Engineering Properties of Soil Immersed in Heavy Fuel Oil Waste

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Abstract--The power production industries often use gas turbines running on diesel oil, crude oil, or heavy fuel oil (HFO); the use of HFO in the gas power plants needs a sequence of treating processes in a particular treating unit. The HFO processes for treating produce large quantities of the wastewater due to the different treatment stages that, in most, are physical, and the resulted wastewater is called the HFO Waste. The common disposal method that majorly used in getting rid of the HFO waste is the ground pits or pools (directly on the natural soil surface) that work as large reservoirs to keep the large quantities of the outcome HFO Waste in order to re-consuming it for another utility or as a permanent disposing method.

In this research, an extensive laboratory testing program was carried out to determine the effects of HFO waste on some of the geotechnical properties of different gypsum soils (slightly, moderately, and highly gypseous soil). The samples were extruded from different positions around the pool area at the Baiji Power Plant site and at different depths (1.0-3.0 m). The testing program includes basic soil properties, direct shear, compressibility, and collapsibility on natural and polluted soil samples at the same densities. The polluted samples were chosen at different saturation levels (10, 50, and 100) % respectively. The results showed an increase in the internal friction angle to its maximum value at a low degree of waste saturation, then going down, the cohesion is zero or negligible. Polluted soil had a compression index less than the compression index for non-polluted soil. The collapse potential for HFO waste flooded soils is higher than that of soils flooded with water.

Keywords Gypsum soil. Heavy fuel oil (HFO) waste contamination. Geotechnical properties.

Introduction

With industrial development, there is an enormous increment of oil usage, but the various treatment techniques and management development lag behind the amount of oil used; therefore, large quantities of wastewater will spill in water or on the ground without any further treatment forming pollution.

Soil contamination with HFO waste occurs due to getting rid of the HFO waste in the ground pits or pools that work as large reservoirs to keep the large quantities of the outcome HFO Waste to re consuming it for another utility or as a permanent disposing method. The contamination of soils with oil causes many changes in soil engineering behavior, Figure (1).

Saleam (1988) showed that the contamination of sandy gypseous soil (from the Habanya area in Iraq) with oil products (Kerosene and gas oil) did not affect any of the strength components.

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Al-Sharrad (2007) studied the effect of cut-back MC-60 on permeability and the compressibility of gypseous soil. He noticed that an increment in treating material percent leads to a reduction in the initial void ratio. It can be explained by the effect of the increase of treatment percent on the value of maximum dry unit weight. AL-Safrany (2007) indicated that the volumetric strain decreases as the binder content (cut back asphalt) increases to a specific value then it increases. The decrease in volumetric strain maybe because of the binder content that performs as waterproofing, which reduces the rate of dissolution of the gypsum in water. Therefore, it is maintaining the cementing effect. Then, the volumetric strain increases when the binder content increases; this may a result of the existence of binder content that rises above the optimum particles, coating; this acts as lubrication separating soil particles.

Taha et al. (2007), with the increment of the binder content, there was a decrement in the values of a collapse potential, initial void ratio, and compression index.

Hussein and Jianlin Ma (2011) studied the improvement of gypseous soil by using fuel oil. The results show that fuel oil is a good material to revise 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 adequate amount of the cohesion appropriate for bearing the loads from the structure.

Al-Obaidi et al. (2020) showed that as HFO waste temperature increases, the penetration speed in the early stages of the penetration is rapidly increasing, and the degree of soil saturation decreases. Also, uprising the HFO waste temperature decreases the settlement for high and medium gypsum content, whereas it increases for soils with a low gypsum content.

This study aims to perform a laboratory testing program to determine the heavy fuel waste effect on the engineering soil properties.

Figure (1): Ground reserve pool at Baiji gas power station

Basic Properties of Soil Samples and HFO Waste

The soil samples (soil I, soil II, and soil III) were collected from Baiji Gas Station site locations were chosen from different points around the gathering basin area and at different depths (1, 2, and 3), respectively, as shown in Figure (2). A sieve analysis test determined the grain-size distribution of the soil according to the ASTM D422-02. The results of the grain-size distribution of the three soil samples are given in Figure (3). The gypsum content results by (Al-Mufty and Nashat method (2000)) are tabulated in Table (1)

Bing Image) site sampling location

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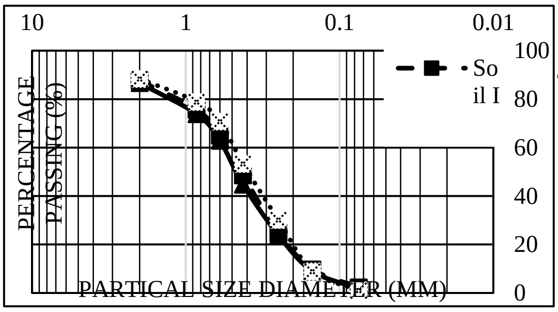

Figure (3): Grain size distribution of soil I, II, and III

Table (1): Results of gypsum content and soils classification

Type of soil	Gypsum content (%)	Unified Soil Classification System (USCS)	Classification, according to Barazanji (1973)
Soil I	10	poorly graded sand (SP)	slightly gypseous
Soil II	22	poorly graded sand (SP)	Moderately gypseous
Soil III	40	poorly graded sand (SP)	Highly gypseous

The contaminant material in this study was the heavy fuel oil waste produced from heavy fuel oil treatment processes. Table 2 is a summary of the basic HFO waste properties, including, viscosity, specific gravity, density and water content.

Table (2): Oily wastewater properties

Properties	Value
Viscosity (cst) at 40^{o}C	369
Density (gm/cm^3) at 15^{o}C	0.963
Specific gravity	0.965
Water content (%)	24

***cst: Centi-Stoke = 1 mm^2/s**

Specimen preparation for soil treated with HFO waste contaminant

The soil samples were taken to be the same field density. The contaminant was taken using volume depending on the soil voids volume percent. Soil samples were firstly dried then mixed thoroughly with HFO waste contaminant at different saturation levels started at 10, 50, and 100 % degree of saturation, respectively. The dry soil was mixed with the required contaminant amount and was hand-blended until the mixture has a uniform texture. Samples were kept in an airtight plastic container for 24 hours to attain a homogeneity before executing the test.

Testing program

The program consists of several tests carried out on natural and contaminated soil samples, direct shear, one-dimensional consolidation, and collapsibility test. These tests were done following ASTM standards.

Results and Discussion

Direct shear test

This test aims to find the strength of soil because of contamination waste with different percentages. The samples were prepared with a density equals to the field soil density. According to (ASTM D3080-72), the soil samples with dimensions (60 × 60 × 20 mm). Table (3) represents the direct shear test results includes internal soil friction angle and the cohesion for unpolluted and polluted soil samples. These test results indicate that the slightly gypseous soil samples showed increases in the frictional angle when the waste degree of saturation increases around 10%, then starts decreasing. Moderately gypseous and highly gypseous soil samples showed an increase in the frictional angle from 0% to approximately 10% waste degree of saturation, as shown in Figure (4). Beyond that, there are progressive decreases in frictional angle up to the 100% waste degree of saturation level. However, these decreases were higher than the 0% of the waste saturation. The soil showed an ignored value of cohesion decreases to zero with the increment of the waste degree of saturation; the cohesion had a noticeable value at 100% waste degree of saturation because of the oil contamination that can be the result of viscosity and inherent cohesion of oil as shown in Table (3).

Compressibility

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One dimensional compression test was performed to study the compression behavior of uncontaminated as well as contaminated soils. The results of Coefficient of Compressibility (a_v), Coefficient of Volume Change (m_v), and Constrained Modulus (D) are shown in table (4) for all the tested specimens. Figure (5) showed the variation of compression index on HFO waste degree of saturation for the three types of soil (slightly, moderately & highly gypseous soils) specimens. The value of (Cc) decreases at 10% waste degree of saturation, due to the gypsum dissolved because that the HFO waste having 24% water content, and then start increasing, because to the HFO waste embedded solid deposits that occupy the voids between coarse soil particles preventing more compression occurring for soil. For moderately & highly gypseous soils, the (Cc) decreases at 100% saturation, and this decrement is attributed to the collapse in soil structure during the test. The coefficient of volume change follows the same trend from the compression index behavior for all tested types of soil.

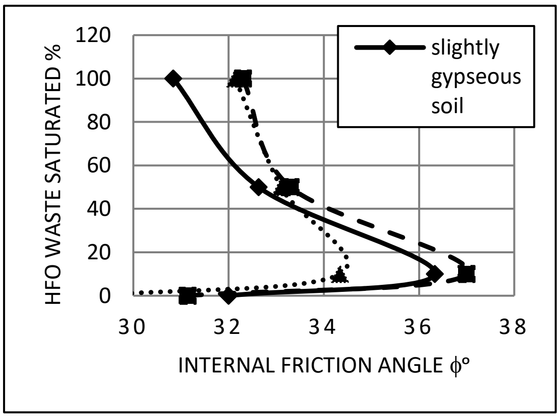
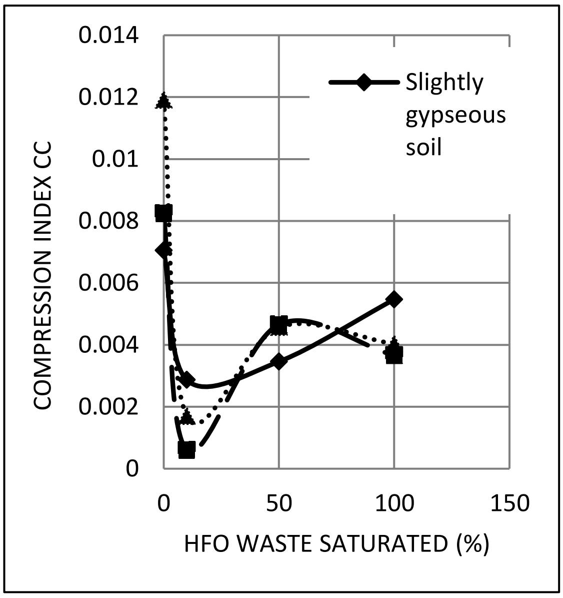


Figure (4): The effect of HFO waste on internal friction angle for the three types of the specimen

Table (3): The effect of HFO waste on cohesion for the three types of the specimen

Soil type	HFO Waste %saturated	c (kPa)
Slightly	0	0.9147
gypseous	10	0
	50	0
	100	3.6649
Moderately gypseous	0	3.308
	10	0
	50	0
	100	7.56
Highly gypseous	0	6.7
	10	0
	50	1.507
	100	6.47



tests for the three types of the specimen with a different waste degree of saturation.

Type of soil	HFO Waste (%)sat.	m_v (m^2/KN) E^{-06}	a_v (m^2/kN) E-06	D (kN/m^2)
Slightly gypseous	0	7.76923	12.4204	128712.8713
	10	3.15985	5.05156	316470.5882
	50	3.81041	6.09159	262439.0244

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	100	6.0223	9.62768	166049.3827
Moderately gypseous	0	9.08922	14.5307	110020.4499
	10	0.669145	1.06974	1494444.444
	50	5.13011	8.20136	194927.5362
	100	4.03346	6.44817	247926.2673
Highly gypseous	0	13.1227	20.9788	76203.96601
	10	1.87732	3.00122	532673.2673
	50	5.03717	8.05278	198523.9852
	100	4.44238	7.1019	225104.6025

Collapsibility

This test was performed to study the effect of the heavy fuel oil waste on the soil's collapse characteristics. The Odometer cell flooded with water for soil samples; other samples were flooded with heavy fuel oil waste; both groups are the same types of soils.

The results of collapse tests were carried out in Figures (6) to (8). Test results relieve the collapse potential for samples flooded with heavy fuel oil waste higher than the collapse potential for samples flooded with water for all tested soil types.

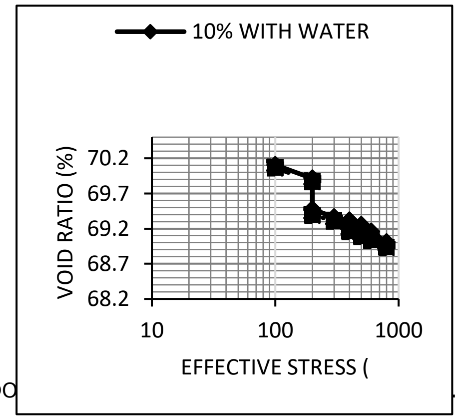

Figure (6): Collapse test for slightly gypseous soil flooded with water and HFO waste

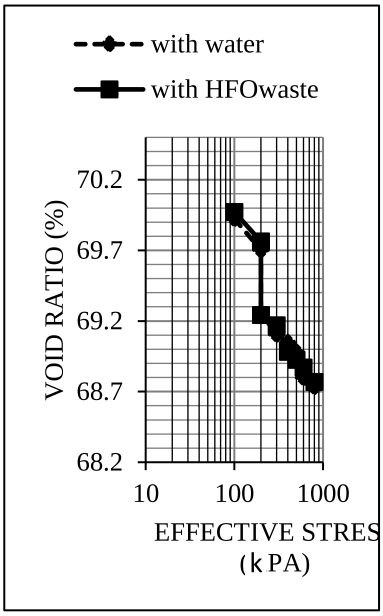

Figure (7): Collapse test for moderately gypseous soil flooded with water and HFO waste

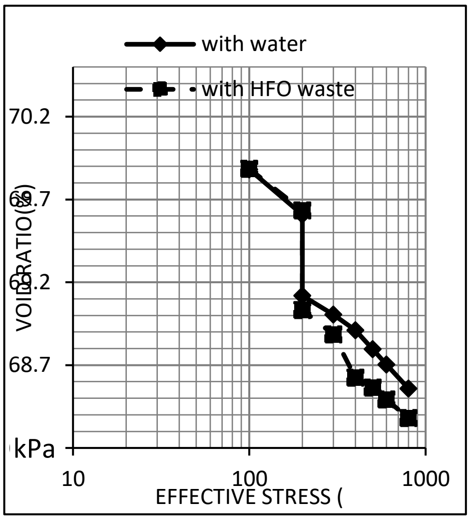

Figure (8): Collapse test for highly gypseous soil flooded with water and HFO waste

Conclusions

- The internal friction angle rises to its maximum value at (10%) degree of HFO waste saturation then going down.
- kPa‹Pa hesion is zero or a negligible value at (10% and 50%) HFO waste degree of saturation. In the case of fully saturated, the cohesion value is noticeable.

- In the slightly gypseous soils, the compression index decreases at (10%) HFO waste degree of saturation then increases at (50 % and 100%) HFO waste degree of saturation (still less than the compression index for non-polluted soil). For highly and moderate gypseous soils, the compression index decreases with the increment of the HFO waste degree of saturation, but a collapse occurred at HFO waste fully saturation.
- The collapse potential for HFO waste flooded soils are higher than resulted for soils flooded with water.
- For the field applications, based on the outcome results, it is not necessary to exchange the whole polluted soil for the construction works. It is enough to cut the pollutant fully saturated layer and consider the resulted surface as the natural ground.

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