Swelling Treatment
By Using Sand for Tamia Swelling Soil

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Abstract- The aim of this research is to study the effect of both sand content percent and gradation on the Tamia swelling clay. It describes an experimental investigation of the physical and mechanical properties of compacted sandy clay. Two sands with different gradation were used. Both sands are fine to medium and well graded sand. Three different sand percentages by weight were used. The results from Atterberg Limits, Compaction, Oedometer, and Direct Shear box tests were compared to find out the effect of sand gradation on swelling soil stabilization. The results show the variations of the maximum dry unit weight and undrained shear strength with the molding moisture content for material with different sand contents and gradation. Sand gradation showed no significant effect on Atterberg limits. It is concluded that the addition of 40% well graded sand reduced the free swell and swelling pressure by 70% and 90%, respectively. While the addition of the same percent of uniform sand reduced the free swell and swelling pressure by 50% and 94%, respectively.

Keywords – Swelling clay, Atterberg limits, Oedometer, Compaction, Shear strength, Stabilization.

I. INTRODUCTION
The most common techniques used for treating expansive soil deposits are lime, cement, and salt stabilization. The last two types reduce liquid and plastic limits and increase both shrinkage limit and shear strength.

Many investigators studied swelling and engineering properties of compacted sandy clay. Faure [1] studied the evolution of compaction curves versus water content with variation of clay content, clay mineralogy, sand content, and compactive effort by using kaolin and montmorillonite mixed separately with sand in different proportions. Daniel and Wu [2] investigated compacted clayey sand liners and covers for arid sites. They used soil samples from west Texas, samples were compacted and tested for hydraulic conductivity, strength, and volume changes. Faure and Mata [3] investigated the penetration resistance along compaction curves and concluded that the maximum dry density of compaction curves had no effect on penetration resistance values. Alawaji [4] investigated the effect of clay/sand contents, initial water content, and dry density on the swell potential, strength, and compressibility of compacted sandy clay soils.

He used Thomamah sand from surface sand dune in north-eastern Riyadh with Al-Ghafft expansive clay from the same region. Leelani et al. [5] investigated the effect of adding fine and coarse uniform sands on stabilizing active clay. The parameters investigated in that study includes Atterberg limits, compaction characteristics and shear strength. Swelling tests were not included in their study.

The presence of expansive clay and shale in many places in Fayoum city such as Tamia, Elazab, Demmo, Khorsheid, Komosheem, and Elberka with the presence of sand in adjacent parts of these regions suggested the potential use of mixed sandy clay soil in road subgrade, shallow foundation, or for other engineering application.

In this study, sand was used as stabilizing material for the Tamia swelling soil in Fayoum city. Two types of sand with different gradation were used. Both types were added to Tamia swelling clay with 10%, 25%, and 40% by weight.

Tests performed were Atterberg limits, oedometer tests, compaction tests, and direct simple shear box test on compacted sample at optimum moisture content.

The objective of this study is to compare the different test results after using two different sizes of sand treatment.

II. MATERIAL AND METHODOLOGY

A Tamia Clay
Tamia is a small village, located at the north of the Fayoum city, the expansive clay has 0.36% fine sand and 99.64% passing U.S. sieve No.200. The clay was classified as high plasticity clay (CH), according to USCS. The samples were brought form a strata in a soil profile that consists of three meter of cemented white silty clay followed by five meter of light yellowish silty clay, which was encountered till the end of the borehole at 12m with some lime for the last two meters. Ground water table is not encountered in the soil profile available data.
TABLE 1
Tamia Clay Properties

<table>
<thead>
<tr>
<th>Clay Properties</th>
<th>Tamia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wc %</td>
<td>17.5</td>
</tr>
<tr>
<td>Dry Unit Weight, $\gamma_d$ t/m$^3$</td>
<td>1.78</td>
</tr>
<tr>
<td>Liquid Limit, LL %</td>
<td>72</td>
</tr>
<tr>
<td>Plastic Limit, PL %</td>
<td>33</td>
</tr>
<tr>
<td>Plasticity Index, IP %</td>
<td>39</td>
</tr>
<tr>
<td>Shrinkage Limit, SL %</td>
<td>9</td>
</tr>
<tr>
<td>Shrinkage Index, IR %</td>
<td>63</td>
</tr>
<tr>
<td>Montmorillonite %</td>
<td>31.98%</td>
</tr>
<tr>
<td>Axial Swelling %</td>
<td>5.1%</td>
</tr>
<tr>
<td>Swelling Pressure t/m$^2$</td>
<td>87</td>
</tr>
<tr>
<td>Swelling Strain (mm)</td>
<td>0.97</td>
</tr>
<tr>
<td>% Free Swell</td>
<td>100</td>
</tr>
<tr>
<td>Clay Fraction (% finer &lt;0.002 mm)</td>
<td>52%</td>
</tr>
<tr>
<td>Silt Content / Sand Content</td>
<td>47.64% / 0.36%</td>
</tr>
<tr>
<td>Activity</td>
<td>0.81</td>
</tr>
</tbody>
</table>

C Sample preparation
Both sands were mixed to Tamia clay. Three sand percentages were used by weight 10%, 25%, and 40%. Samples were prepared at three selected water contents; at optimum moisture content, dry and wet sides of optimum of the compaction curves. Samples for Oedometer, and Direct shear box tests were taken at optimum moisture content after the compaction test.

D Oedometer Tests
Oedometer tests were used to investigate the influence of both sand size gradation and sand content on the swelling potential of Tamia clay. The swelling potential was measured for the Natural non-treated silty clay samples. Treated specimens were prepared by compact the Tamia silty clay in proctor compaction test at optimum moisture content with desired mixed sand percentage for both uniform and well graded sands, undisturbed samples were taken from the compaction mold to be used in oedometer. In the Oedometer, a constant pressure of about 1 t/m$^2$ was applied and then water was added while the sample allowed to swelling in the vertical direction under the constant pressure until it reached equilibrium. The swelling pressure was then measured by applying additional load to reduce the volume of the sample to its pre-inundation volume.

E Compaction Test
Maximum dry density, $\gamma_d$, and optimum moisture content, OMC, were determined from compaction tests which were carried out on the Tamia clay soil mixed by 10%, 25%, and 40% with uniform and well graded sands. For each sand percentage, four different water contents were added to the mixed soil to reach the dry and the wet sides on compaction tests.

F Direct Simple Shear Box Test
Treated samples with 40% sand content were taken from compacted soil after compaction test at optimum moisture content and then tested in the direct simple shear both. The samples were sheared at fast enough rate (0.5mm/minute) to obtain undrained shear strength of the treated samples.

III. RESULTS

A Atterberg Limits
Liquid limit, LL, plastic limit, PL, and shrinkage limit, SL, were tested before and after adding the stabilizing uniform and well graded sands. Typical results are shown in Figure 1. The results indicate that LL and PL...
values decrease with the increase in sand content for both uniform and well graded sands. Shrinkage limit slightly increases with the increase of sand content. Figure 1 shows that added sand gradation does not have major influence on Atterberg limits results.

For graded sand:

\[
LL = -0.77 \% \text{ of Sand} + 74.33 \quad (R^2=0.98) \quad (1)
\]

\[
PL = -0.49 \% \text{ of Sand} + 30.49 \quad (R^2=0.92) \quad (2)
\]

\[
SL = 0.1 \% \text{ of Sand} + 8.6 \quad (R^2=0.95) \quad (3)
\]

For uniform sand

\[
LL = -0.68 \% \text{ of Sand} + 77.55 \quad (R^2=0.95) \quad (4)
\]

\[
PL = -0.397 \% \text{ of Sand} + 27.96 \quad (R^2=0.68) \quad (5)
\]

\[
SL = 0.06 \% \text{ of Sand} + 8.89 \quad (R^2=0.75) \quad (6)
\]

Where, the \(R^2\) indicates the corresponding coefficient of determination.

**B Swelling Potential**

According to the Egyptian Code, part 5, [6], Tamia clay is considered as high swelling clay. Seed et al, [7], classified the swelling clay from low to very high according to the percentage of clay content and the activity with the swelling potential. Dakshanamurthy and Raman, [8], classified the swelling clay from low to very high according to the liquid limit and the plasticity index.

According to Snethen [11] if shrinkage index (IR) is 30 to 60, swelling potential is high, and for IR>60, swelling potential is very high. Tamia swelling clay is classified as high to very high swelling according to the fore mentioned empirical methods..

The addition of 40% of uniform sand reduced the measured free swell from 100% for the natural soil to 50% for the admixture. On the other hand, the addition of the same amount of well-graded sand reduced the free swell % fro 100 to 30%. Figure 2 shows the Oedometer test results. The swelling strains of the natural clay, clay plus 40% well graded sand, and clay plus 40% uniform sand are 5.1%, 0.13%, and 0.08%, respectively. The swelling pressure of the natural clay was 87 t/m\(^2\). The addition of 40% well graded sand and uniform sand reduced the swelling pressure to 8 t/m\(^2\) and 5.3 t/m\(^2\), respectively.

**C Compaction Tests**

Maximum dry unit weight and optimum moisture content were determined using the proctor compaction test. Figures 3 and 4 show typical results of adding three different percentage of uniform and graded sand. The results reflect the effect of sand content on the unit weight and optimum moisture content. Samples with larger amount of sand result in higher dry unit weight and lower optimum moisture content values which are consistent with the general trend shown by Henderson and Lisle [12], Faure and Mata [3], Alawaji [4], and Leelani et al. [5]. Unit weight of clay treated with well graded sand is higher than that of the clay treated with uniform sand.

Van der Merwe [9] and similarly Williams and Donaldson [10] a version of which is in the Egyptian Code), swelling potential according to clay fraction and plasticity index.
Compaction Tests For Treated Clay with Uniform Sand

Fig. 3 Variation of dry density with molding water content with uniform sand

Compaction Tests For Treated Clay with Graded Sand

Fig. 4 Variation of dry density with molding water content with graded sand

The maximum dry density $\gamma_d$ kg/m³ and the optimum water content OMC% were regressed with uniform sand percentage or graded sand percentage, and liquid limit percentage and plastic limit percentage as follows:

$$\gamma_d = 82.4 \text{ uniform sand } % + 66.5 \text{ LL} + 119.7 \text{ PL} - 6442.3$$
$$\left(R^2=0.998\right)$$

$$\gamma_d = 29.8 \text{ graded sand } % + 52.5 \text{ LL} - 44.4 \text{ PL} - 1045.3$$
$$\left(R^2=0.98\right)$$

OMC% = 0.12 uniform sand% + 1.39 LL - 4.92 PL + 19.75
$$\left(R^2=0.97\right)$$

OMC% = 0.82 graded sand% - 1.65 LL + 2.04 PL + 91.83
$$\left(R^2=0.98\right)$$

**D Shear Box Test Result**

Direct shear box test was used to measure the undrained shear strength for undisturbed clay sample. The undrained shear parameter $c_u$ was 7.1 t/m².

As the sand content increases the shear strength increase, Alawaji [4] and Leelani etaL [5]. Figure 5 shows the results of the direct shear box test results for natural and treated clay. In general, the addition of 40% of sand (uniform or well graded) and compacting to maximum dry unit weight and optimum water content results in an increase in the undrained shear strength of the clay. The addition of well graded sand resulted in more pronounced increase in undrained shear strength with the increase in effective normal stress as compared to slight increase in the case of adding uniform sand (Figure 5 - Table 3).

**TABLE 3**

<table>
<thead>
<tr>
<th>Clay Properties</th>
<th>Tamia before treatment</th>
<th>Tamia after treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wc %</td>
<td>17.5</td>
<td>10</td>
</tr>
<tr>
<td>$\gamma$ dry t/m³</td>
<td>1.78</td>
<td>1.92</td>
</tr>
<tr>
<td>LL%</td>
<td>72</td>
<td>49</td>
</tr>
<tr>
<td>PL%</td>
<td>33</td>
<td>15</td>
</tr>
<tr>
<td>IP %</td>
<td>39</td>
<td>34</td>
</tr>
<tr>
<td>$C_u$ t/m²</td>
<td>6</td>
<td>15.6</td>
</tr>
<tr>
<td>$\phi'$</td>
<td>6.28</td>
<td>9.1</td>
</tr>
<tr>
<td>Axial Swelling (mm)</td>
<td>0.97</td>
<td>0.015</td>
</tr>
<tr>
<td>Swelling Pressure t/m²</td>
<td>87</td>
<td>5.34</td>
</tr>
<tr>
<td>Swelling Potential %</td>
<td>5.1</td>
<td>0.008</td>
</tr>
<tr>
<td>% Free Swell</td>
<td>100%</td>
<td>50%</td>
</tr>
</tbody>
</table>

Fig. 5 Shear strength before and after sand treatment
IV. CONCLUSIONS

1. By correlating activity with swelling pressure, and by plotting these results on the Egyptian Codes charts it is found that Tamia samples are considered swelling soils. This must be taken into consideration in foundation design. The addition of sand to the expansive soil as stabilizing material is efficient, beneficial from economical and environmental views.

2. Treating the clay by adding sand results in reduction in liquid and plastic limits of swelling clay and slight increase in shrinkage limit. There was no major influence of gradation on the results.

3. The addition of 40% well graded sand reduced the free swell and swelling pressure by 70% and 90%, respectively. While the addition of the same percent of uniform sand reduced the free swell and swelling pressure by 50% and 94%, respectively.

4. The addition sand resulted in an increase in maximum dry unit weight and a decrease in the optimum water content. The trend is pronounced with the increase in sand content. The addition of well graded sand gave higher increase in dry unit weight than the increase by adding uniform sand.

5. The addition of sand increased the undrained shear strength of the compacted clay. The increase in undrained shear strength with the increase in effective normal stress is higher in the case of adding well grade sand as compared to that in the case of adding uniform sand.

REFERENCES