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The effect of Lubricant Oilson the Swelling Behavior of Loam

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Abstract : In the world, Soils with different properties are available andit is distinguished based on the particle size and the consistency limits. Expansive soils are special soil type that is very sensitive to any change in their inner water content. Such Soils show a noticeable volumetric deformation as response to any variation in their moisture content which in turn affects the over-lied construction badly. Loam soil is a good example of expansive soils that was collected from El-MahmoudeyaLake that is in Alexandria Governorate, North of Egypt. This investigation aims to study the effect of Lubricant oils on the swelling behavior of the loam soil. Lubricant oilswere chosen in this work to minimize its negative environmental impact by finding a new utilization area for itand due to its economic effect as it is considered the least cost treatment method and to detect its ability as stabilizer to use the soil as an adequate fill instead of importing a new one. The swelling parameters effectiveness were studied through the Atterberg limits, free swell, and swell pressure tests.

Keywords: Expansive Soils stabilization, Expansive soil hazard, Swelling Parameters, Factors affecting Swelling, Lubricant oil uses.

1. Introduction

Loam soil is a very good example of swellings soils as it contains sand, silt, and clay grains and according to the percentage of these particles, the loam soil is classified. Loam Soil color ranges from yellow to grey to black color. Loam is classified based on U.S Department of Agriculture textural classification Chart into 4 types which are Sandy Loam, Clay Loam, Silt Loam and Loam Soil. Clay Loam is a fine textured soil that breaks into hard lumps when gets dry, it contains the highest clay content when compared to the other types which in turn may show the highest volume change behavior. Therefore it was the tested soil used in this study[1].

Expansive soils are distributed all over the world as in Canada, China, Saudi Arabia, Egypt, and the United States. In Egypt, they are in Nasr City, Sinai, the New Valley, Suhag, etc[2]. Expansive soils show a significant volumetric change in regarding to any change in their inner moisture content as it shows a cycle of swell-shrink which causes damages on the rested constructions upon it. This behavior of change in volume also depends majorly on the mineralogical nature of the soils and their proportion. Xidakis (1979) expressed the expansive soil as “A clay soil capable of undergoing a large volume change (shrink and swell) when subject to variation in moisture content when the predominant clay mineral of the soil is of swelling type lattice i.e.,Montmorillonite, such clay soil is an expansive soil”[3].

Swelling soils exhibit swell-shrinkage potential in relation to any change in water content. When the soil hydrates, its volume increases remarkably due to absorbing large amount of water. However, when it dehydrates its volume decreases and becomes very hard causing a noticeablecrack near the ground surface with maximum width up to 20 mm or more. Swelling soils can cause a structural failure due to its seasonal volumetric change and cautions should be taken pre and after construction of foundations and pavements. The hardening-softening behavior that is associated to the shrink-swell soil cycle is the main cause for the over-lied structure to fail and may affect some infrastructures such as transportation, water pipes, and sewage collection pipes. Damage isdemonstratedby differential heave in roads, inclined cracks in slab of basement and masonry walls, and failure in underground storage tank and buried pipeline.The American Society of Civil Engineers (ASCE) have weighed the harm due to expansive soil by 25% of all structures in the United States. The economical loss may be greater than that caused by floods, earthquakes, and tornadoes. The annual cost from the structure failure rested on expansive soils is estimated at $1000 million in the United State, £150 million in the UK, and many billions of pounds worldwide. Insurance companies in USA spend millions of dollars annually to repair the damage of the lightly loaded constructions resting on such soils.[4]

As result to the swelling soil hazards that were mentioned, Searches has been made to stabilize the swelling soil and to eliminate its hazards.The most used method was adding lime or cement or bothto the soils.In-spite of their effectiveness, they cannot be used in every needed times due to their industrial priorities and their increasing costs.Therefore, the need of a new chemical additives which can eliminate these drawbacks were needed.Thus, this work aims to study the effect of usingLubricant oilon the swelling behavior of the tested soil to be capable to be an adequate fill instead of importing a new one. Lubricant oilsare used in the industries to lubricate the machine parts and then it becomes useless to the industry. Therefore,Lubricant oils were chosen for two main reasons:firstly,finding a new utilization area for it that willdecrease their environmental impact and secondly, for its ease of availability and its low cost.

2. Shrink-Swell behavior of swelling soils

It is obvious from Xidakis (1979) definition for the swelling soil that one of the predominant factors that control the shrink-Swell behavioris the inner clay mineralogy of the swelling soil. Clay minerals are alumina-silicate layers that are formed from the weathering of other silicate minerals at the earth's surface[5].Clay minerals are group of layered sheets not having a significant grain size and can be classified based on their structure lattice as one layer type (1:1) or two layers type (2:1).Furthermore, the type and the amount of the clay mineral found in the soil controls some engineering behaviors such as soil reactivity, soil plasticity and volume change behavior[6].

The atomic lattices of the clay minerals are made of two units: tetrahedral silica unit and octahedral unit of aluminum or magnesium (Grim, 1968). The ratio between the tetrahedral units to octahedral units is what controls the clay mineral type. The common clay mineralsin Egypt soils are montmorillonite, Kaolinite and illite.Montmorillonite exhibits very high shrink-swell behavior, high liquid limit and high activity when compared to kaolinite and illite due to the weak Van der Vaal bond that connects the lattice units.Therefore, clay soils with large percent of montmorillonite mineral are a very weak soil. Secondly, kaolinite exhibits the lowest plasticity, activity and swelling behavior due to the presence of un-dissociated hydrogen bond between the units.Finally, the illite unit is very close to that of the montmorillonite unit, the units are attached by potassium ions which made us consider the swelling behavior of the illite is intermediate between kaolinite and montmorillonite[3].

Grim (1962,1968) showed that the clay soil is always surrounded by a negative charge cloud that attracts cations.These cations are positively charged ions available in the salts in the pore water, these cations are bonded to the clay surface by electrostatic forces to balance the excess negative charge. The cation exchange capacity of the mineral is another term that controls the amount of water absorbed. Montmorillonite particles have the maximum CEC due to the large negative charge on its surface and its large specific area. Therefore, montmorillonite has the largest swelling potential among the minerals[3].

3. Swelling Soil identification

The excess movements lead to negative impacts on the structure workability from the cost and the time point of view. Therefore, identifying the expansive soils became necessary prior the construction phase to reduce the anticipated damages. The criteria adopted to identify the swelling soil can be categorized into two groups: Mineralogical Identification group and Inferential Identification group which are grouped to direct Methods and Indirect Methods[7].

Mineral identification are methodsused to identify the type and the amount of the expansive lattice andthe soil chemical properties. Some of the mineralogical methods that are used: Differential thermal analysis, Dye adsorption, X-ray Diffraction, Infrared analysis, Chemical analysis, microscopic examination[7].However, Inferential identification methods depend on creating a bond between some of the index properties of the soil and the clay mineralogy to estimate the soil swell potential. Inferential methods are two groups which are indirect and direct method. The indirect method uses some of soil index properties such as the Atterberg limits, plasticity index, Shrinkage index and the particle size composition and correlates them with the swell potential of the soil. However, the direct methods measure the swell potential of the soil directly from some laboratory tests such as: Free swell index, one dimensional odometer test and potential volume change (PVC)[8].

In this investigation, the swelling behavior of the tested soil was studied before and after adding the stabilizer through some of the inferential tests based on the indirect group the liquid limit, Plastic limit and the plasticity Index measurements were taken and for the direct group the free swell index and the swelling pressure by using one dimensional odometer test were measured.

4. Plan of Study

4.1. Materials used in the study

The materials used in this study are the tested soil that is classified as a high expansive loam Soil and the lubricant oil that was used as a stabilizer. The oil was added to the soil by different percentages which satisfy the ultimate limit of effectiveness and until then any increase in the percentage was useless.

Firstly, the tested soil was obtained from El Mahmoudeya lake that is located in Alexandria Governorate, North of Egypt. The engineering properties of the tested soil are shown in table (1). Further-more, X-Ray Diffraction test was carried out on the tested soil, and it was found that the main clay minerals found in this soil was montmorillonite, quartz and Gypsum as shown in table (2).On the other hand, the stabilizeris a liquid waste that was extracted from the lubricant oils used to lubricate the machines in iron industries and was collected from iron industry in Cairo.It was added to the soil by the following percentages 2.5,5 ,7.5 and 10%, The waste material is added as a percentage of volume of waterrequired to print the soil sample to liquid limit, plastic limit, free swell and odometer tests, the water added is not equal in all tests. Its chemical properties were studied through Heavy metals analyses using per-ken Elmer Atomic Absorption as shown in Table (3).

Table 1: Engineering properties of Tested swelling soil

Liquid Limit(%)	**119**
Plastic Limit(%)	**39**
Plasticity Index	**80**
Specific Gravity	**2.7**
Maximum Dry density (gm/cm^3)	**1.52**
Optimum Moisture Content (%)	**12**
Unified Soil Classification System	**CH**
AASHTO	**A-7-5**
Free Swelling (%)	**155**
Swelling Pressure (kg/cm2)	**3.6**

Table 2: X-Ray Diffraction Analysis of the tested Soil

Mineral Name	Chemical Formula	Semi-Quant (%)
Gypsum	**Ca S O4.2 H20**	**25**
Quartz	**Si O2**	**35**
Montmorillonite	**CaO.2 (AL, Mg)2 Si4O10 (OH)2.4H2O**	**40**

Table 3: Chemical Properties of the Lubricant oil used

Chemical Name	Result (mg/L)
Cd	< 0.01
Pb	1.2
Hg	< 0.01
Cu	26.5
Ni	0.4
Fe	11
Mn	2

4.2. Experimental tests analogy

The inferential tests are commonly preferred for its ease of performance and its low performance cost when compared to the mineralogical tests.The swelling behavior of the tested soil was measured through some common inferential tests which are the Free Swell Test, the One-Dimensional Test, the Liquid Limit Test, and the Plastic Limit test.All the tests were performed first on the pure Loam Soil to provide a standard base value and then was performed on the soil with the addition of the lubricant oil that was added by a range of percentage of volume of water required to print the soil sample to liquid limit, plastic limit, free swell and odometer tests, the water added is not equal in all tests.

The free swell test was used as an initial indicator to provide the percentage range that will be used, it was performed based on Holtz and Gibbs (1956)[9].In order to calculate the plasticity Index, Liquid Limit and Plastic Limit tests were performed based on ASTM D-4318[10].The one-dimensional Swell test was performed to obtain the soil swelling pressure and it was performed as Consolidation Swell test.Seed et al. (1962) defined the swell potential as the volume change of a remolded soil sample at optimum moisture content and maximum dry density[11]. Therefore, based on Seed et al. (1962) and Gueddouda et al. (2011) the remolded soil was compacted to the maximum proctor density and the optimum moisture content prior performing the test[11,12].

4.3. Experimental test Results

The free swell, liquid limit , plastic limit and the odometer tests were performed on the Pure Loam soil at first and based on Mohan and Goel (1959) and Phanikumar (2006), the Egyptian code, Holtz and Gibbs (1956), Chen (1965) and Snethen et al. (1977) the tested soil can be classified as a very high expansive swelling soil based on the free swell test , liquid limit and plasticity index results, [13,14,15,9,16,17].

4.3.1 Free Swell Test

The oil was added by 2.5, 5, 7.5 and 10% from the volume of water used in the free swell testand as shown in Table (4), the addition of 7.5% of the oil showed the optimum effect as the free swell reduced by 26%. The free swell test results are shown in figure (1).

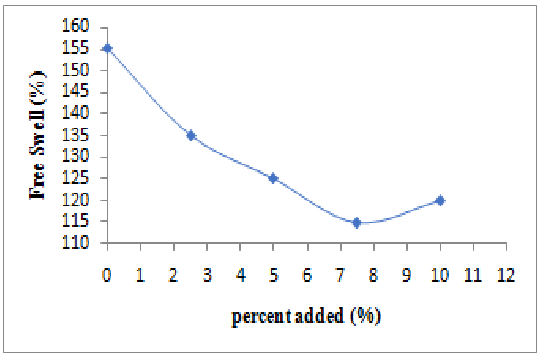

Fig 1. Free swell test results by the addition of the lubricant oilby percent (2.5, ,5, 7.5 and 10%) of water used in the free swell test

4.3.2 Liquid Limit, plastic Limit and Plasticity Index tests

After performing the free swell test and determining the percentage used, the liquid and plastic limit tests were performed, and the plasticity index was computed.

Firstly, the liquid limit continued to decrease by adding the oil until it reached the maximum loss at 7.5% which represent the optimum measurement as the liquid limit was reduced by 50% and then it showed a slight increase at 10% as shown in Figure (2).However,the plastic limit continued to increase until reached the maximum increase at 7.5% as the plastic limit increased by 27% and then it showed a slight decrease at 10% as shown in Figure (3).

On the other hand, the plasticity index showed a noticeable decrease at 7.5% as it was decreased by 87% as shown in figure (4,5).We can conclude that the lubricant oil was able to transform the soil from very high expansive soil to a low expansive soil based on Holtz and Gibbs (1956) [9].

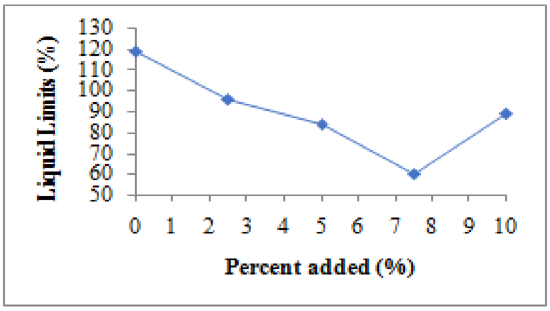

Fig 2. Liquid limit testresults in case of adding lubricant oilby percent (2.5, ,5, 7.5 and 10%) of water used in the liquid limit test

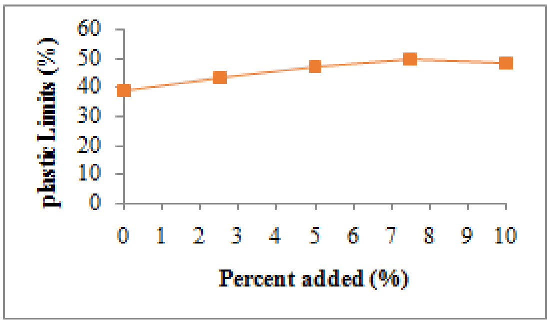

Fig 3. Plastic limit test results in case of adding lubricant oilby percent (2.5, ,5, 7.5 and 10%) of water used in the plastic limit test

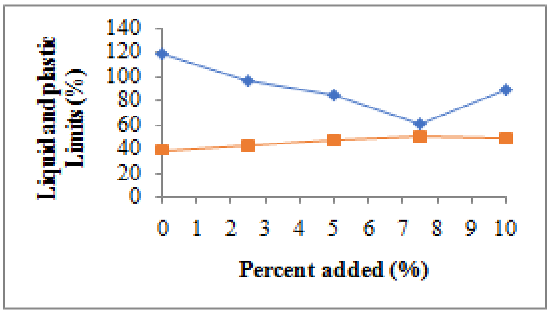

Fig 4. Liquid and plastic limit test results in case of adding lubricant oilby percent (2.5, ,5, 7.5 and 10%) of water used in the liquid and plastic limit tests

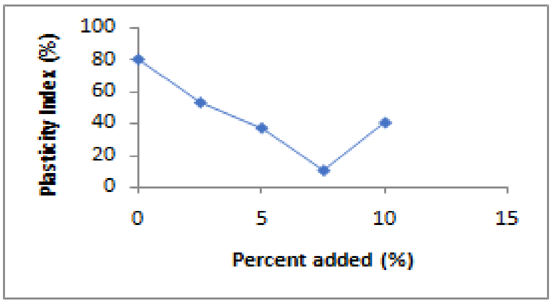

Fig 5. Plasticity Index test results in case of adding lubricant oilby percent (2.5, ,5, 7.5 and 10%) of water used in the liquid and plastic limit tests

4.3.3 Proctor test

As mentioned before, the standard proctor test was performed on the tested soil to obtain the maximum dry density and the optimum moisture content to perform the swelling pressure test.The standard proctor test was made based on the Egyptian code [15].This test was made in six trials with different water content starting from 8% to 20% with increment 2%. In each trial a soil sample was taken, and the water content and dry density was measured as shown in figure (6).

As shown in figure (6), the maximum dry density was 1.52 gm/cm^3 at optimum moisture content 12%. Thesevalues were used in all the one-dimensional odometer tests that were performed on the tested soil before and after the addition of the oil.

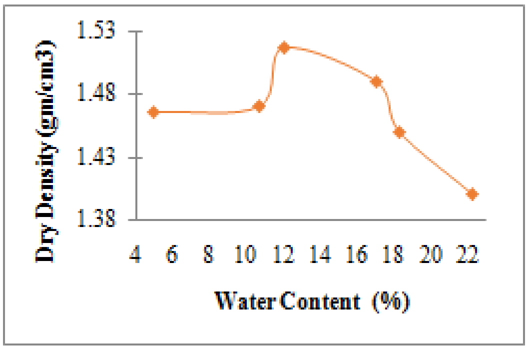

Fig 6. Standard proctor test results on the pure loam soil

4.3.4 Swelling pressure Test

The Swelling pressure test was performed through Consolidation swell method and based on Seed et al.(1962) and Gueddouda et al. (2011) all the swelling pressure measurements are obtained at maximum dry density and optimum moisture content[11,12].The Swelling pressure of the pure loam soil was measured as 3.6 Kg/cm^{2}as shown in Table (1). However, the addition of the oil showed a noticeable decrease at7.5% of the oil used as it decreased from 3.6 to 0.8 Kg/cm^2.As shown in figure (7), the lubricant oil contributed in decreasing the swelling pressure value to more than 75% it is initial standard value.

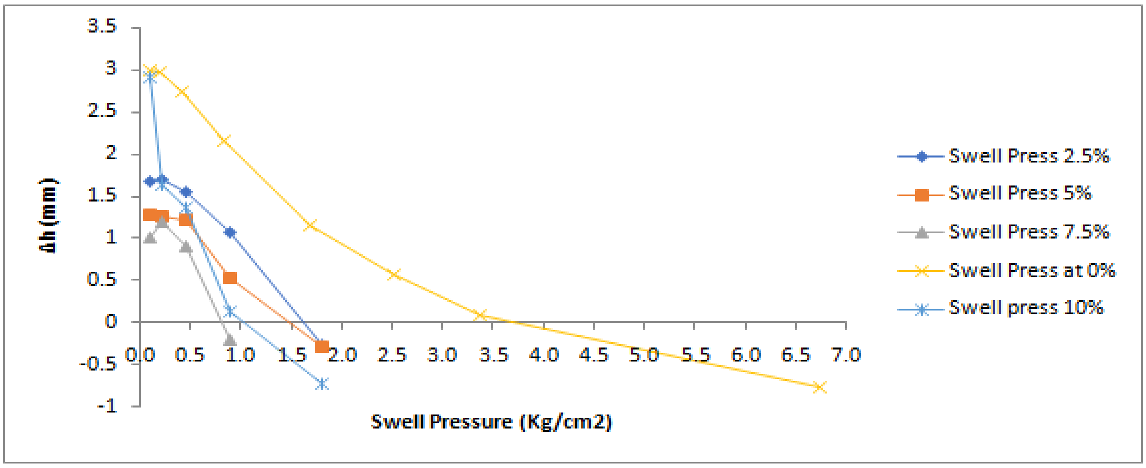

Figure 7. Consolidation swell test results by the addition of lubricant oil

Table 4 Combination of the experimental Results on the tested Expansive Soil

	Percent of oil added(%)	FS (%)	LL (%)	PL (%)	PI (%)	Sp (Kg/cm^2)
Pure Soil	0	155	119	39	80	3.6
Lubricant Oil	2.5	135	96	43	53	1.62
	5	125	84	47	37	1.45
	7.5	115	60	49.5	10.5	0.8
	10	120	89	48.5	40.5	1

5. Conclusion

This investigation studied the effect of adding the industrial lubricant oil on the swelling behavior of a clay loam soil as it was added with in specific range of percentage. This effect was studied through some laboratory measurements that predicts the swelling behavior of the soil which were Free Swell Index, Liquid Limit, Plasticity Index, and the Swelling pressure through one dimensional odometer.

The lubricant oil was added by percentages based on the free swell test which was 2.5,5,7.5 and 10% from volume of water used in each test. The addition of the oil showed some remarkable results as the free swell reduced from 155% to 115%, liquid limit reduced from 119 to 60%, the plastic index reduced from 80 to 10.5 and the swelling pressure was reduced from 3.6 to 0.8 kg/cm^2 which were obtained at 7.5%.

Finally, it was concluded that the addition of the oil succeeded in improving the swelling behavior of the tested soil and that was touched in the laboratory measurements. It is worth mentioning that the availability of the stabilizer and its construction analogy must be considered beside it is experimental results and cost economy in order to recommend the stabilizer type that will be used. It is also concluded through this study that using other iron industry products than the lubricant oil may improve the swelling behavior and decrease its negative impact on the over-lied construction.

6.References

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