚C	2.1 at T 20 ˚C	20 at T 20 ˚C	80 at T 20 ˚C
Sp. Gravity	0.801 at T 15 ˚C	0.85 at T 15 ˚C	1.01 at T 15 ˚C	1 at T 4 ˚C
Viscosity (Centi poise)	1.5	6	40	1

5. Test results

5.1. *Grain size distribution*

The grain size distribution test (sieve analysis) is conducted according to (ASTM, D422-72) [16]. 98% of the soil particles passing 0.075mm sieve. Hydrometer test was not conducted due to technical difficulties with sample preparation. The soil was very dense and its sedimentation was very little.

5.2. *Atterberg limits*

These tests are conducted on natural soil and on natural soil mixed with different percentage of different petroleum products. Liquid limit test is carried out in accordance with [17], using the cone penetration method. The plastic limit is determined according to [17]. The values of liquid limit and plastic limit of natural clay soil used are 163 and 65 respectively. Table (2) shows the effect of adding petroleum products at different percentages on L.L, P.L and P.I of clayey soil.

Table (2) Effect of adding petroleum products on L.L, P.L and P.I of clayey soil

		% of Petroleum Products					
		0%	2%	4%	6%	8%	10%
Kerosene	L.L	163	150	145	137	131	126
	P.L	65	59	56	50	46	42
	P.I	98	91	89	87	85	84
Gas oil	L.L	163	152	149	140	138	130
	P.L	65	60	58.57	51.25	50	43.75
	P.I	98	92	90.43	88.75	88	86.25
Cut-back asphalt (MC-30)	L.L	163	161	160	155	151	149.5
	P.L	65	64.89	64.63	63.43	60.25	59.3
	P.I	98	96.11	95.37	91.57	90.75	90.2

Figures (3),(4)and (5) show the effect of adding petroleum products at different percentages on L.L, P.L and P.I respectively of clayey soil.

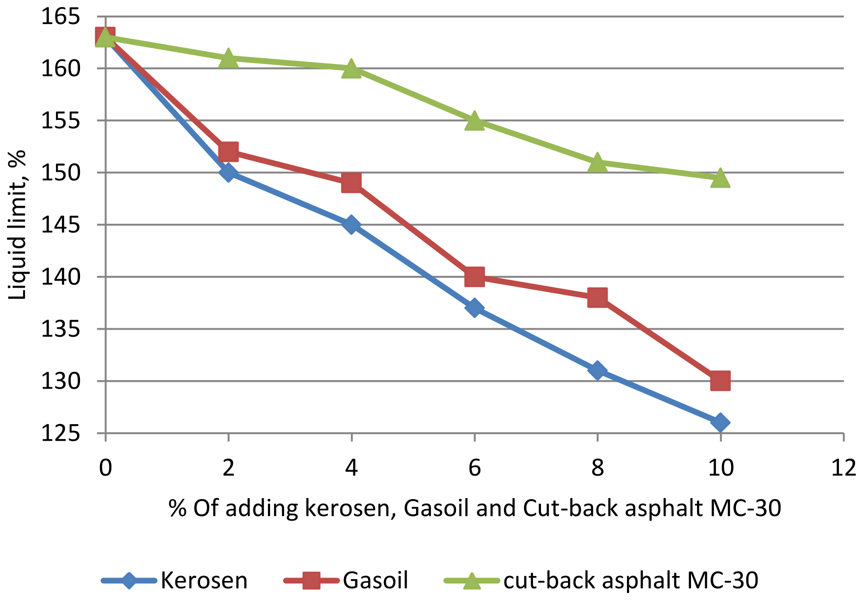


Figure (3) Effect of adding (kerosene , gasoil & cut-back Asphalt MC-30) on L.L

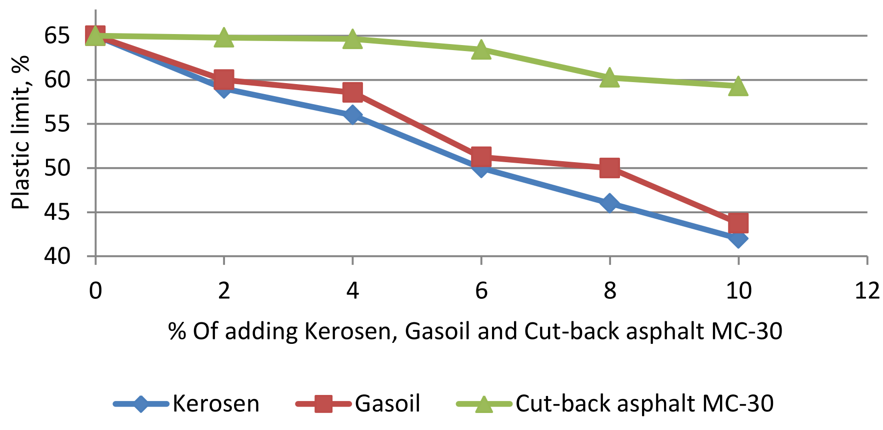


Figure (4) Effect of adding (kerosene , gasoil & cut-back Asphalt MC-30) on P.L

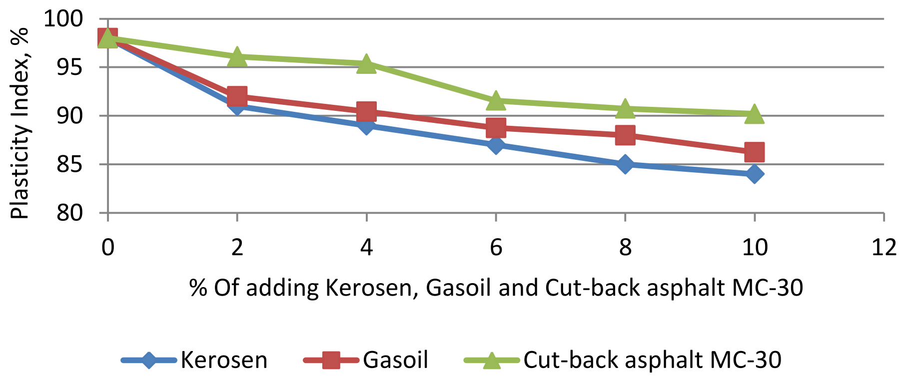


Figure (5) Effect of adding (kerosene , gasoil & cut-back Asphalt MC-30) on P.I

The effect of addition of different petroleum products on the atterberg limits values of the expansive clay used. Liquid limit, Plastic limit, and Plasticity index decreased with increasing petroleum product for all types of petroleum products used in this study. The maximum decrease is found with the addition of Kerosene then Gasoil and Cut-back asphalt (MC-30). This reduction is due to the effect of petroleum product on the thickness of the double layer which surrounds the clay particle. The clay soil gains its plasticity characteristics due to presence of double layer. Any changes in double layer properties such as its thickness, type of dissolved cations and ions in water, electrical properties of fluid in voids, and other parameters.

5.3. *Specific gravity (Gs)*

The specific gravity for soil used is determined according to [18] using the density bottle of 250 ml capacity. The average value is found to be (2.84).

5.4. *Dry unit weight versus water content Relationship*

This test is conducted on natural soil and on natural soil mixed with different percentage of different petroleum products. Standard proctor test is carried out according to [19]. The results of this test on natural soil are shown in figure (6). The maximum dry density and optimum moisture content for natural soil are 15.1 kN/m^3 and 29.8% respectively. Table (3) shows the summary of physical and classification tests results.

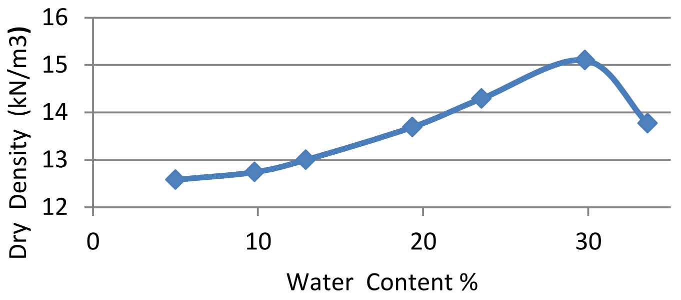


Figure (6) Dry density Vs water content relationship for the natural soil used

Table (3) physical and classification tests results of the natural soil used

Property	*Value*	*Standard method*
Liquid Limit %	163	ASTM, D4318
Plastic Limit %	65	ASTM, D4318
Plasticity Index %	98	ASTM, D4318
Specific Gravity	2.84	ASTM, D854-02
Max. Dry unit weight (kN/m^3)	15.1	BS:1377:1975,Test 12
Optimum Moisture Content %	29.8	BS:1377:1975,Test 12
% Passing sieve No. 0.075mm	98	ASTM, D422-63
Classification of Soil According to Unified Soil Classification System	CH	USCS

For all types of petroleum products the maximum dry unit weight will decrease with the increase of adding petroleum products as shown in figure (7) and table(4).(the texture of expansive soil become rough as sandy particles because petroleum particles coated the soil particles and separate it from water).

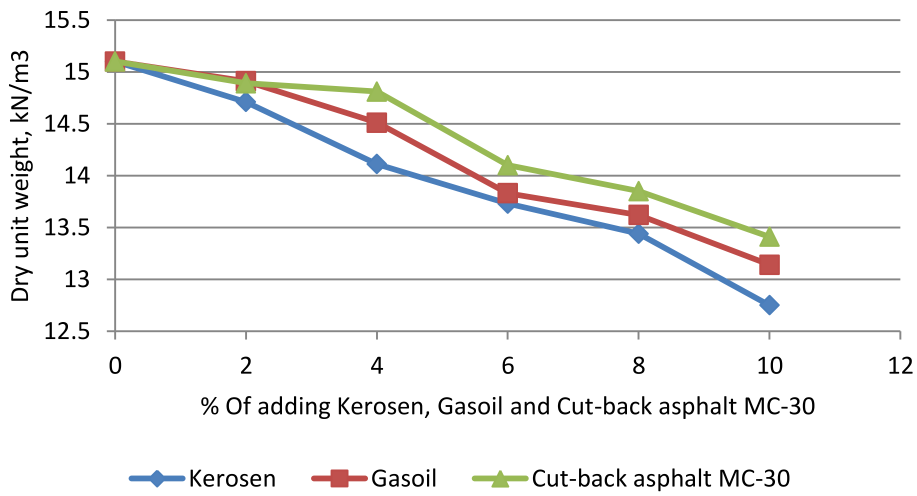


Figure (7) Effect of adding Kerosene, Gasoil and cut-back Asphalt (MC-30) on maximum dry unit weight on clayey soil.

Table (4) Effect of adding products on maximum dry unit weight and optimum moisture content

		% of Petroleum Products					
		0%	2%	4%	6%	8%	10%
Kerosene	$\gamma_{d\ max}$	15.1	14.71	14.11	13.73	13.44	12.75
	ω_{opt}	29.8	23.54	18.58	18.86	18.78	18.7
Gas oil	$\gamma_{d\ max}$	15.1	14.91	14.51	13.83	13.62	13.14
	ω_{opt}	29.8	24.69	24.59	19.25	18.81	19.53
Cut-back	$\gamma_{d\ max}$	15.1	14.89	14.81	14.1	13.85	13.41
asphalt	ω_{opt}	29.8	24.97	24.6	20	19.5	19.4

5.5. *Chemical Tests*

Chemical tests on natural clayey soil used are carried out at the laboratories of State Company of Geological Survey and Mining. Table (5) shows the results of these tests.

Table (5) Chemical analysis of used soil

Property	*Property value*
T.S.S %	7.3
SO_3 %	0.41
Gypsum %	0.98
pH	8
Montmorillonite %	70
CEC meq/100 gm	65
CaO %	5.5
SiO_2 %	57
Al_2O_3 %	13.5
Fe_2O_3 %	5.5

5.6. *Free swell test*

The test is carried out on natural soil and on natural soil mixed with different percentage (2%, 4%, 6%, 8% and 10%) by weight of different petroleum products [Kerosene, Gasoil and Cut-back asphalt (MC-30)]. Also, samples at unit weight (100%) of maximum dry density at optimum moisture content for all samples are tested.

A pre-determined weight of soil with known initial water content depending on different densities for each petroleum products percent. Soil is statically compacted inside the consolidation ring of 75mm internal diameter and 19mm in height using a compression machine.

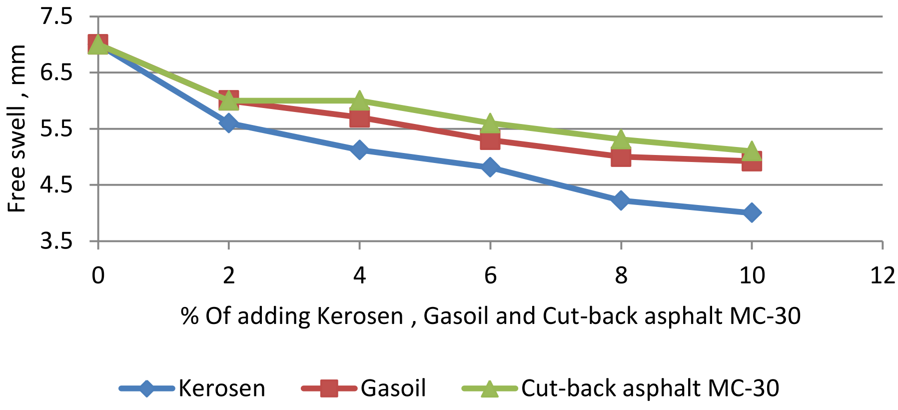
The specimen height is made to be 7mm less than the height of the consolidation ring to ensure that the specimen will remain laterally confined during swelling. The inner surface of the ring is oiled to minimize the frictional effect. Then, sample is inundated with water and left to swell freely. The increase in sample thickness is recorded using dial gauge of 0.001mm/division. This test is conducted according to [20]. The free swell percent is calculated as:

$$[\text{Free swell } (\%) = (H-H_o/H_o)*100] \qquad (2)$$

Where : H: the final thickness of sample (after end of swelling), mm

H_o: the initial thickness of sample, mm

Free swell decreased with increasing petroleum product added for all types of petroleum products used, (The texture of expansive soil become rough as sandy particles because petroleum particles coated the soil particles and separate it from water), as shown in figure (8).



Figures (8) Effect of adding different percentage of Kerosene, Gasoil and Cut-back asphalt (MC-30) on free swell of clayey soil

5.7. *Swelling pressure and Consolidation tests*

The tests are carried out on natural and treated soil samples. The effect of dry density on swelling pressure and consolidation characteristics is studied. The samples are prepared according to the same procedure followed for free swell test (figure9).

After samples inundation with water, samples were prevented to swell by increasing applied stresses on the top of samples gradually to satisfy that no swelling will take place. It takes a time to reach the equilibrium state. The maximum stress required to prevent the sample from swelling is recorded. This stress is defined as swelling pressure according to [20]. The test was continued by increasing the stresses on samples to study the consolidation characteristics of samples according to [21].

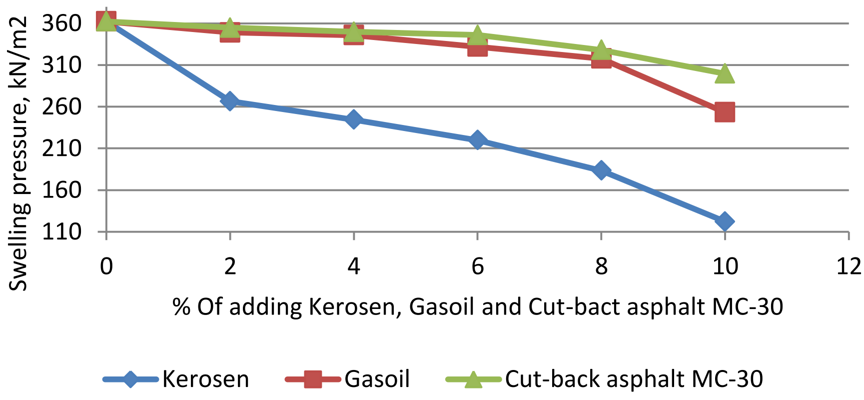


Figure (9) Effect of adding different percentage of Kerosene, Gasoil and Cut-back asphalt (MC-30) on swelling pressure of clayey soil

The maximum swelling pressure reduction is found with the use 10% of kerosene then gasoil and cut-back asphalt (MC-30). This reduction is due to the changes in double layer properties due to the addition of petroleum product.

5.8. *Effect of adding petroleum products on Cc*

The effect of addition of different petroleum products on compression index (Cc). The compression index increased with increasing petroleum product for all types of petroleum products used in this study. The maximum increase is found with addition of kerosene then gasoil and cut-back asphalt (MC-30) because, the dielectric constant, which is a measure of electrical permittivity of a material, of kerosene (1.8) is less than that of water (80) which makes the kerosene much less electrical primitive material compared with water and the other petroleum products as shown in (figure10).

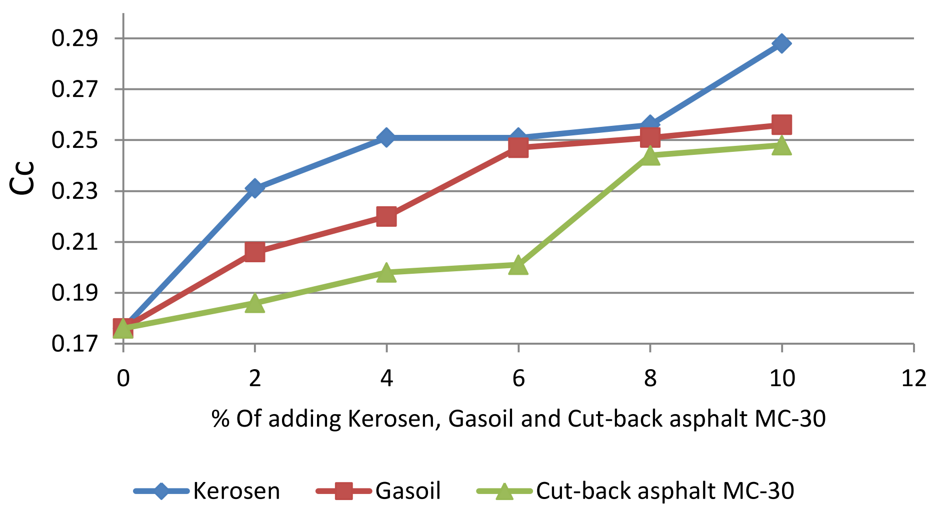


Figure (10) Compression index vs percentage of different petroleum product relationship

5.9. *Direct shear tests*

The test is carried out on natural and treated soil samples. The effect of dry density on shear strength characteristics was studied. A pre-determined weight of soil, with a known moisture content depending on different densities for each petroleum products percentage, was mixed and compacted statically inside the direct shear mold of a dimension (60mm*60mm*20mm). Each sample is tested under three normal stresses (27.25, 54.5 and 81.75) kpa. The test is carried out according to [22] as shown in (figures 11 and 12). A calibrated proving ring of (2 kN) capacity to measure the shear force applied and dial gauges of (0.002mm) for horizontal and vertical deformation are used. The rate of strain adopted in this test is (1mm/min). The samples are inundated with water for at least one hour before testing.

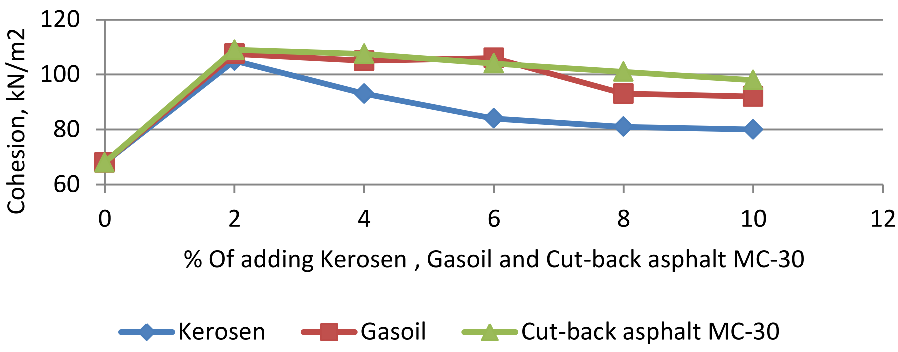


Figure (11) Cohesion vs percentage of different petroleum product relationship

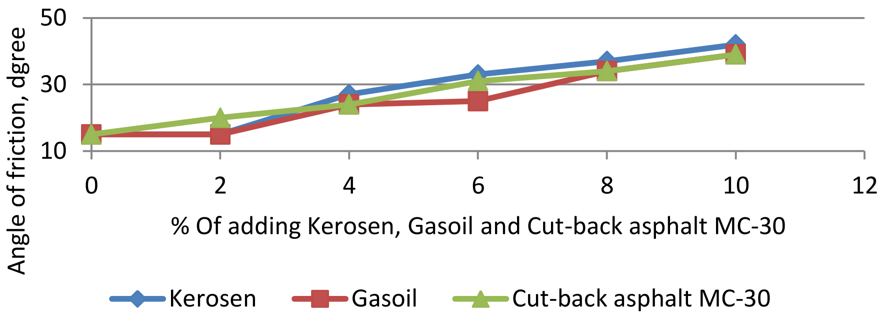


Figure (12) Effect of adding different percentage of Kerosene, Gasoil and Cut-back asphalt (MC-30) on an angle of friction of clayey soil

The relationship between angles of friction with dry unit weight respectively for different percentages of different petroleum products used as shown in (table 6). The variable in those values depending on the behavior of clayey soil when it is mixed with petroleum products which it is changing its texture from plastic to non-plastic like sandy soil.

Table (6) Effect of adding petroleum products on Cc, C, φ, swell pressure and free swell.

Petroleum Product	Percent%	Cc	C	φ	Swell pressure Kn/m^2	Free swell mm
Kerosen	0	0.176	68	15	362.17	7
	2	0.231	105	15	266.52	5.6
	4	0.251	93	27	244.38	5.12
	6	0.251	84	33	219.94	4.81
	8	0.256	81	37	183.4	4.22
	10	0.288	80	42	122.19	4
Gasoil	0	0.176	68	15	362.17	7
	2	0.206	107.5	15	348.97	6
	4	0.22	105	24	345.8	5.7
	6	0.247	106	25	331.89	5.3
	8	0.251	93	34	317.69	5
	10	0.256	92	39	253.2	4.92
Cut-back asphalt MC-30	0	0.176	68	15	362.17	7
	2	0.186	109	20	354.84	6
	4	0.198	107.5	24	349.73	6
	6	0.201	104	31	345.97	5.6
	8	0.244	101	34	328.03	5.31
	10	0.248	98	39	299.63	5.1

6. Conclusion

According to the experimental results conducted in this study to investigate the effect of adding different percentage of certain petroleum products (Kerosene, Gasoil, and cut-back asphalt (MC-30)) on properties of clayey soil used, the following conclusion can be drawn:

1- The addition of petroleum products to expansive clay decreases the liquid limit, plastic limit, and plasticity index. The reduction increases as petroleum products increase

2- The maximum dry unit weight decreased with the increase of the petroleum products percent.

3- The free swell and swell pressure decrease as petroleum products increase.

4- The addition of petroleum products effect on soil texture and then will be like sandy soils (soil texture founded by Casagrande cup test- plastic limit test).

5- The volumetric changes will decreases with increase of adding products, because free swell and densities were decreased with increasing of adding petroleum products.

6- Kerosene is the more favorable petroleum products for treating expansive soil, where swelling, density, liquid limit and plastic limit decrease. Followed by Gasoil and finally Cut-back asphalt (MC-30).

7. References

1. Das, B.M. (1990): Principles of Foundation Engineering, PWS-KENT Publishing Company, Boston.
2. Chen, F.H. (1975):" Foundation on Expansive Soils", Elsevier Scientific Publishing Company, Amsterdam.
3. Hattab, T. and Kachachi, J. (1986):" Expansive Soil in Baghdad Area," Research from National Center for Construction.
4. Al- Ashou, O. and Al-Khashab, M.N.(1993):"Treatment of expansive clay soil with potassium chloride", Al-Rafidian Engineering Journal, Vol.1, No.2, pp.17-31.
5. Fredlind, S., Ravina, I. and Ehrenreich, T.(1977):" Stabilization of Heavy Clay with Potassium Chloride", Geotechnical Engineering, Vol. 8,pp.95-108.
6. Al-Omari, R.R. and Hamodi, F.J.(1991):"Swelling Resistant Geogrid-A New Approach for the Treatment of Expansive Soils", Geotextiles and Geomembranes, Vol.10, pp.295-317.
7. Sabaa, M.R. (1987):" Evaluation of Soil Expansive Properties in Mid Part of Iraq", M.Sc. Thesis, University of Technology, Baghdad.
8. Al- Layla, M.T. and Al- Ashou, M.O.(1985):"Swelling properties of Mosul clay" In proceeding Iraqi Conference On Engineering Baghdad,1, pp.18-23.
9. Korhn,J.P., and Slosson, J.E., (1980):"Assessment of Expansive Soils in The United State", 4^{th} Int. Conf. on Expansive Soils, Vol.1.
10. Fredlind, D.G.(1987):" The Prediction and Performance of Structures on Expansive Soils", Prediction and Performance Geotechnical Engineering/ Calgary, 17-19 June, pp.51-60.

11. Sabaa, M.R. (1987):" Evaluation of Soil Expansive Properties in Mid Part of Iraq", M.Sc. Thesis, University of Technology, Baghdad.
12. Saxena, K.R. (1994):" Geotechnical Engineering-Emerging Trends in Design and practice", A.A Balkema, Rotterdam, pp.33-63.
13. Sivapullaiah, P.V., Sridharan, P.V. and Stalin, V.K. (1996):"Swelling Behavior of Soil-Bentonite Mixtures", Can. Geotechnical. Journal, Vol.33, pp.808-814.
14. Komine, H. and Ogata, N. (1996):" Prediction for Swelling Characteristics of Compacted Bentonite", Can. Geotech. Journal, Vol. 33, pp. 11-22.
15. Namir, K.(1986):"Free Swell Properties of Bentonite/ Kaolinite Mixture" Research, Building and Construction Dept., Univ. of Technology.
16. ASTM D422- 63 "Standard Test Method for Particle-Size Analysis of Soils".
17. ASTM D 4318-05 "Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils".
18. ASTM D 854-05 "Standard Test Methods forSpecific Gravity of Soil Solids by Water Pycnometer".
19. BS 1377-1975, "Methods of test for soils for civil engineering purposes".
20. ASTM D 4546 " Standard Test Methods for One-Dimensional Swell or Collapse of Soils".
21. ASTM D 2435-96 "Standard Test Method for One-Dimensional Consolidation Properties of Soils".
22. ASTM D 3080-98 "Standard Test Method for Direct Shear Test of Soils Under Consolidated Drained Conditions".