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Gypseous Soil Improvement using Fuel Oil

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***Abstract*—**This research investigates the suitability of fuel oil in improving gypseous soil. A detailed laboratory tests were carried-out on two soils (soil I with 51.6% gypsum content, and soil II with 26.55%), where the two soils were obtained from Al-Therthar site (Al-Anbar Province-Iraq).

This study examines the improvement of soil properties using the gypsum material which is locally available with low cost to minimize the effect of moisture on these soils by using the fuel oil. This study was conducted on two models of the soil gypsum, from the Tharthar area. The first model was sandy soil with Gypsum content of (51.6%) and the second is clayey soil and the content of Gypsum is (26.55%).

The program included tests measuring the permeability and compressibility of the soil and their collapse properties. The shear strength of the soil and the amounts of weight loss of fuel oil due to drying had been found. These tests have been conducted on the treated and untreated soils to observe the effect of soil treatment on the engineering properties when mixed with varying degrees of fuel oil with the equivalent of the water content.

The results showed that fuel oil is a good material to modify the basic properties of the gypseous soil of collapsibility and permeability, 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.

***Keywords*—**Collapsibility, Enhancement of Gypseous Soils, Geotechnical Engineering, Gypseous soil, Shear Strength.

I. INTRODUCTION

GYPSEOUS soils are usually found in arid and semi-arid areas, where the annual quantity of rain water is inadequate for leaching the gypsum of these soils. Its sediments or rocks may be present in the form of hydrated calcium sulphate ($CaSO_4.2H_2O$) or an-hydrated ($CaSO_4$), which are both crystalline non-crystalline form is alabaster [1].

The gypsum content usually varies in such soils from few percents to more than (90%) as in rocks of gypsum. Specific gravity of gypsum is 2.3 [2] and is considered to be a fairly soluble salt [3], but its solubility depends on many factors such as the velocity of flow water, temperature and many others.

The dissolution of gypsum due to percolation, irrigation water, and rain water or from other sources is a dangerous case in gypseous soils since this process will lead to an excessive and sometimes catastrophic settlement. Shear strength of soil also reduces as a result of this process; therefore, the safety and good performance of the foundations of structures especially in hydraulic structures and earth structures such as embankments and dams will be governed by the changes in the properties of these soils. The presence of gypsum in the soils represents one of the most complicated engineering problems due to its detrimental behavior, especially when accompanied by environmental changes in moisture content, temperature, and presence of certain types of salts; therefore, some measures are needed to treat these soils before constructing in such areas.

The aim of this study is to introduce a more economical material which acts as an impermeable layer, and can sustain the applied structure loads. This material is the same gypseous soil, but after treating it with fuel oil, which is a low cost oil refinery residue. This enhanced soil is to be spread to form an impermeable blanket of finite thickness below foundations and so controls harmful effect of water leak or percolation.

Many of researches trying to find a cheap and effective material for improvement the gypseous soils like [4] studied the stability of lime in treatment of the gypseous soil, while [5] used cement as an improvement material. Bituminous materials are considered as main water proofing agent that could be used for gypseous soil, [6] used cut back bitumen, while [7] suggest a treatment with emulsion asphalt. The stabilization of gypseous soil by lime and emulsion asphalt was done by [8].

II. MATERIALS AND METHODS

A. Fuel oil

"F.O.", Fuel oil from Al-Dura Refinery was used throughout this investigation. "The Fuel oils are brownish-black petroleum fractions consisting largely of the distillation residues from asphaltic-type crude oils, with a relative density of about 0.95" [9].

The maximum water-content is specified as 1 percent by volume. Fuel oils are used for heating and steam-raising in ships and industry due to its cheap cost.

B. Compaction Test

Remolded gypseous soils with different percents of fuel oil were used to study fuel oil effect on the compaction characteristics i.e.-maximum dry density and optimum (moisture + water) content. Compaction was conducted according to ASTM, D 1557-70 [10]. For each fuel oil percent considered the corresponding water content that reveals maximum dry density was obtained and this "blend" was considered for the rest of tests. The standard Proctor mold with 4-inch diameter and 4.6-inch height was used and standard hammer of 5.5-lb (2.5kg) weight in the preparation of all tested samples, and compacted in three successive layers with 25 blows for each layer.

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III. Results and Discussions

A. Linear Shrinkage Limit

This test was performed on treated samples of soil I at different F.O. content which are (2, 4, 6, and 8%), in addition to the untreated samples. Each sample had an optimum moisture content (O.M.C) corresponding to its F.O. content. The results of shrinkage limits are shown in Fig. 1, from which it can be noticed that the shrinkage limit of treated specimens has increased slightly due to increasing the F.O. content, but they are less than the untreated specimens.

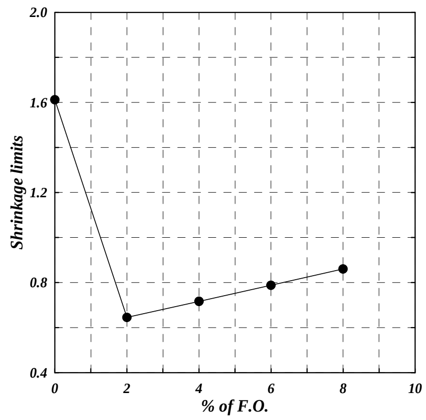

Fig. 1 The relationship between shrinkage limit and percent of fuel oil

B. Permeability-Leaching Test

Leaching test was run on several samples of soil I under a head of 2m of water and the hydraulic conductivity was measured by the falling head method. The specimens prepared by compacting the gypseous soil at different F.O. contents (0, 2, 4, 6, 8) % at the corresponding O.M.C for each F.O. percent.

The hydraulic conductivity was followed-up during the leaching process and the results are shown in the Figs. 2 to 6. These Figs. show the variation of the hydraulic conductivity with time. It is noticed that the hydraulic conductivity decreases with increasing the percent of F.O.

Specimens with (6% and 8%) F.O. lost little quantities of F.O. due to leaching, but these samples maintained their low hydraulic conductivity for appreciably long period more than 300 days.

C. Durability

Durability is to be defined here as the period of time, during which as specimen can sustain a certain hydraulic gradient before piping.

As shown in Figs. (2) to (6), it is noticed that the treated specimens are more stable than the untreated soil. After a period of 73 days, the percolating water through the untreated specimen managed in making a relatively large hole (piping), where the flow was freely flowing. The durability of the specimen treated with 2% F.O. was 143 days before the occurrence of piping. The specimens treated with higher percents of F.O. were more durable than the specimen treated with 2% F.O., since they were stable for over 300 days and remain durable for all the period of this study.

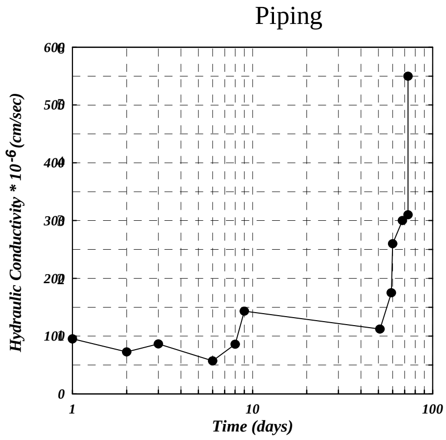

Fig. 2 The hydraulic conductivity for untreated soil I

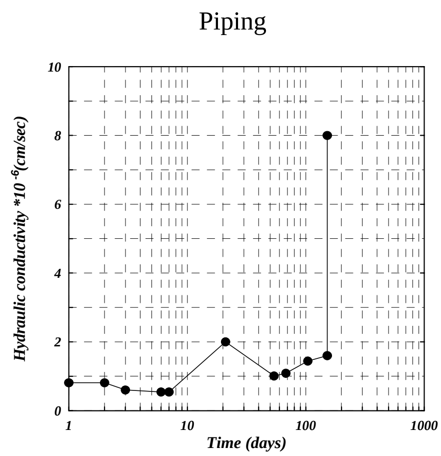

Fig. 3 The hydraulic conductivity for soil I with 2% treatment

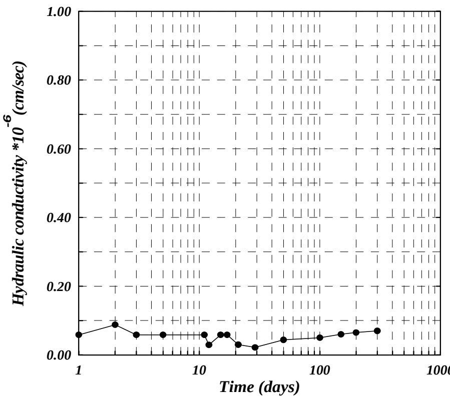

Fig. 4 The hydraulic conductivity for soil I with 4% treatment

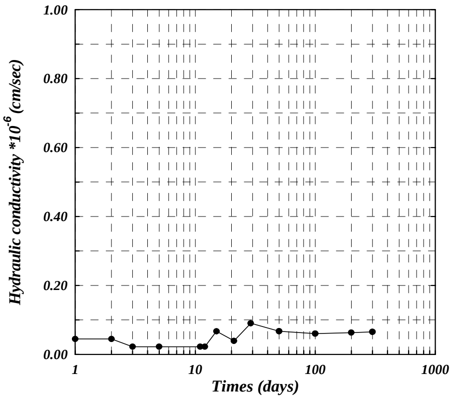

Fig. 5 The hydraulic conductivity for soil I with 6% treatment

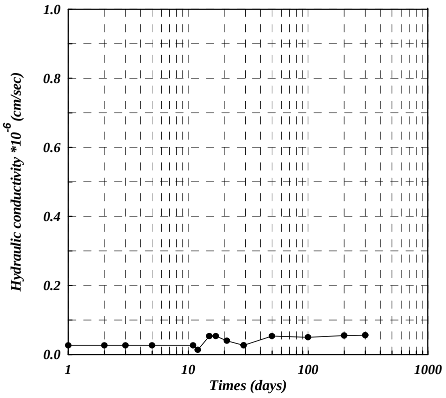

Fig. 6 The hydraulic conductivity for soil I with 8% treatment

D. Collapse Test

The results of collapse tests which were carried out in accordance to [11] in the form of (e-log p) curves are shown in Fig. 7. The remolded samples were tested using standard Odometer, and they were compacted with different percents of F.O. plus specified amounts of moisture that assures maximum dry density.

A sudden change in void ratio during testing was noticed after the addition of water at the loading of 200 kPa according to *Jennings and Knight*, and then loading was continuously increased to a load of 800 kPa, after that unloading test was carried out in one or two stages. The collapse is represented by a vertical line in the (e-log p) curves.

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.

The percent of collapse potential (C.P.) at any stress level could be determined from:

$$C.P. = \Delta e/(1 + e_0) \quad (1)$$

Δe = Change in void ratio upon wetting.
e_0 = Natural void ratio.
$C.P.$ = Collapse potential

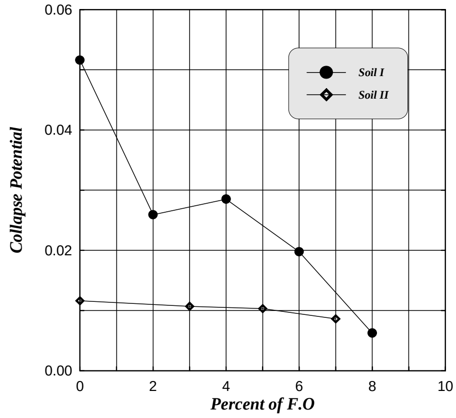

Fig. 7 The relationship between collapse potential and percent of F.O. for Soil I and II

The collapse (Δe at the load of 200kPa) for both soils decreases when increasing the percent of F.O., till it reaches a very small value at the largest percents used of F.O. The collapse potential (*C.P.*) of the soil treated with 8% of F.O. is only 12% of the untreated soil as shown in Fig. 7. This behavior may be attributed to the effect of water-proofing of F.O., when it coats the soil and gypsum particles as this coating reduces the gypsum dissolution by the water and controls the skeleton destruction, which leads to a reduction in the collapsibility of the soil. This phenomenon is clearer as the F.O. percent is increased to a value of about 8%.

The initial voids ratios of treated specimens are less than that of untreated specimens. This may be attributed to the fact that the lubrication action of F.O. is better than that of water, so a lower void ratio is obtained for the treated specimens.

The values of compression index (C_c), swelling index (C_r), reduce for soil I&II as shown in the Figs. (8) & (9).

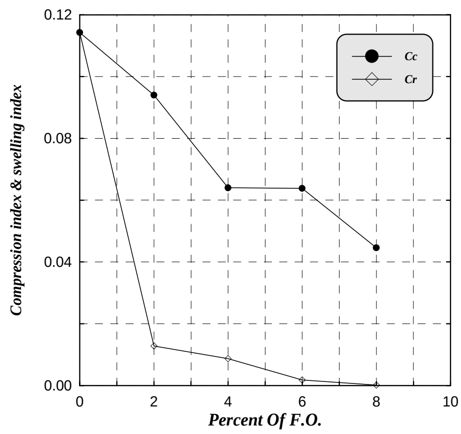

Fig. 8 The relationship of compression index & swelling index with percent of F.O. for soil I

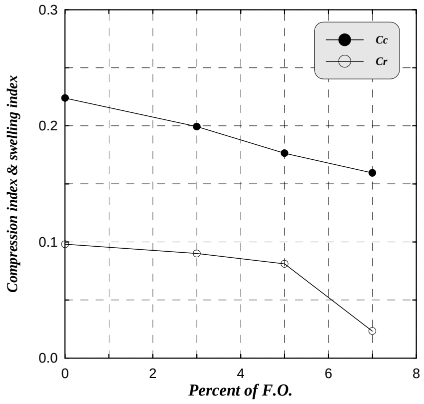

Fig. 9 The relationship of compression index & swelling index with percent of F.O for soil II

E. Shear Strength Test

1. Unconfined Compression Tests (UC)

The results of UC tests shown in Figures 10 and 11 are the relationship between the stress and axial strain of soil I&II, by which it can be noticed that increasing the percent of F.O. reduces the apparent cohesion of the soil.

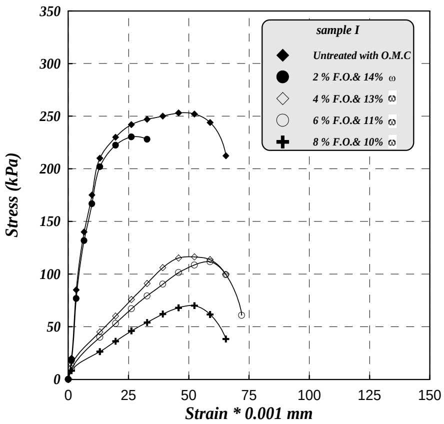

Fig. 10 The relationship between the stress and axial strain of soil I

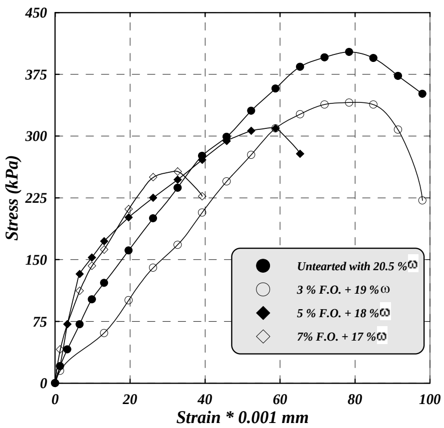

Fig. 11 The relationship between the stress and axial strain of soil II

2. Variation of Strength upon Drying

The specimens of the two soils were compacted at the specified O.M.C with the corresponding percents of F.O., then three specimens were extracted from each mold using thin liner tubes and their moisture contents were reduced with aid of an oven that has a temperature of 50^0C. Unconfined compression test were carried out on samples at various moisture contents. The strength increases as the moisture content for any F.O. content is reduced.

3. Unconsolidated Undrained Test (UU)

The results of UU tests show that the deviator stress versus the axial strain and (p – q) diagrams as following [12].

$$p = \frac{\sigma_v + \sigma_h}{2} \quad (2)$$

$$q = \frac{\sigma_v - \sigma_h}{2} \quad (3)$$

Where:
σ_v = vertical stress of soil.
σ_h = horizontal stress of soil.

It can be noticed that a slight increase in the angle of internal friction and a significant decrease in cohesion are obtained due to the addition of F.O. The combined effect of the two is a reduction in shear strength of the soils.

The cohesion component of strength is reduced due to the coating film of F.O. that surrounds the soil particles and prevents any cementing bond to develop between the soil particles. On the other hand the slight increase in (φ) values may be attributed to the impurities present in F.O. which may increase the surface frictional resistance at the contact points between the particles.

F. Losses of Weight upon Drying

The specimens were oven dried at 50^oC for a period of about 120 days, and during this period the losses of weight were measured. The loss of weight was 11% for the specimen of (6% F.O. + 11% w), 10% for the specimen of (8% F.O. + 10% w), and 1% for the specimen of (6% F.O. + 1% w), and so it was concluded that the loss is equal to the weight of water present in the soil sample and no loss is attributed to the evaporation of F.O.

This losses in the weight of the F.O. due leaching explain the reason of the higher hydraulic conductivity in the treated with 2% of F.O. as shown in Fig. 3, while this losses is not effected with higher percents of F.O. like 4, 6 and 8; therefore, the using of 4% or 6% treatments with this material of soil I gives less cost of F.O. material, less hydraulic conductivity, more durability, less collapsibility and appropriate value of cohesion (strength parameters).

IV. CONCLUSION

It can be concluded that increasing the fuel oil content was effective in:

1- Decreasing the permeability and leaching due to the effect of reducing void ratio of the treated soil by increasing the lubrications between the soil particles and maintain rearrangement and reducing the voids.
2- Increasing the durability that the percent of 2% of treatment gives more durable time than the untreated soil, while the percents of 4, 6 and 8% give durability for all the period of the test and may be still durable for all the age of the structure.
3- Decreasing the collapsibility and compressibility, which are the main controls of the soil failure and it is the purpose of the research to solve this problem by using a cheap material in our country. This happened by the coating of the soil particles by the F.O. including the gypsum and leading to reduce the dissolution of gypsum and preventing the collapse.
4- Decreasing the shrinkage limit that the F.O. is considered as a viscous material and gives more flexibility for the soil.
5- Decreasing the cohesion with keeping a suitable bearing capacity for carrying the loads.
6- The using of 4% for sandy soils and 3% for clayey soils of F.O. is the suitable solution for treatment the gypseous soil from the collapsibility. In the same time maintain enough value of bearing capacity suitable for carrying the loads coming from the structure.

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