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Using Low Permeability Sand-Fadr Mixture Membrane for Isolated Swelling Soil

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Abstract**—**Desert regions around the Nile valley in Upper Egypt contain great extent of swelling soil. Many different comment procedures of treatment of the swelling soils for construction such as pre-swelling, load balance OR soil replacement. One of the measure factors which affect the level of the aggressiveness of the swelling soil is the direction of the infiltration water directions within the swelling soils. In this paper a physical model was installed to measure the effect of water on the swelling soil with replacement using fatty acid distillation residuals (FADR) mixed with sand as thick sand-FADR mixture to prevent the water pathway arrive to the swelling soil. Testing program have been conducted on different artificial samples with different sand to FADR contents ratios (4%, 6%, and 9%) to get the optimum value fulfilling the impermeable replacement. The tests show that a FADR content of 9% is sufficient to produce impermeable replacement.

Keywords**—**Swelling soil, FADR, soil improvement, permeability

I. Introduction

BUILDING, highways, embankments, airports and irrigation structures built on expansive soil are subjected to differential movement due to the changes in atmospheric and seasonal conditions [1]-[3]. The cause of damage to such structures is related to the generation of unequal stress beneath structure foundations. The causes of water reaching the expansive soil underneath structures may be due to atmospheric conditions, infiltration from domestic sources, and ground water extraction by trees [4]. Due to the problems related to expansive soils, there are different solutions which were introduced by researchers to reduce the potential energy of volume change that is formed when water is introduced [5]. Nowadays, the Upper Egypt southern area is subjected to different development activities due to the desert reclamation projects. Various construction projects such as pavement, canal lining, and buildings well-construct to establish infrastructure that is essential for reclamation projects. The construction of such projects over an expansive soil is a serious problem in that area.The fatty acid distillation residuals (FADR) used in this study is a black viscous liquid inexpensive material or (by-product) of the edible oil and butter industry.

II. Materials

A. Fatty Acid Distillation Residuals (FADR)

The chemical analysis of FADR is shown in Table1. The Chemical components of FADR are done by Oils Institute associated - (Agricultural Research Center) - Ministry of Agriculture in Egypt. The analyses in Table1 show that the unit weight of FADR is about1.03 gm/cm3. In addition, the chemical analysis shows that the FADR consists of various carbonaceous ties and also a percentage of free fatty acid and humidity. The residue remaining after the volatile fatty acids have been removed from crude cottonseed fatty acids is termed "pitch". It consists of nonvolatile fatty acids, polymerized fatty material, unsaponifiable materials originally present in the seed stock, and other impurities not completely identified. The pitch is a black amorphous material having good waterproofing properties. It is used principally in special paints and varnishes, asphalt tile and roofing materials and electrical wiring insulation requiring high resistance to moisture. Only a few millions pounds of oil per year are consumed in non-edible products. Principal uses are in soap, detergent agents, lubricants, emulsifiers, sulfonated oil, pharmaceuticals, protective coatings, rubber, and in vehicles for nickel bearing catalysts. It is also used, to a lesser extent, in the manufacture of toilet articles, printing ink, polishes, synthetic plastics and resins, waterproofing bonding agents. A limited amount of cottonseed oil has been subjected to hydrogenation and the hardened product used as substitute for palm oil in metal working industries [6], [7].

Fatty acids from cottonseed oil foots are important because they provide through fractional distillation: (a) a pure source of palmitic acid for saturated alkyl chain compounds containing 16 carbon atoms, (b) a uniform source of mixed oleic and linoleic acids for slightly unsaturated 18 carbon atom alkyl compounds, and (c) a pure source of stearic acid for saturated 18 carbon atom alkyl compounds. The stearic acid is obtained by hydrogenation of the mixture comprising the oleic and linoleic acid fraction. The type of chemical compounds derived from cottonseed oil fatty acids and their applications are of the same nature as listed above. Although the volume of production of fatty acid derivatives is not large in comparison with the production in the entire fat and oil field, their applications in industry are important. The FADR used in this study is a by-product of cottonseed oil industry. It has a unit weight of 1.03 gm/cm3 and looks like liquid bitumen.

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TABLE I
CHEMICAL ANALYSIS OF FADR

Fatty acid	C14:0	C18:0	C18:1	C18:2	F.F.A.% (Free fatty acid)	Moisture %
1	17.2	6.9	33.5	42.4	26.14	0.898

B. Sand

Sand used in this study is local sand, which is typically used as a construction material in concrete and mortar production. Grain size distribution test was performed in accordance with the ASTM-D422 test method for particle size analysis of soils [5]. Sand characteristics are extracted such as effective diameter (D10), coefficient of uniformity (Cu), coefficient of curvature (Cc), percentage passing Sieve No. 200, these characteristics are classified according to the Unified Soil Classification System (USCS) (test method for classification of soils for engineering purposes), The specific gravity (Gs) was found to be 2.62.

C. Fundamental Properties of Expansive Soil

The expansive soil, was obtained from an area in south of Aswan city. This place named Toshka area which is located between longitudes 31027- and 31032- East and latitudes 23000- and 23010- North. The soil used in these tests was taken as undisturbed state from open pits. The samples were collected from about 5 to 10 meters in depth below ground surface through creating Toshka canal. The measured physical and mechanical properties, chemical composition, and the x-ray diffraction results of the tested expansive soil are tabulated in table (II).

TABLE II
PROPERTIES OF THE EXPANSIVE SOIL

1. Bulk density, (gm/cm^3)	2.18
Natural water content, (%)	6.85
Specific gravity, (G_s)	2.68
Void Ratio (e)	0.25
Dry Density (t/m^3)	2.03
Liquid limit, LL, (%)	75.4
Plastic limit, PL, (%)	29.5
Shrinkage limit, SL, (%)	10.05
Plasticity index, PI, (%)	45.9
Free swelling, (%)	260
Degree of swelling	Very high
Swelling pressure, Ps, (kg/cm^2)	15.35
Chemical composition	
Ion Hydrogen Concentration (pH)	7.20
Total dissolved salts, (T.D.S) p.p.m.	7552
Sulphur trioxide (So^-_3) p.p.m	1400
Chloride (Cl^-) p.p.m.	2736
Sodium (Na^+) p.p.m.	1771
Clay minerals	
Montmorillonite %	65
Kaolinite %	32
Illite %	2

III. EXPERIMENTAL PROGRAM

Tests were carried out using testing tank made of Plexiglas walls 10.0mm thickness 1000mm length, 330mm width and 480mm height, braced with steel angles to prevent lateral movements of the tank sides during placing, compaction and loading. The soil thickness used in the tank is 300mm. volume change of the soil was measured by three dial gages as shown in Fig. 1. The maximum and minimum water levels in the model were 120 mm and 50 mm above the soil level. Loads of the model above the soil layer is Plexiglas plate of 20.0mm thickness with dimensions of 990 mm length, 320mm width placed on the soil, and three square Steel plates of 300mm*300mm with 30 kg in weight each plate place above the Plexiglas plate.

In this paper some expressions were used as following: Above soil: means surface submerging, under soil: means sub surface submerging

Our laboratory works were done as following:

Fig. 1 Model shape with volume change measuring unites

A. Swelling soil was placed in the model without replacement, submerged by water from surface or subsurface

1) Soil without replacement

In this case we filled the model by 300mm of swelling soil and the soil was submerged by surface water, the water start to spirit in swelling soil, the maximum water level above the soil was 100.0 mm. we started to record the soil volume change through the heave happened due to the swell of the soil from the start until 7 days using the three dial gages that fixed in the model. Through this time we noticed that as the time increases as the swelling soil swell, more of water more of soil swelling. It is clear from Fig. 2&3 that the dial gage no1&2 have the same swelling value but dial gage no3 has small less of swelling value.

2) Soil with replacement

We have used our model filled by swelling soil with 30cm in depth. also we used membrane consists of mixture of sand and FADR with different mixing ratio of 4,6,9% and fixed thickness equal to 10 cm located above the swelling soil. To prevent water to go on swelling soil, increase thickens of the membrane or increase the ratio of the component that effect on the permeability of the mixture. In our study we fixed the membrane thickens and we changed of FADR ratio in the mixture. After that we used the surface water to fell the model and effect on the swelling soil. Through this time we started to record the volume changes of the soil with replacement and the elapsed time. At first water started to go on through the membrane mixture without any swelling, because of no swelling activities of the membrane material. After water touched the swelling soil, soil started to swell. The swelling depends on the activity of the soil itself and the amount of water available.

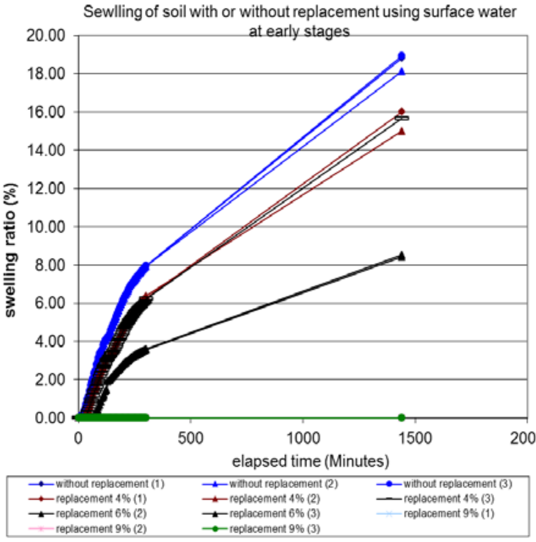

Fig. 2 Relation between swelling of the soil with or without replacement submerged by surface water and the elapsed time at the early stages

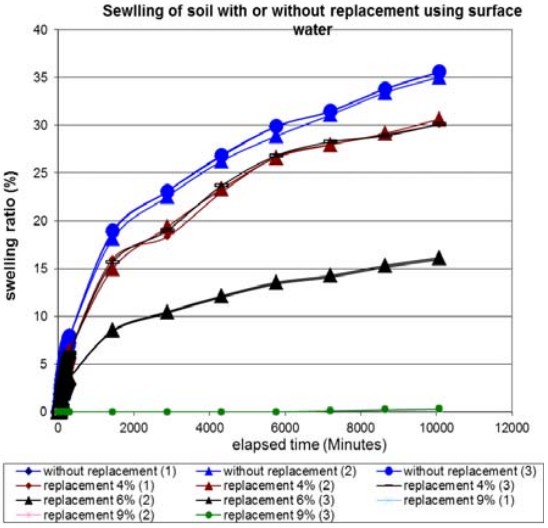

Fig. 3 Relation between swelling of the soil with or without replacement submerged by surface water and the elapsed time

If we decreased the amount of water to go to soil to swell, it means the amount of swelling will decreases also. By membrane mixture we can control the amount of water needed by the soil and control also the swelling value. Through Fig. 2 this represents the relation between swelling ratio of the soil, with or without replacement mixture, and the elapsed time. It is also clear that as the elapsed time increase as the soil swell. The rate of swelling is very high in the first 24 hours and it is almost equal to 50 % of the total swelling through the 7 days recording. It is clear that the total load used is very small compared to the soil swelling pressure. The swelling of the soil without replacement are much more than the swelling of the soil with replacement (as membrane). In case of soil with replacement, an increase of the FADR ratio in the replacement soil mixture decreases the swelling of the soil. This means that an increase of the FADR ratio decreases the permeability of the mixture. The best mixture in our case is the mixture contains 91% sand and 9% FADR which gives almost 1% swelling after 7 days. In case of soil without replacement water takes less time to go into the swelling soil. But in case of soil with replacement water takes more time to go into the swelling soil. Elapsing time in case of FADR 9% is higher than the other FADR ratio replacement. Soil replacement with FADR 9% it is very good ratio to use for normal building soil replacement and also very good for a canals soil replacement in swelling soil. Through our recording we get that the heave recorded through the three gages almost have the same value ie. Stable heave and leads to no deferential heave happened.

Fig. 4 indicates that Water goes through soil only in one direction through up to down. Soil heaves by same values in the entire model.

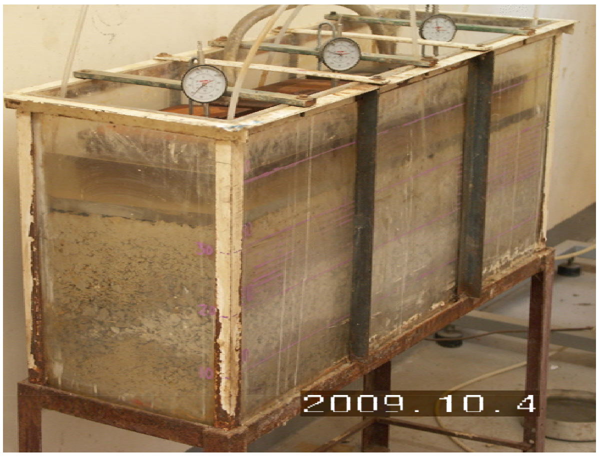

Fig. 4 Picture of surface submerging

B. Swelling soil was placed in the model with replacement of sand FADR mixtures (4,6,9% FADR with sand) submerged by water from surface or subsurface

In this case we consider the water comes from sewage or water pipe lines (Means water under pressure) or because of plants irrigations around water canals, in this case water will be like jetting, this fast water will make disturbance of the soil particles and make cavities. These cases make soil heave fast more than the surface water heaves and makes big volume change. But after few times this disturbance and the cavities happened before will collapse and leads to volume decrease suddenly. After this time the soil will swell again normally and these are clear in Fig. 4&5. Because of the water pipe line leakage the soil near will be affected by the leakage more than the soil far away from this leakage. This is clear in our model through the heave happened near dial gage no.3 which is faster and more than the heave happened at dial gages no. 2

and 1. In this case the heave will not be steady through the model and this leads to subsurface differential heave between the points. Subsurface water makes heave more than the heave happened because of surface water submerging. Through our model we used the water sources near to gage no.3, it means soil near this gage will have more water to swell more than the others and this is clear in Fig. 5&6 where swelling ratio in case of under soil (3) is more than the others gage. Also under soil (2) have water more than gage no1 where the swell happened near this gage 2 is more than the swell at gage 1. Comparing the swell happened through surface water or subsurface water through Fig. 5&6 we found that surface water makes almost constant heave, but subsurface water makes deferential heaves. Subsurface water makes big problems because of sudden have and sudden collapse.

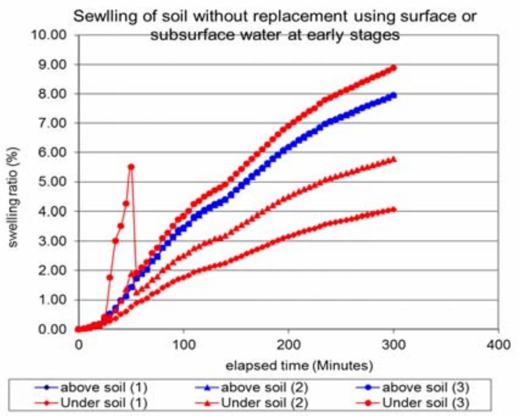

Fig. 5 Relation between swelling of the soil without replacement submerged by surface and subsurface water and the elapsed time at the early stages

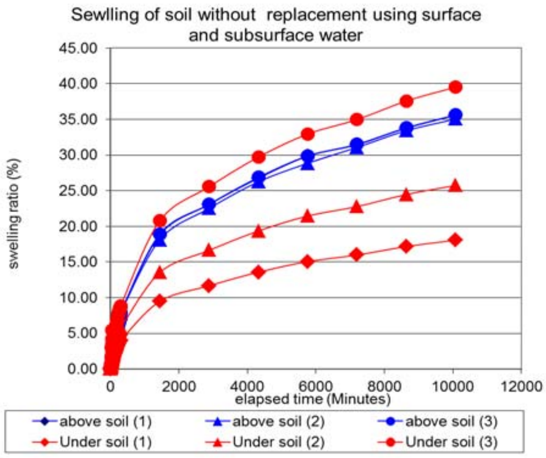

Fig. 6 Relation between swelling of the soil without replacement submerged by surface and subsurface water and the elapsed time

Fig. 7 indicate the sub surface submerging and it is clear that water goes through soil in many directions, and soil heaves by different values in the entire model.

Fig. 7 Picture of sub surface submerging

IV. CONCLUSION

Based on the results of experimental work the following can be concluded:

1. The chemical analysis of FADR shows that FADR consists of mainly various carbonaceous ties, free fatty acid and humidity. It is not poisonous or dangerous on the surrounding Environment including labors
2. Sub surface water causes deferential swell (heave), which makes dangerous on construction more than the dangerous happened duo to surface water.
3. An increase of FADR ratio in the membrane mixture decreases the swelling ratio of the underneath Swelling soil through increasing the path time of water or decreasing the permeability of the membrane.

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