Some Geotechnical Properties of Two Organoclays

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ABSTRACT

Engineering characteristics of clay depends on its mineral and chemical structure. When the clay soils encountered with water, their volume and resistance properties would be change gradually. Large amount of decrease is observed at the bearing capacity of swelling clay soils because of varieties in the characteristics confronted with water. In order to solve these problems, stabilization of clay soils using chemical additions is a prevalent subject of research. Researchers are interested in usage and correction of clay via surface active matter (surfactant) and polymer adsorptions. With this study, organoclays were developed by a raw clay modification with two surfactants and geotechnical properties of them were determined in laboratory. The optimum water content and maximum dry unit weight of both organoclay samples were decreased as compared with those of raw clay samples. Additionally, the direct shear test results showed that the internal friction angles of organoclays were increased.

1. INTRODUCTION

Because of its low permeability, clays are the main material used in solid waste disposal landfills as a liner. It is exposed there to various chemical, biological and physical events, and the clay is affected by the resulting leachate (Yilmaz et al. 2008). For this reason, the researchers are interested in surfactants and polymers to modify clays for improving their engineering properties. Surfactants are surface-active agents that alter the properties of fluid interfaces. The organoclays (surfactant–clay complexes) have been considered as appropriate landfill liner (Lo 2001; Ashmawy et al. 2002; Gates et al. 2004; Matott et al. 2006) and also potential sorbents in wastewater and contaminated soils (Zhu & Zhang 1997; Mulligan et al. 1999a, b; Mulligan et al. 2001; Al-Asheh et al. 2003; Li et al. 2003; Wibulswas 2004; Ghiaci et al. 2004; Yang et al. 2005).

There are a large number of studies on organoclays (Fu & Qutubuddin, 2000; Gungor et al. 2001; He et al. 2005; Isci et al. 2008; Guegan et al. 2009; Gurses et al. 2009). Most of the researchers were focused on the investigation of electrokinetic properties of organoclays such as zeta potential, cation exchange capacity, electrical conductivity, etc. However there is no comprehensive study that compares the geotechnical properties of organoclays. The objective of this paper is to investigate the effect of two different surfactants on the optimum water content, and maximum dry unit weight, shear strength parameters (internal friction angle and cohesion) of raw clay. The surfactants used in suspensions are 5% (250 ppm), 10% (500 ppm), and 15% (750 ppm) of dry raw clay weight.

2. MATERIALS AND METHODS

Clays

The clayey soil sample taken from Erzurum region in Turkey and according to the Unified Soil Classification System-USCS, the class of clay is CH. X-ray diffraction (XRD) and X-ray fluorescence (XRF) methods have been used to identify the major minerals and chemical compounds present in the clay. The chemical compositions and XRD patterns of clay are given in Table 1 and Fig. 1, respectively. Additionally, some index properties of clay are given in Table 2. According to the X-ray diffraction results (Figure 1) for clay, smectite (56%) appears to be

<table>
<thead>
<tr>
<th>Chemical Composition</th>
<th>Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>53,28</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>20,67</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>6,13</td>
</tr>
<tr>
<td>CaO</td>
<td>1,71</td>
</tr>
<tr>
<td>MgO</td>
<td>2,82</td>
</tr>
<tr>
<td>K₂O</td>
<td>0,82</td>
</tr>
<tr>
<td>Na₂O</td>
<td>0,02</td>
</tr>
<tr>
<td>Ti₂O</td>
<td>0,63</td>
</tr>
<tr>
<td>LOI</td>
<td>13,9</td>
</tr>
</tbody>
</table>
the predominant clay mineral, whereas kaolinite (34%) and illite (3%) appear in lesser proportions. Silt and sand size particles are composed of quartz (4%) and feldspar (3%).

Table 2: Index Properties of Clay

<table>
<thead>
<tr>
<th>Property</th>
<th>CTAC</th>
<th>QEFA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay Content, &lt;0.002 mm</td>
<td>74</td>
<td>74</td>
</tr>
<tr>
<td>Finer Content, &lt;0.075 mm</td>
<td>99</td>
<td>99</td>
</tr>
<tr>
<td>Specific Gravity, G_s</td>
<td>2.72</td>
<td>2.72</td>
</tr>
<tr>
<td>Liquid Limit, w_l (%)</td>
<td>88</td>
<td>88</td>
</tr>
<tr>
<td>Plastic Limit, w_p (%)</td>
<td>38</td>
<td>38</td>
</tr>
<tr>
<td>Plasticity Index, I_p</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Cation exchange capacity, (meq/100 g dry)</td>
<td>39</td>
<td>39</td>
</tr>
<tr>
<td>BET (N_2) surface area,</td>
<td>7.3</td>
<td>7.3</td>
</tr>
<tr>
<td>Contact Angle</td>
<td>35</td>
<td>35</td>
</tr>
</tbody>
</table>

Surfactants and Preparation of Organoclays

In this research, two different cationic surfactants (Cetyl trimethyl ammonium chloride-CTAC and Quaternised ethoxylated fatty amine- QEFA) were used. The formulas of CTAC and QEFA are (C_{16}H_{33})N(CH_{3})_{3}Cl, (Fatty Amine)R-(OCH_{2}CH_{2})_{n}-NH, respectively. The preparation of organoclay was also undertaken by the following procedure as described by Xi et al. (2007) and Liu et al. (2008): 40 g of clay was first dispersed in 8 lt of deionized water then stirred with a magnetic stirrer at about 1000 rpm for about 2 h. Previously prepared surfactant solution was slowly added to the clay suspension at 30° C. All modified products were dried at room temperature. The surfactants were used 5% (250 ppm), 10% (500 ppm), and 15% (750 ppm) of clay weight.

Geotechnical Properties

Maximum dry unit weight (\(\gamma_{d_{max}}\)) and optimum moisture content (OMC) were determined on the samples in accordance with ASTM D 698. In order to determine the shear strength parameters of samples, a series of direct shear tests was carried out in accordance with ASTM D 3080. All samples were initially compacted in a Standard Proctor mould by Standard Proctor tests and then extruded using a cutting ring before direct shear tests. For these tests, samples were placed in the standard shear box apparatus with 60 mm in diameter and 35 mm in length.

3. RESULTS AND DISCUSSION

Compaction Test

Standard proctor tests were done on both raw clay and organoclay samples to determine their optimum water content (OMC) and maximum dry unit weight (\(\gamma_{d_{max}}\)) relationships. The compaction test results were reported in Table 3. Additionally, the compaction result of CTAC and QEFA were shown in Fig. 2 and 3, respectively. The addition of surfactants to clay samples decreased the optimum moisture content and the maximum dry density for the same compaction effort.

Table 3: Optimum Moisture Content and Maximum Dry Density of Organoclays

<table>
<thead>
<tr>
<th></th>
<th>(\gamma_{d_{max}}) (kN/m^3)</th>
<th>OMC (%)</th>
<th>(\gamma_{d_{max}}) (kN/m^3)</th>
<th>OMC (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw clay</td>
<td>13.7</td>
<td>35</td>
<td>13.7</td>
<td>35</td>
</tr>
<tr>
<td>5% surfactant</td>
<td>12.1</td>
<td>35</td>
<td>12.0</td>
<td>32</td>
</tr>
<tr>
<td>10% surfactant</td>
<td>12.0</td>
<td>32</td>
<td>12.3</td>
<td>29</td>
</tr>
<tr>
<td>15% surfactant</td>
<td>12.6</td>
<td>30</td>
<td>12.3</td>
<td>29</td>
</tr>
</tbody>
</table>

Some previous studies indicated that cationic surfactants are increased contact angle of clays (Cipriano et al. 2005), are decreased consistency limits of clays (Akbulut et al. 2010a) and produced a hydrophobic surface. Due to this hydrophobic surface, water affinity of organoclays decreases. Similarly, Akbulut et al. (2010b) reported that the maximum dry unit weights decrease with increasing percentage of cationic surfactant because of low specific gravity of organoclays. In this sense, it could be said that the organoclays are compacted with lower water contents.
**Direct Shear Test**

Direct shear tests (unconsolidated-undrained) were done on samples for determination of shear strength parameters of organoclays. The Mohr-Coulomb failure envelope of CTAC and QEFA organoclays were given in Fig. 4 and Fig. 5, respectively. Additionally, the unconsolidated-undrained cohesion and internal friction angles of organoclays were given in Table 4. The internal friction angle of the CTAC organoclay initially increased with addition of 5% CTAC, beyond which the internal friction angle decreased when the percentage slightly increased. However, the internal friction angle of the QEFA organoclay continuously increased with addition of QEFA (Table 4). However, the values of unconsolidated-undrained cohesion were decreased with increasing percentage of surfactants.

**Table 4: Shear Strength Parameters of Organoclays**

<table>
<thead>
<tr>
<th></th>
<th>CTAC</th>
<th>QEFA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>c</td>
<td>c</td>
</tr>
<tr>
<td>(kPa)</td>
<td>(kPa)</td>
<td>(kPa)</td>
</tr>
<tr>
<td>Raw clay</td>
<td>415</td>
<td>415</td>
</tr>
<tr>
<td>5% surfactant</td>
<td>146</td>
<td>30</td>
</tr>
<tr>
<td>10% surfactant</td>
<td>145</td>
<td>30</td>
</tr>
<tr>
<td>15% surfactant</td>
<td>136</td>
<td>38</td>
</tr>
</tbody>
</table>

4. CONCLUSIONS

The following conclusions are made based on the test results and on the discussion presented in this study:

- Compaction parameters were changed as compared with those of raw clay. The addition of surfactants to clay samples decreased the optimum moisture content and the maximum dry density for the same compaction effort.
- The organoclays with CTAC and QEFA surfactants gave the higher internal friction angles than the raw clay. However, the organoclays with surfactants gave the lower unconsolidated-undrained cohesion.

It should be pointed out that further studies on the engineering properties of organoclays (e.g., swelling pressure, consolidation, permeability) are needed to make more reasonable judgments. Also, in these studies, the behavior of the organoclays may be explained more reasonably.

ACKNOWLEDGEMENTS

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