Experimental Investigation of Square Footing Resting on Gypseous Soils Contaminated by Kerosene

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Abstract. This study investigated the behavior of square footing (Length =100 mm) constructed over a gypseous soil contaminated with four percentages of kerosene (5, 10, 15, and 20%) and several thicknesses of the contaminated soil (0.5B, B, and 1.5B) was taken from Tikrit University in Salah Al-Deen governorate from the depth of (1.5-2) m under natural ground level. The tests revealed that the soil is high gypsum content (62%). The main loading tests of the gypseous soil were carried out [field density (dry) and field density (with soaking)] which are a reference for comparison with the contaminated gypseous soil loading tests. The results that are represented by the relationship between pressure and settlement show that the gypseous soil has a good resistance reached to (385 kN/m²) when compacted to field density before soaking. For the contaminated gypseous soil tests, the bearing capacity does not improve as the bearing capacity is reduced by 50% or more compared to the non-contaminated gypseous soil, as for the settlement there is a slight improvement. As for the soaked gypseous soils, it was showing an improvement in bearing capacity and an improvement in the settlement of footing.

Keywords: Shallow foundation, gypseous soil, kerosene, soaking.

1. Introduction

Gypseous soils are those soils that contain a sufficient amount of gypsum and are considered collapsing and unstable soils which are highly affected by weather conditions, gypseous soil is one of the most complex geotechnical engineering materials engineers encounter, they are classified to be “problematic soils” and show unexpected actions that can cause major civil work problems [1]. Gypsum is essentially metal salt, namely hydrated calcium sulfate (CaSO₄·2H₂O) and anhydrite calcium sulfate (CaSO₄). A Gypseous soil is usually found in arid and semi-arid areas and is in the form of rocks or gypsum deposits and when it is dry it is of high strength, but when gypseous soil is exposed to wetting it will settlement and shear strength soil will decrease [2]. Such as rain and high levels of groundwater, as this leads to the dissolution of gypsum and salts, where the soil loses the bonding between the particles. It causes problems to the buildings where evaporation of the soil occurs and these salts accumulate [3]. It covers gypsum soil more than 20% of areas of Iraq [4] and it is concentrated in Mosul, Tikrit, Samarra, Baiji, Ramadi, Anna, North West of Baghdad, Heet, and Fallujah [5]. Gypseous soil problems are many, which may cause landing and cracking of structures constructed on this soil. Therefore, many studies and research have been conducted to find out the behavior of this soil, especially when exposed to water. The results of these studies proved the effect of gypsum on the engineering properties of the soil, and their results varied, as they matched with some properties and differed with others [6].

Soil contamination is one of the appearances of contamination that appeared in recent decades, especially contamination with industrial waste. Gypseous soils are found in many areas in Iraq and there are also oil refineries in Baiji that contain gypseous soils. Many researchers have studied the
Many researchers are conducting studies on gypseous soils contaminated with oil residues. Ibrahim and Schanz [7] studied the improvement of gypseous soil with crude oil, the results show the shear stress increased when silicone oil content increased, so silicone oil is an improved material for gypseous soil. Aziz and Ma [8] studied the effect of fuel oil on gypseous soil, the result shows a significant decrease in cohesion when adding fuel oil, thus the shear strength of the soils decreases, so fuel oil is an unimproved material for gypseous soil. Al-Adhamii et. al. [9] studied the effect of crude oil on gypseous soil, the results show the crude oil is an improved material for gypseous soil especially at 6% of crude oil. Taha, [10], Kadhim [11], and Shakir [5] studied the effect of liquid asphalt on gypseous soil, the results show the liquid asphalt is an improved material for gypseous soil. There are several studies focused on investigating the geotechnical properties of clayey and sandy soils contaminated by kerosene, the results of the direct shear strength showed that the higher the kerosene percentage, the cohesion, and the angle of internal friction are decreased [12-15].

2. Experimental Program

2.1 Apparatus and Procedures

The test box consists of two vertical armrests for carrying the horizontal armrest for carrying the load-bearing arm. The manual lever rotates to carry the load and arm shedding load. There is also a pressure gauge counter and two dial gauges. The inside dimensions of the box are (900×900×600 mm), it is placed inside the soil to be tested. At the bottom of the box is a steel plate on which the first layer of soil is placed, this plate allows the passage of water in the event of immersion. Under this plate, there is a gap along the base where water collects. There is a valve connected to a 500 mm cylindrical plastic tube used to monitor the water level land as an indication when the soil becomes saturated, and as shown in Fig. 1.

![Figure 1. The setup of the testing model.](image)

2.2 Soil sampling

Gypseous soil is taken from Tikrit city in Iraq from Tikrit University, where the top surface of the soil was scraped to get rid of the jungle by using the excavator and shovel then digging the soil and taking
disturbed samples with a depth (1.5-2 m) to the soil mechanics laboratory at civil engineering department in Tikrit University. The properties of gypseous soil were referring within Table 1. Gypsum content test is performed according to the method proposed by Al-Mufty and Nashat [16].

| Table 1. Properties of gypseous soil. |
|--------------------------------------|
| Properties | Gypseous soil | Specification |
| Moisture content, (ω%) | 4 | ASTM-D2216 |
| Specific gravity, (Gs) | 2.6 | ASTM-D854 |
| M.I.T Classification | | |
| Gravel | 4.3 | ----- |
| Sand | 89.7 | ----- |
| Fines | 6 | ----- |
| Unified soil classification | SP | ----- |
| Field unit weight, (γ\text{field}) kN/m³ | 14 | ASTM-D1556 |
| Compaction characteristics | | |
| Max unit weight (kN/m³) | 18.75 | ASTM-D1557 |
| Optimum moisture content | 12.4 | ASTM-D2216 |
| Gypsum content | 62 | [17] |

3. Experimental procedure

The size of the soil to be examined is (900×900×500 mm) is divided into 5 layers (100 mm), the size of each layer (900×900×100 mm). The test is as follows:

1) Based on the field density and multiply it by the value of volume, the weight of one layer is obtained.

2) Take the balanced soil for one layer and put it in the test box and marks are placed inside the box for each (100 mm) and the cans are put for each layer.

3) The soil is compacted with the hammer to the limit indicated in the box as well as is extracted cans of pre-defined size and weighs to calculate the density and take the average and compare it with the density that deals with (Field or Maximum).

4) If the density value is less than the required, must be an increased number of blows but if the value is more, then this means that it exceeded the required density, then the number of blows must be reduced. The permissible deviation ratio is 1%.

5) For the layers to which kerosene is added, is taken the weight of the layer (0.5B, B, and 1.5B) and add kerosene to it with a percentage of the weight of the layer (5, 10, 15, and 20%).

6) The layer is compressed taking into account the density as mentioned previously.

7) After the process of compaction, the footing is put on the surface of the soil in the middle and put on both sides of the foundation the gauge for reading the settlement when the load is transferred, is started by shedding the load and reading it from the pressure gauge counter and is record the landing from the land gauge counter where the rate of settlement is taken.

8) As for soil soaking, the soil is soaked for 24 hours, and the water level should reach the same height as the soil, this is observed from the plastic tube located on one side of the box. For layers mixed with kerosene, these layers are not soaked in water, it is over submerged gypseous soil.

4. Results and Discussion

The work was divided into two stages, the first stage included 12 tests (without soaking), while the second stage also included 12 tests (with soaking) and as shown later:

4.1 Results of the first stage

This stage is divided into three sections depending on the thickness of soil contamination (0.5B, B, and 1.5B) where four tests are conducted for each thickness by treating gypseous soil with different proportions of kerosene (5, 10, 15, and 20%) taking into consideration the field density. Figures 2-4 show the relationship between pressure and settlement of each case. It is noticed from these figures that
there is no significant improvement in the settlement. As for the bearing capacity, it has decreased by half or more, and the reason is that kerosene reduced the cohesion and weakened the bonds between gypseous soil particles, and reduced the internal friction angle.

**Figure 2.** Pressure-settlement curves for dry gypseous soil contaminated with depth (0.5B).

**Figure 3.** Pressure-settlement curves for dry gypseous soil contaminated with depth (B).

**Figure 4.** Pressure-settlement curves for dry gypseous soil contaminated with depth (1.5B).
The higher the thickness of the contaminated gypseous soil layer and the higher the kerosene percentage, the lower the bearing capacity of the soil, and it is noticed that the settlement decreases a very slight percentage, the layer (0.5B) is the highest bearing capacity compared with the other two layers (B and 1.5B). With regard to 20% of kerosene, soil subsidence occurred significantly because the bonds between soil particles are weaker than the rest of the layers and the cohesion fades at a very large rate than the rest of the layers and the cohesion fades at a very large rate.

4.2 Results of the second stage

This stage is also divided into three sections depending on the thickness of soil contamination (0.5B, B, and 1.5B) where four tests are conducted for each thickness by treating gypseous soil with different proportions of kerosene (5, 10, 15, and 20%) based on gypseous soil (soaked case) taking into consideration the field density. Figures 5 to 7 show the relationship between pressure and settlement of each case. Through these Figures, it is clear that all the proportions of kerosene used at different depths showed an improvement in the bearing capacity of the contamination gypseous soil and it showed a settlement improvement compared to the gypseous soils soaked in the water. The reason is that kerosene surrounded the contaminated soil and worked to reduce the effect of the contaminated soil with the gypseous soils submerged in water.

**Figure 5.** Pressure-settlement curves for gypseous soil contamination with depth (0.5B) (with soaking).

**Figure 6.** Pressure-settlement curves for gypseous soil contamination with depth (B) (with soaking).
5. Conclusions

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

- The gypseous soil showed a good bearing capacity using field density and the gypseous soil lost 91% of its bearing capacity after soaking in water.
- Gypseous soil contaminated with kerosene (dry condition) does not improve the bearing capacity
- Slight improvement of decline for all percentages except for 20% (dry condition)
- At soaking, the contaminated gypseous soil was an improvement in the bearing capacity and its settlement
- The type of shear failure for the non-contaminated gypseous soil was general and for the contaminated gypseous soil, it was local. For soaked gypseous soils failure was punching.

References

[1] Petrukhin V. P. and Boldyrev G. B., 1978. Investigation of the deformability of gypsified soils by a static load. Soil Mechanics and Foundation, 15(3), 178-182.
[2] I. H. Nashat, 1990. Engineering characteristics of some gypseous soils in Iraq. Ph.D. Thesis, Civil Engineering Department, University of Baghdad.
[3] N. M. Al-Mohmmadi, I. H. Nashat, and G. Y. Bako, 1987. Compressibility and collapse of gypseous soils. In Proc. 6th Asian Conf. on Soil Mechanics, Tokyo, 1, 151-54.
[4] F. S. Al-Kaabi, 2007. Distribution of the gypsiferous soil in Iraq. State Company of Geological Survey and Mining, Report No.3044, Iraq, Baghdad.
[5] F. H. Al-Janabi, 2002. Soil treated with fuel oil. M.Sc. Thesis, Building and Construction Department, University of Technology.
[6] F. A. Al-Jumaily, 1994. Gypsum and its mechanical effect on engineering properties of soils. Journal of Arabic Universities Union, 19 (in Arabic).
[7] A. N. Ibrahim and T. Schanz, 2017. Gypseous soil improvement by silicone oil. Al-Nahrain Journal for Engineering Sciences, 20(1), 49-58.
[8] H. Y. Aziz and J. Ma, 2011. Gypseous soil improvement using fuel oil. World Academy of Science, Engineering and Technology, 51, 299-303.
[9] R. A. Al-Adhamii, F. H. Rahil, Y. M. Kadhim, and T. A. Atia, 2020, February. Geotechnical
properties of gypseous soil contaminated with crude oil. In IOP Conference Series: Materials Science and Engineering, 737(1), 012115.

[10] O. T. Taha, 2006. The use of liquid asphalt to improve engineering properties of gypseous soils. M.Sc. Thesis, Civil Engineering Department, Tikrit University, Iraq.

[11] A. J. Kadhim, 2014. Stabilization of gypseous soil by cutback asphalt for roads construction. Journal of Engineering and Sustainable Development, 18, 46-76.

[12] M. O. Karkush and A. G. Jihad, 2020. Studying the geotechnical properties of clayey soil contaminated by kerosene. Key Engineering Materials, 857, 383-393.

[13] M. O. Karkush, Zaboon, A.T. and Hussien, H.M., 2013. Studying the effects of contamination on the geotechnical properties of clayey soil. Coupled Phenomena in Environmental Geotechnics, Taylor & Francis Group, London, pp.599-607.

[14] M. O. Karkush and D. A. Resol, 2017. Remediation of sandy soil contaminated with industrial wastewater. International Journal of Civil Engineering, 15(3), pp.441-449

[15] Z. H. Shakir, 2017. Improvement of gypseous soil using cutback asphalt. Journal of Engineering, 23(10), 44-61.

[16] A. A. Al-Mufty and I. H. Nashat, 2000. Gypsum content determination in gypseous soils and rocks. 3rd International Jordanian Conference on Mining, 500-506.