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Gypseous Soil Improvement by Silicone Oil

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Abstract:

Gypseous soils are usually stiff when they are dry especially because of the cementation of soil particles by gypsum, but great loss in strength and sudden increase in compressibility occur when these soils are fully or partially saturated. The dissolution of the cementing gypsum causes high softening of soil. The problem becomes more complicated when water flows through the gypseous soil causing leaching and movement of gypsum. This study examines the improvement of gypseous soil properties using the Silicone oil to minimize the effect of moisture on these soils. This study was conducted on artificial gypseous soil (mixture of 30% Silber sand & 70 % Pure Gypsum) treated with silicone oil in different percentages. The reason for use the silicone oil as an additive to study the gypseous soil properties is due to the leakages of oil products from oil refinery in north of Iraq build on gypseous soil, this oil products infiltrate to the foundation soil of the refinery building facilities.

The results showed that the Silicone oil is a good material to modify the basic properties of the gypseous soil of collapsibility and shear strength, which are the main problems of this soil and retained the soil by an appropriate amount of the cohesion suitable for carrying the loads from the structure.

Key Words: Gypseous soil, Shear Strength, Compression, and Collapse.

Notation

cSt = Centistokes
DIN = German Institue for standardization
C = Cohesion
ϕ = Angle of internal friction
CP = Collapse Potential
Δe = Change in void ratio
e_o = Initial void ratio
70G30S = Mixtures of 70 % pure gypsum and 30% Silber sand
DOT = Double oedometer test

1- Introduction:

Gypseous soils are one of the most complex materials that challenge the geotechnical engineers. Structures or dams founded on gypseous soil may experience unpredictable deformations that ultimately may cause catastrophic failure. In Iraq it has been reported that several structures have experienced different patterns of cracks and uneven deformations generated primarily from the dissolution of bonding materials between soils particles due to water fluctuated in soil. It is a well known fact that gypseous soils demonstrate high bearing capacity and very low compressibility when they are in the dry state. On the contrary a sudden collapsible behaviour was reported when the gypseous soils are exposed to water. ***(Al- Saoudi, et. al., 2013)***[6].

Aziz and Jianlin Ma (2011)[11] reported that many of former researches were trying to find an economic and effective material for improvement of the gypseous soils like, Aziz ***(2001)***[10] improved gypseous soil by fuel oil, ***Al-Zory (1993)***[6] studied the stability of lime in treatment of the gypseous soil, while ***Al-Busoda (1999)***[3] used calcium chloride ($CaCl_2.2H_2O$) as an improvement additive. Bituminous materials are considered as main water proofing agent that could be used for gypseous soil, ***Al-Morshedy (2001)***[4] used cut back bitumen, while ***Al-Alawee (2001)***[1] suggest a treatment with emulsion asphalt. The stabilization of gypseous soil by lime and emulsion asphalt was studied by ***Esho (2004)***[13].

Soils containing gypsum as cementing agent may be affected considerably when subjected to change in water contents. Water will cause dissolution of gypsum within the soil mass, which leads to one or a combination of the following three processes:

The first process is the collapse of soil structure due to breakdown of bonds between soil particles provided by the gypsum, this process occurs almost immediate. The second process is that of consolidation.

The third is leaching process s that prevails when water continuous to follow through the soil mass. This last process leads to progressive collapse of the soil structure due to the continuous removal of gypsum ***(Petrukhin , 1989)***[15].

The combination of these processes will cause the soil to settle considerably when loading is applied. In general, the settlement of gypseous soils are mainly due to the dissolution of the cementing gypsum, which is accompanied by the collapse of soil structure, especially in sandy gypseous soils ***(Arutyunyan, 1978)***[7]. Even capillary water may sometimes be sufficient to cause the collapse of soil structure in gypseous sandy soil ***(Arutyunyan and Manukyan, 1982)***[8].

2- Experimental Work:

2.1- Material Characterization:

The mixture of 70% artificial gypsum-30% Silber sand 70G30S is used in order to investigate the difference in the geotechnical behaviour between the naturally and artificially occurrence of gypsum as a cementing material within soil structure. Artificially pure gypsum $CaSO_4$.2H2O (produced by Alfa Aesar GmbH & Co. KG, Johansson Matthey Company, Germany) of 70% dry weight is added to 30% dry weight of Silber sand passing sieve size of 1.0 mm. The two materials were carefully mixed at dry state. In this research, the soil samples mixtures were compacted for all the tests to a target dry density of (1.3 g/cm^3) while the moisture content was the hygroscopic value, which is about (0.25%) according to ***(D2216-10) ASTM*** [9]. Hygroscopic water content is water absorbed from the atmosphere and held very tightly by the soil particles. Such water can only be removed from the soil specimen by heating ***(Schanz et. al., 2010)***[16].

This artificial mixture mix with silicone oil (100 cSt Viscosity) , Three percentages were adapted in this study , 4 % , 10 % & 16 % of silicone oil in order to study the effect of silicone oil on the artificially gypseous soil.

Physical properties like water content, specific gravity, particle size distribution, and compaction properties were investigated. The summary of physical tests results is shown in Table (1).

Table 1: Physical Soil properties for gypseous soil ***(Al-Obaidi , 2014)***[2].

Property	**Tested Soil (70G30S)**
Hygroscopic water content	0.25%
Specific Gravity	2.41
Maximum dry density(g/cm^3)	1.69
Optimum water content	12.85
Particle size distribution (DIN18123- with water)	
d10(mm)	0.018
d30(mm)	0.032
d60(mm)	0.35
Passing sieve (0.125mm) (dry, kerosene, water)(%)	21.6, 43.2, 74.1
Passing sieve (0.075mm) (dry, kerosene, water)(%)	7.4, 35.5, 71.8
Classification	Sandy Clayey Silt

2.2- Direct Shear Tests:

In order to study the effect of silicone oil on shear strength, the direct shear test in soaked condition were performed for two gypseous soil samples with 0 % & 16 % Silicone oil.

The specimen size was (60 x 60 x20) mm, while the normal stresses were 10, 20 & 40 kPa , the tests were done according to ***DIN 18137-3*** [12] at soil mechanics laboratory at Ruhr Universitäte-Bochum, Germany.

Fig. (1) shows the direct shear test apparatus. The soil samples were compacted directly in the shear box to reach field unit weight. Shear strength parameters (c andϕ) at saturation condition were determined from the shear stress- normal stress curve.

Fig. (2) & (3), show the direct shear test results for untreated gypseous soil (0% Silicone oil) and treated gypseous soil with 16 % silicone oil.

It is clearly shown that the soil samples treated with 16 % silicone oil increases the value of c (cohesion), and slightly reduce the angle of internal friction compared with untreated specimen the combined effect of two increases the shear strength of the soil. This phenomenon can be attributed to the silicone oil viscosity, where the silicone oil bonds the soil particles together and increases soil tenacity.

Figure 1: Direct Shear test Apparatus.

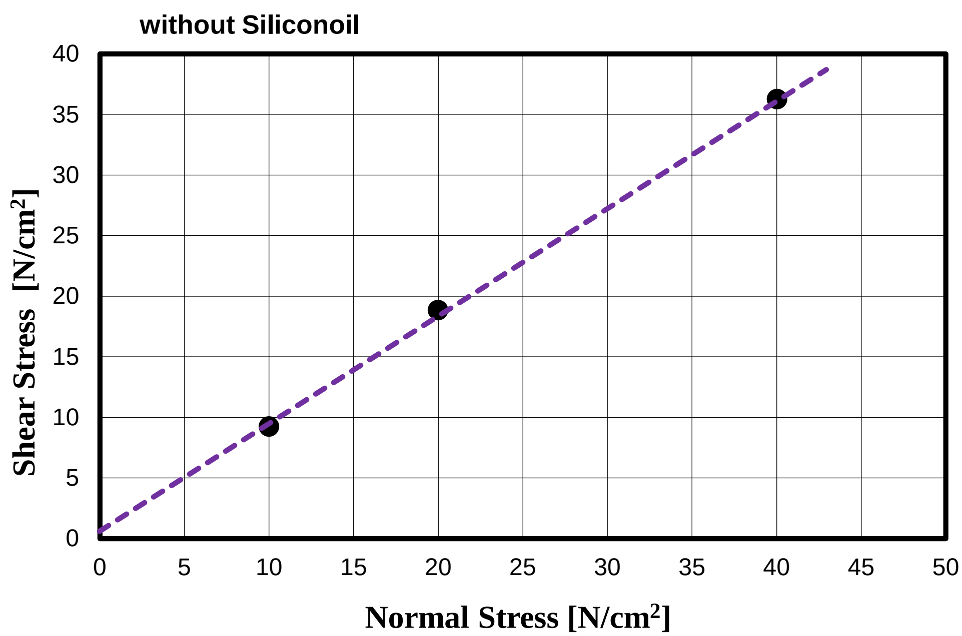

Figure 2: Direct shear test result for untreated gypseous soil.

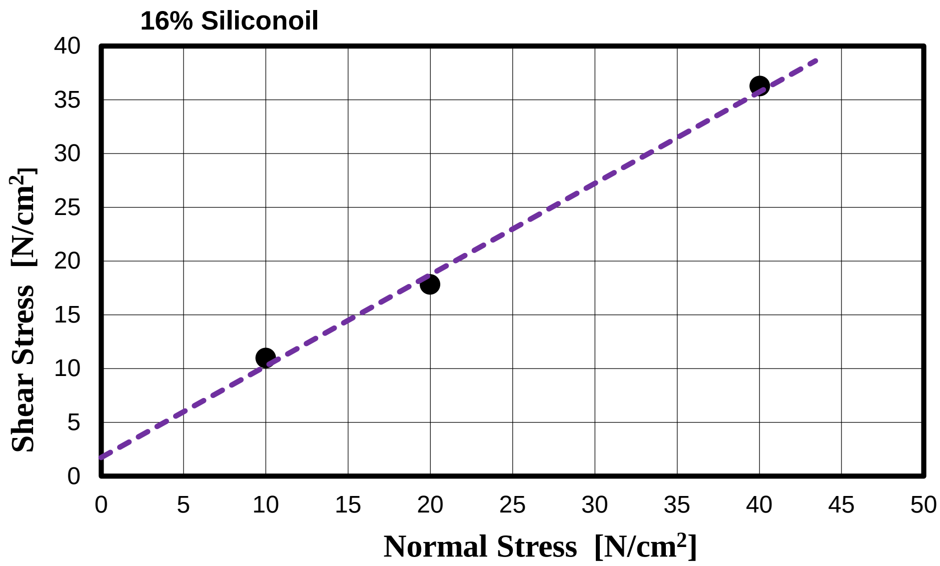

Figure3: Direct shear test result for treated gypseous soil with 16 % Silicone oil.

2.3- Unconfined Compression Test (Quick Compression Test):

This test was conducted according to ***DIN 18136*** [11]. The sample diameter was 3.5 cm and its height was 7.58 cm .The rate of strain selected was (7.6 mm/ min). The test was stopped when 20% strain was reached or when the strain continued to increase with no further loading.

In order to study the effect of silicone oil on unconfined shear stress four gypseous soil samples treated with 8, 12, 20 & 25 % of silicone oil were tested.

Fig. (4) shows the TRITECH compression machine used in this study , while Fig (5) shows the relation between unconfined shear stress and silicone oil percentages.

It is worth to mention that the shear stress increased when silicone oil content increases. When gypseous soil is mixed with silicone oil , silicone oil adhere the soil particle together and the soil reaches high consistency (tenacity) , which increases the shear stress when silicone oil content increases.

Figure 4: TRITECH Compression Machine.

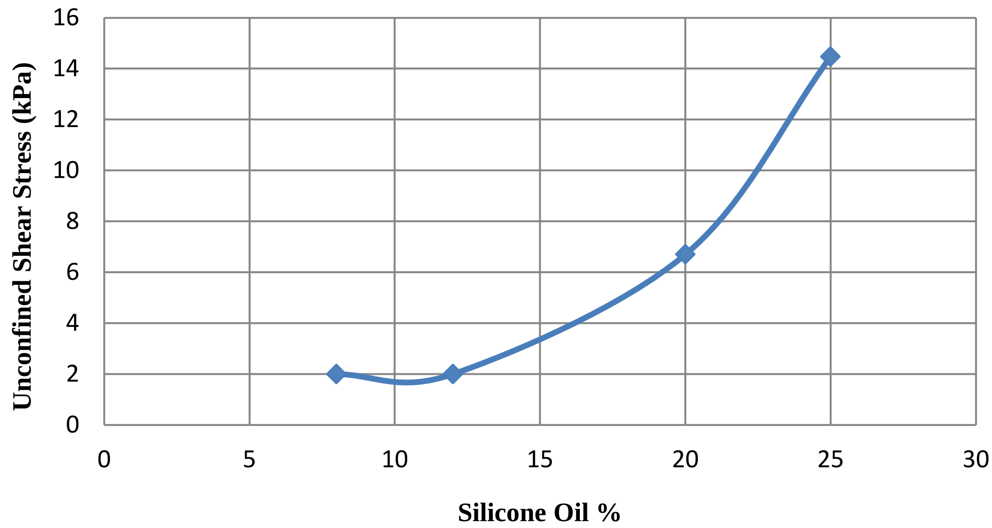

Figure 5: Unconfined shear stress versus silicone oil content (quick compression test).

2.4- Double Oedometer- Collapse Test (DOT):

Jennings and Knight (1957) [14] proposed the Double Oedometer test to determine the collapse potential (CP) of soil samples. This test is characterized by using two similar samples. The first sample is tested dry until the end of the test, while the other sample is soaked at the beginning of test. The procedure for testing the two samples is the same as in the conventional consolidation test procedure.

The difference between the two e-log σ curves quantifies the amount of deformation that would occur at any stress level when soil is saturated. The collapse potential CP is then defined at a specific pressure as:

$$CP(\%)=\Delta e/1+e_o*100 \quad \dots (1)$$

where:

Δe = change in void ratio.

e_o = initial void ratio.

In this research two gypseous soil samples treated with 4 % & 16 % of Silicone Oil were prepared and tested in dry and soaked condition according to ***DIN 18135*** [12] under the following loads 25, 50,100,200, 400 and 800 kPa for loading stage and 400, 100 and 25 kPa for unloading stage. The results of the treated gypseous soil with Silicone oil compared with the untreated gypseous soil DOT test results after ***(Al-Obaidi , 2014)*** [2].

From Figs. (6), (7) & (8) (untreated soil and treated soil with 4% & 16 % Silicon Oil) , it can be noticed that the initial void ratios and the amounts of void ratios at any stress level are less than that of untreated specimens. This may be attributed to the fact that the lubrication action of Silicone Oil is more than that of water, so the voids of the treated specimens are reduced by filling them with lubricated particles ,since the layers rolling over each other is better than in the later case and thus in turn will increase the dry density. Fig. (9) shows one- dimensional compression Oedometer apparatus.

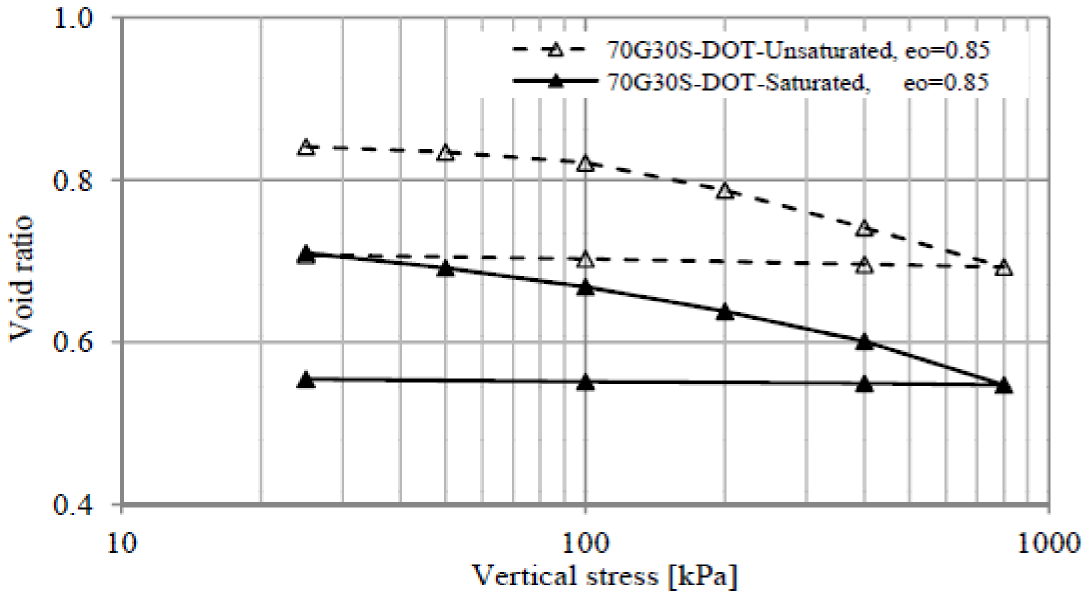

Figure 6: Double Oedometer- Collapse test 70G30S untreated soil (*Al-Obaidy, 2014*) [2].

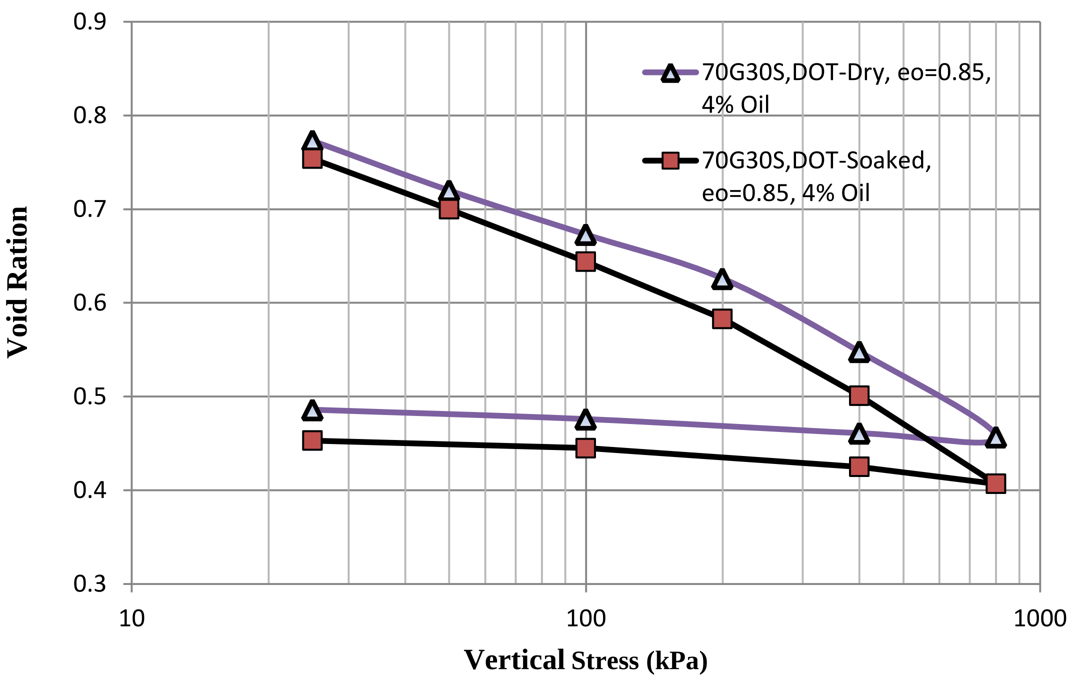

Figure 7: Double Oedometer- Collapse test for gypseous soil treated with 4% Silicone oil.

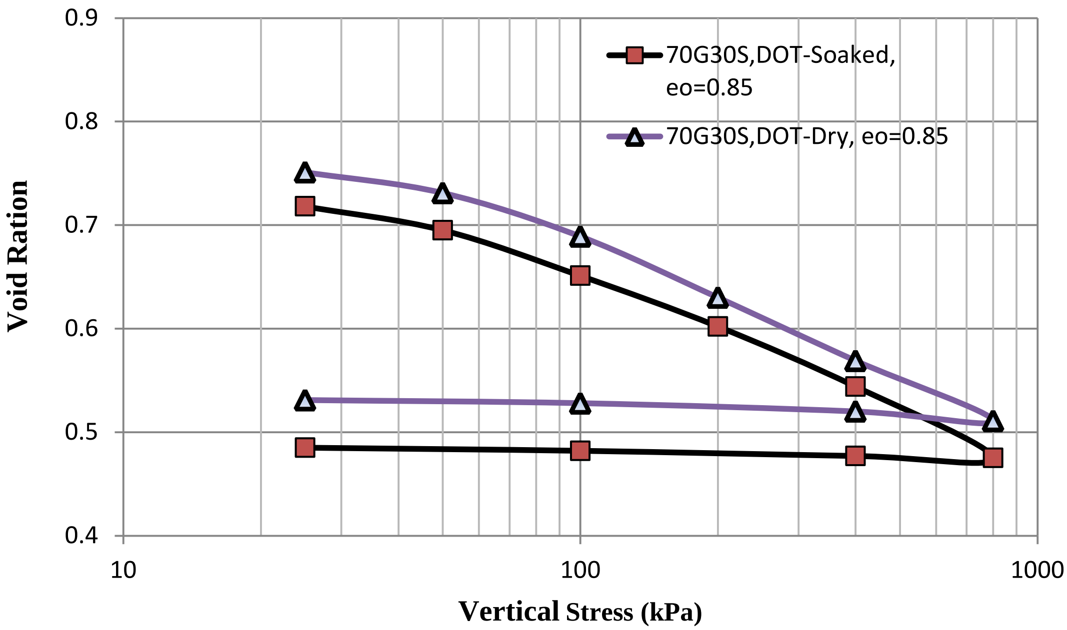

Figure 8: Double Oedometer- Collapse test for gypseous soil treated with 16 % Silicone oil.

Figure 9: One Dimensional Compression (Oedometer apparatus).

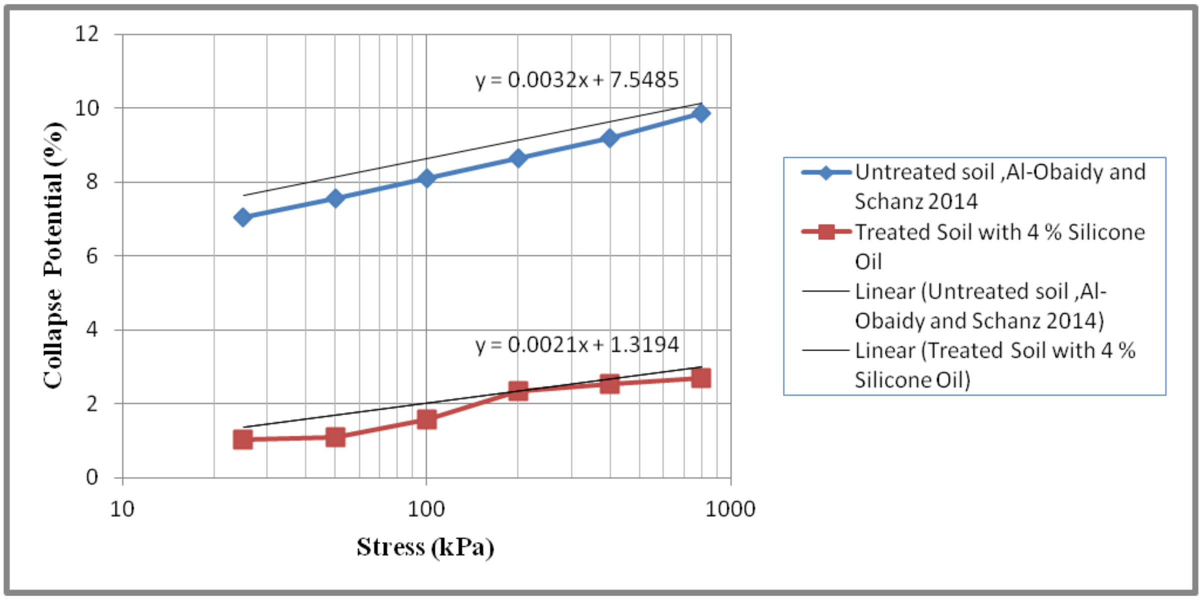

Figure 10: Collapse Potential versus stress.

Accordingly, Fig.(10) shows that the collapse potential of treated soil with 4% Silicone oil is less than that for untreated soil (the collapse potential for treated soil at 800 kPa stress level is 27.4% from untreated soil). This behavior may be attributed to the effect of water –proofing of silicone oil, when it coats the soil and gypsum particles because this coating reduces gypsum dissolution by the water and reduces soil skeleton destruction, which leads to decrease in the collapsibility of the soil, this results coincide with (***Aziz and Jianlin Ma ,2011)***[11].

Also ***Aziz and Jianlin Ma (2011)*** [11] reported that for the untreated soil the saturation of the specimens with water destroyed the inter-particle cementing bonds and new particles rearrangement was achieved maintaining a new state of equilibrium. This phenomenon increases the overall observed soil compressibility.

3. Conclusions:

1- The soil samples treated with 16% silicone oil increases the value of c (cohesion), and slightly reduce the angle of internal friction compared with untreated specimen. The combined effect of two increases the shear strength of the soil. This observation is attributed to the silicone oil viscosity, where the silicone oil bonds the soil particles together and increases soil tenacity.
2- The shear stress increased when silicone oil content increases, when gypseous soil mix with silicone oil , silicone oil adhere the soil particle together and the soil become high consistency (tenacity) , that increase the shear stress when silicone oil increase.
3- The initial void ratios and the amounts of void ratios at any stress level are less than that of untreated specimens. This may be attributed to the fact that the lubrication action of Silicone Oil is more than that of water , so the voids of the treated specimens are reduced by filling them with lubricated particles ,since the layers rolling over each other is better than in the later case and thus in turn will increase the dry density.
4- The collapse potential for treated soil with 4% Silicone oil less than that for untreated soil (the collapse potential for treated soil at 800 kPa stress level is 27.4% from untreated soil) . This behavior may be attributed to the effect of water –proofing of silicone oil, when it coats the soil and gypsum particles because this coating reduces gypsum dissolution by the water and reduces soil skeleton destruction, which leads to decrease in the collapsibility of the soil.

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تحسين التربة الجبسية بدهن السيليكون

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الخلاصة

تكون الترب الجبسية في الغالب قوية عندما تكون جافة بسبب جزيئات الجبس التي تعمل كمادة رابطة لجزيئات التربة، لكن يحدث فقدان كبير في مقاومة التربة ونقصان مفاجئ في انضغاط هذا النوع من التربة عندما تكون مشبعة بالماء بصورة كلية او جزئية. ان ذوبان المادة الجبسية الرابطة يسبب طراوة عالية للتربة . المشكلة تصبح اكثر تعقيدا عند جريان الماء في الترب الجبسية والذي يسبب غسل وتحريك جزيئات الجبس. هذه الدراسة تختبر تحسين خواص الترب الجبسية باستخدام دهن السليكون لتقليل تاثير الرطوبة على هذا النوع من التربة. تم استخدام تربة جبسية اصطناعية مكونة من 30% رمل و70% جبس نقي في هذه الدراسة حيث تم خلطها مع مادة دهن السليكون بنسب مختلفة. ان الهدف من استخدام دهن السليكون كمادة مضافة لدراسة خواص الترب الجبسية هوة لمحاكاة عملية نضوح منتجات البترول من منشات التكرير في شمال العراق المشيدة على هذا النوع من الترب ، حيث ان منتجات البترول تتغلل في تربة اسس هذه الابنية.

النتائج بينت ان المادة دهن السليكون هي مادة جيدة لتحسين خواص الانظغاطية ومقاومة القص للترب الجبسية، والتي تعتبر من المشاكل الرئيسية التي تواجه هذا النوع من الترب. وتؤدي الى احتفاظ التربة بنسبة ملائمة من التماسك لنقل احمال المشأ.