Effect of oil on the behavior of collapsible soil

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ABSTRACT
The presence of collapsible soils has been reported at several locations in the Egyptian deserts. By definition, collapsible soils are moisture sensitive and susceptible to large reduction in volume when subjected to wetting. Nowadays, as a result of industrial developments in the desert regions, collapsible soils can also be subjected to leak oil contamination.

In this research, the effect of oil contamination on the collapsibility of soil is investigated through a laboratory testing program. A series of oedometer tests were carried out on samples of collapsible soils with different constituents, obtained from different locations in the Egyptian deserts. For each soil type the collapse potentials due to oil contamination and moisture increase were compared.

The results showed that, the collapse potential of a soil inundated by oil is always less than when inundated by water. This difference in behavior depends on many factors such as type and percent of the cementing material, chemical components of soil and others.

Keywords : oil contamination, collapsible soil, laboratory testing program

1 INTRODUCTION

Through the last decades, Egypt showed development in petroleum industries. After the refinement process of petroleum, several oil grades transported through pipes from the factories to several tanks embedded in earth. If any leakage occurred during the transportation process through pipes or from tanks, the leaked oil will contaminate and affects the properties of soil that supports the containers. (Abd-El-Aziz 1986).

If the supporting soil is of collapsible one, the oil will also affect its properties (Shelakova and Grigorieva 2006). In fact, the semi arid region and climatic condition in Egyptian deserts produces an environment in which potential evaporation greatly exceeds rainfall. This environment produces the factors that are most favourable to collapsible soil.

In view of macro-structure, collapsible soil was investigated by Dias (1994), Clemence (1981), Radwan et al (1996), Duddley (1970), Knight (1963), Labib and Baligh (2004), El-Guindy (1991), Yassin (1999), Tarek et al (2000) and others. Their studies showed that, collapsible soil consists of cohesionless soil and slightly cohesive soil. It may have low relative density. The natural structure of these soils may contain cement binders which lose their strength upon adding water causing collapse of soil.

Radwan et al (1996) proved that, collapsible soil is granules held in place with connectors of clay particles with either iron oxides or calcium components and that softening of bonds in the connectors between large particles could cause high collapse potential for samples that have higher calcium, sulphur-tri and magnesium oxides. This behavior occurs on adding water. Labib and Baligh (2004) investigated the most important factors that affect collapsibility, on adding water.

Referring to adding oil to collapsible soil, investigation made by Grigorieva (2006) showed that, the properties of contaminated soil by oil differ from properties of initial soils as well as watered soils. On the other hand the effect of oil on collapsibility has not been studied.

In this research, the effect of oil on the collapsibility of some collapsible soils extracted from different sites in Egypt is investigated in the laboratory using oedometer tests.

2 EXPERIMENTAL WORK

Six samples of collapsible soil from different sites were investigated. Table (1) shows the location and the visual description of each of the samples.

2.1 *Chemical analysis*

Chemical analyses were carried out on samples 4 and 5 by Construction Research Institute. Whereas, chemical analyses on samples 1, 2 and 3 were previously obtained by Radwan et al (1996). Table 2 shows the results of chemical analyses of the five samples.

Table 1. Locations and description of soil samples.

Sample No.	Location	Description
1	6th of October City	Light reddish brown clayey sand and trace of gravel
2	6th of October City	Dark reddish brown slightly clayey sand
3	6th of October City	Yellowish clayey sand
4	6th of October City	Grey medium to fine sand with some silt
5	Km. 28 Cairo-Alexandria desert road.	Yellowish med sand with some fines
6	El-Shorouk area, Cairo-Suez road.	Light brown silty sand

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Table 2. Chemical analysis of tested soils.

Chemical Compound	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
<u>Soluble Salt Conten</u>					
CL^- (%)					
SO_4^{--} (%)	3.88	2.98	1.86	0.038	0.134
Na (%)	0.72	0.1	1.67	-	0.25
K (%)	3.45	2.35	1.35	0.024	0.084
	0.2	0.25	0.2	-	-
<u>Oxide Content:</u>					
SiO_2 (%)	48.89	45.38	58.55	93	92
AL_2O_3 (%)	8.00	16.18	6.7	1.6	2.515
Fe_2O_3 (%)	8.4	15.8	7.9	0.9	2.515
TiO_2 (%)	0.82	0.66	0.92	-	-
CaO (%)	6.7	3.2	2.78	3.7	3.1
MgO (%)	4.3	1.2	4.2	-	-
Na_2O (%)	2.47	3.55	3.25	-	0.84
K_2O (%)	1.32	1.41	1.20	-	-
SO_3 (%)	2.47	0.67	0.93	-	0.21
L.O.I. (%)	16.6	11.53	14.27	-	-

2.2 *Index properties*

The index properties of the tested samples were obtained by following the standard procedures. Table (3) presents the index properties for the six samples. All soil samples are almost dry where the water content ranges between 2% and 5%.

Table 3. Index properties for tested soils, (samples 1,2 and 3 after Radwan et al, 1996).

Index properties	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
<u>Grading:</u>						
Fine gravel (%)	10	-	-	1.4	-	4.8
Coarse sand (%)	20	1	15	5.6	-	7.2
Medium sand (%)	34	67	50	63	93.2	43
Fine sand (%)	14	23	15	25	-	23
Silt (%)	10	4	8	5	-	22
Clay (- 2 μ) (%)	12	5	12	-	6.8	-
<u>Plasticity:</u>						
Liquid limit	24	32	21	NP	NP	29
Plasticity index	NP	18	NP	NP	NP	19

2.3 *Oedometer tests*

Collapse potential under stress of 200 kN/m^2 was measured for both oil and water inundated soil samples. The procedure described by Jenning and Knight (1975) was followed. The tests were carried out in oedometer ring 50 mm. Heavy oil for car motors was used for soil inundation.

3 ANALYSIS OF RESULTS

The oedometer test results are presented in Figs. 1 to 6. Figures 1, 2 and 3 show the relationship between axial strain (Δh/H) versus logarithmic stress (log p) for samples 1, 2 and 3 when inundated with oil. Whereas, the stress-strain relations for samples 4, 5 and 6, when submerged with water and oil, are illustrated in Figs. 4, 5 and 6. As expected, soil samples collapsed just after they are subjected to water at a stress level of 200 kN/m^2. Whereas, in adding oil at the same stress, 200 kN/m^2, the collapse of all soil samples does not occur instantaneously but it delays about 24 hours and occurs after adding the consequent stress, 400 kN/m^2. It is common that the rate at which a cementing agent loses its effectiveness depends on the rate of collapse of the cementing agent involved. Therefore, the difference between soil response due to water and oil inundation can be attributed to the higher viscosity of oil which delays its diffusion through the soil pores and consequently, delays its collapse. Also, the increase in the applied pressure helped in the diffusion process.

The collapse potentials of the watered soil samples were also compared with the collapse potentials due to oil, Fig. 7. The average values of collapse potentials for watered samples 1, 2 and 3 were found to be 11%, 0.55% and 4%, by Radwan et al (1996). While oedometer test results showed that, collapse potentials for the watered samples 4, 5 and 6 were 9%, 5% and 14.8%, respectively. When oil was added instead of water, collapse potentials for samples 1 through 6 was found to be 1.6%, 3.3%, 2%, 5.2%, 3.3% and 0.32%, respectively.

Generally, collapse potential due to water inundation was higher than that due to oil. This may be explained as water has higher solubility to the cementing agents contained in the collapsible soils, than that of oil. It can also be noticed that, the ratio between the two collapsibilities, due to water and oil, cannot be formulated as it considerably varied for the examined samples. Therefore, the impact of both water and oil on the collapsible soil behaviour should be examined for each particular site.

4 CONCLUSIONS

This research investigates the behaviour of collapsible soil when subjected to oil contamination. For this purpose, a series of oedometer tests was performed on six soil samples collected from different sites in Egypt. Comparison between the rate and magnitude of collapse potential due to water and that due to oil was carried out. The following conclusions were obtained:

- On adding water to collapsible soil, the collapse occurs immediately, while on adding oil, the collapse delayed and it occurs after the addition of the consequent load because of the higher viscosity of oil.
- The collapsibility of watered soil is often more than the collapsibility of oiled soil because of the higher solubility of water to the cementing agents contained in the collapsible soils.
- The impact of both water and oil on the collapsible soil behaviour should be examined for each particular site, as no specific relation between the two collapsibilities could be detected.

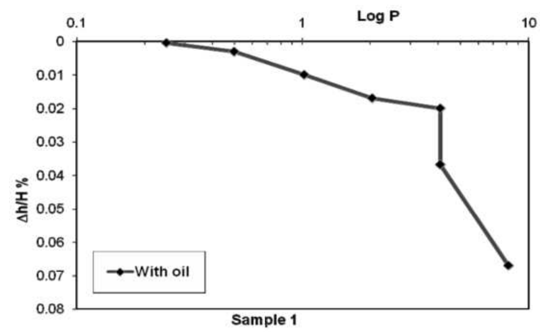

Figure 1. Vertical Strain (Δh/H %) versus logarithmic stress (log p) for sample 1 inundated with oil.

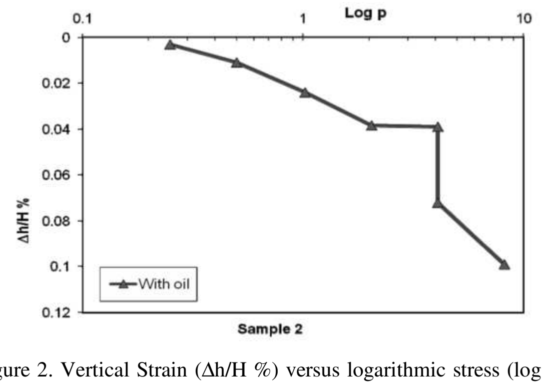

Figure 2. Vertical Strain (Δh/H %) versus logarithmic stress (log p) for sample 2 inundated with oil.

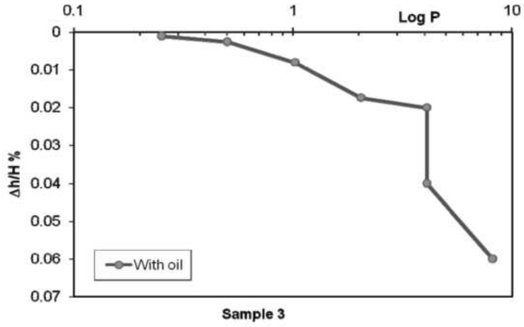

Figure 3. Vertical Strain (Δh/H %) versus logarithmic stress (log p) for sample 3 inundated with oil.

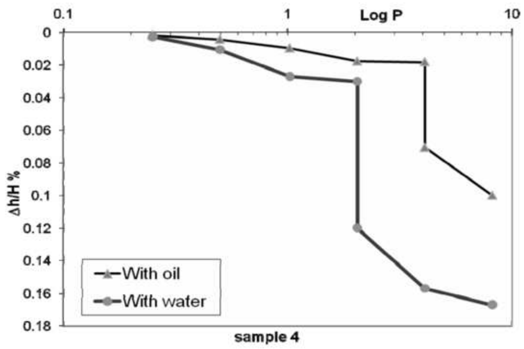

Figure 4. Vertical Strain (Δh/H %) versus logarithmic stress (log p) sample 4 inundated with oil.

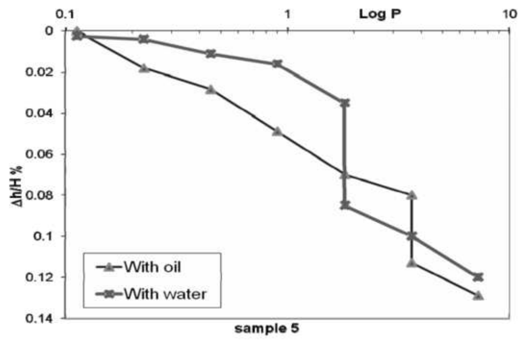

Figure 5. Vertical Strain (Δh/H %) versus logarithmic stress (log p) for sample 5 inundated with oil.

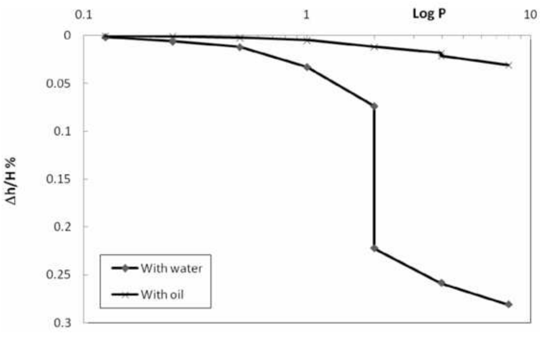

Figure 6. Vertical Strain (Δh/H %) versus logarithmic stress (log p) for sample 6 inundated with water and oil.

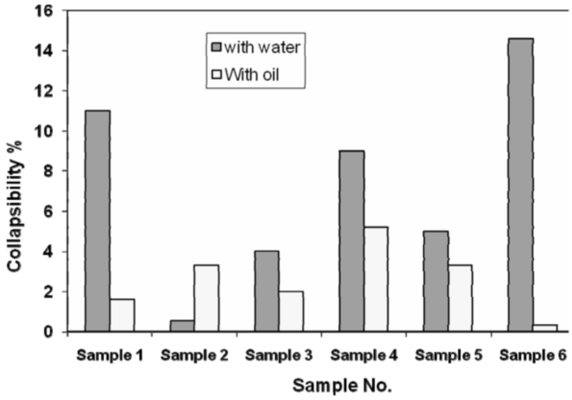

Figure 7. Comparison between soil collapsibilitie due to water and due to oil inundation.

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