EFFECT OF SAMPLE DIMENSION ON EFFECTIVE SHEAR STRENGTH PARAMETERS OF REMOLED SEDIMENTARY RESIDUAL SOIL

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ABSTRACT

The residual sedimentary soil is one of the largest residual soils in Peninsular Malaysia. Its vast presence enables engineering activities to use this type of residual soil in the construction sector such as in construction of retaining walls and roads. Nevertheless, this residual soil often brings in heterogeneities because it is structurally complex and extensively weathered in most places which it can cause a structure to fail. This can be solved by determining the value of the shear strength parameter of the soil in a particular area. In order to determine the effect of sample’s dimension on the effective shear strength parameters of the samples, consolidated drained (CD) triaxial test was conducted on two different diameters size of 38 mm and 50 mm. This study shown that is has a significant effect in different sizes of sample used. 22.5 kPa and 32˚ were recorded for effective cohesion value, c’ and effective friction angle, Ø’ for 38 mm soil samples and for 50 mm soil samples, the recorded c’ and Ø’ values were 20 kPa and 30˚ respectively. 38 mm size soil sample recorded high values of both parameters. The small size of remolded sample will make soil particle denser hence reduce the void. This will not represent the actual condition on the site. As a result, by using small size samples for determining shear strength parameters can result in false value in designing while large sample dimension is more accurate representation of soil condition.

Keywords: sample dimension, sedimentary residual soil, shear strength parameters, effective cohesion, effective friction angle.

INTRODUCTION

Residual soil is formed by the composition of parent’s rock where more than half of the land area in Peninsular Malaysia is covered with residual soil [1,2,3,4]. Thus make this soils type is advantages to the construction industries such as roads, airports, dam, foundation and slopes. It is highly structured in nature and may also be cemented with the percentage or degree of weathering. Figure-1 shows, granite and sedimentary residual soils cover most part of Peninsular Malaysia and the rest in coastal area soft clay dominates.

With rapid development in Malaysia, residual soil is commonly encountered during construction activities. As reported by many researcher [1,2,3,6,7,8,9,10,11,12] the residual soil is known as one of the soils with heterogeneities due to the differences in the percentage of depth or different weathering rates. These will cause changes in soil properties to be unpredictable, directly will extremely affect the engineering parameters and characteristics of residual soil.

Strength of soil is the result of the resistance of the failure movement of soil molecules that are connected with one another, that will bring failure related too with the shear strength as one of the most engineering properties in soil [11,13]. In geotechnical engineering, shear strength parameters which are value of apparent cohesion, c’ and effective friction angle, Ø’ are very useful in designing process of geotechnical structure to safety and economical geotechnical structure design.

These shear strength parameters affected by many factors such as degree of weathering [14,15], pore pressure, disturbance of the soil structure [16], stress history, time and environmental conditions, natural moisture contents and percentage of clay particle [17,18]. Field and laboratory tests are the most common methods to measure the shear strength parameters [18]. Standard penetration test (SPT), cone penetration test (CPT) and pressuremeter test are common methods for field test while triaxial and shear box test are popular methods in laboratory to determine shear strength parameters [19].

Most of the researcher’s studied the behavior of soil are compare without due attention to the differences in sample dimension and its effect on shear behaviour. As reported by [20] the use of different size samples provides significant value to the shear strength parameters of particular soil.

Mohr Coulomb failure criterion was used to determine two shear strength parameters for saturated sedimentary residual soils, i.e c’ and Ø’. This work studied the effective shear strength parameters of remoulded saturated sedimentary residual soil by using consolidated drained (CD) triaxial test and focused on the effect of sample dimension used.
METHODOLOGY

The disturbed sedimentary residual soil samples were collected from open space near to the Block IST, UiTM Pahang. The soil samples were collected by using shovel at a depth of 1.0 - 1.5 m below the ground surface. All the top soil and humus were removed before the soil sample brought to laboratory for dried in an oven at 105°C. Figure-2 show the location of soil sample.

The physical properties of sedimentary residual soil were conducted before triaxial test and the test was carried out according to BS 1377: Part 2:1990 [25] and Head: Volume 1:2006 [26]. While in CD triaxial test, the test was conducted according to Head: Volume 3:2014 and BS 1377:Part 8:1990. Using static compaction of standard compaction method at a specified moisture contents and density, the samples were compacted in standard compaction mould and were extruded to get the size of samples of 38 mm diameter with 76 mm height and 50 mm diameter with 100 mm height respectively.

Both samples were then tested under saturated triaxial compression test under consolidated and drained condition. The soil samples were then saturated until a value of pore pressure coefficient ($B_w$) exceeding 0.95 and at the end of saturation process, the soil sample were consolidated under an effective confining stress of 50,100,200 and 300 kPa using same back pressure of 400 kPa. Then the soil samples were sheared at a strain rate of 0.029 mm/min.

RESULTS AND DISCUSSIONS

Table-1 shows the physical properties of sedimentary residual soil and based on Unified Soil Classification System (USCS), the soil sample was silty sand or sand silt mixture(SM).
Four samples with different diameter size and length were prepared and tested under CD triaxial test condition and by plotting the Mohr’s Circle failure envelope, the effective shear strength parameters ($c'$ and $\phi'$) were determined. Figures 3 and 4 show the curves of effective stress failure envelope, deviator stress vs axial strain and pore water pressure vs axial strain for both soil samples respectively while Figure-5 show the combination Mohr Coulomb failure for both samples.
Figures 2(a), 3(a) and 4 are represent Mohr’s circle envelope that were plotted to get the value of $c’$ and $Ø’$ while Figures 2(b) and 3(b) are to determine the pattern of deviator stress applied toward the recorded axial strain. Figures 2(c) and 3(c) show the graph of changes in volume versus changes in axial strain. For soil, failure is usually considered occurring at 15% to 20% of strain and for this study, 20% of strain were chosen.

Figure-4 shows, during the shearing stage, the value of $c’$ and $Ø’$ is more higher for 38 mm diameter of sample rather than 50 mm diameter. This happened maybe due to the closer soil particle to each other thus will produce higher result. This results show the same pattern as founded by [20].

As reported by [20], this small size sample reflecting higher compressibility and exhibit steeper critical state line (CSL). Unfortunately, in order to design the slope stability analysis, the less stable or even at failure is more reliable. Thus testing larger specimens is recommended.

Other than that, [20] states that the difference value of $Ø’$ will effect on the lateral earth pressure such as value of $K_a$. As an example, by referring to Figure-4, larger specimens will get lower value of $Ø’$ but will result higher value of $K_a$. Therefore, specimens size could significantly affect the lateral earth pressure and at the same time the sliding or overturning analysis can be made to design of safer retaining structure.

In general, the effective internal friction angle determined in this paper were in the range of 30° to 32° and the value of effective cohesions were 20 to 22.5 kPa for soil sample of 50 mm and 38 mm diameter respectively. Table-2 shows the summarize value an effective shear strength parameters for both soil samples.
Table 2. Effective shear strength parameters for different sizes of soil sample.

<table>
<thead>
<tr>
<th>Size of soil sample in triaxial test (mm)</th>
<th>Effective cohesion, c’ (kPa)</th>
<th>Effective friction angle, Ø’ (˚)</th>
</tr>
</thead>
<tbody>
<tr>
<td>38</td>
<td>22.5</td>
<td>32</td>
</tr>
<tr>
<td>50</td>
<td>20.0</td>
<td>30</td>
</tr>
</tbody>
</table>

The finding results are then compared to the existing results founded by the earlier researches to make sure the value is accepted or not. The comparison is strictly for sedimentary residual soil in Malaysia only. Based on [21], reported that the range of effective cohesion for shale as a parent’s rock is 20 kPa while effective friction angle is 30˚. While [22] mention the value of c’ is in the range of 36 - 39 kPa and 42˚ - 44˚ is Ø’ value for sandstone. Other than that, [23] reported that the value of shear strength parameters for sedimentary residual soil at Kedah is 3.5 kPa and 27˚ - 28˚. Another researcher, [24] determined the value of c’ is between 0 - 12 kPa and Ø’ value is between 23˚-39˚. Choose Sepang as a location for soil sample, [7] founded that the value of c’ is between 0 - 10 kPa while Ø’ is between 26˚ - 33˚ for difference weathering grade of sandstone. Table 3 shows the summary of this data at selected locations.

Table 3. Shear strength parameters of sedimentary residual soil at selected location.

<table>
<thead>
<tr>
<th>Source</th>
<th>Location</th>
<th>Parents Rock</th>
<th>Effective cohesion, c’ (kPa)</th>
<th>Effective friction angle, Ø’ (˚)</th>
<th>Weathering grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ting et al. (1972)</td>
<td>Malaysia</td>
<td>Shale</td>
<td>20</td>
<td>30</td>
<td>-</td>
</tr>
<tr>
<td>Komoo (1985)</td>
<td>Malaysia</td>
<td>Sandstone</td>
<td>36-39</td>
<td>42-44</td>
<td>-</td>
</tr>
<tr>
<td>Taylor and James (1967)</td>
<td>Muda Irrigation, Kedah</td>
<td>Sandstone</td>
<td>3.5</td>
<td>27 – 28</td>
<td>-</td>
</tr>
<tr>
<td>Wong and Singh (1996)</td>
<td>Putra LRT line between Kuala Lumpur &amp; Petaling Jaya</td>
<td>Interbedded sandstone, siltstone &amp; shale/mudstone</td>
<td>0-12</td>
<td>23-39</td>
<td>-</td>
</tr>
<tr>
<td>Huat et al. (2005)</td>
<td>Cut slope 40 m link road near KLIA, Sepang Selangor</td>
<td>Sandstone</td>
<td>10</td>
<td>26</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>8</td>
<td>28</td>
<td>IV</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4</td>
<td>31</td>
<td>IV - III</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0</td>
<td>33</td>
<td>III</td>
</tr>
</tbody>
</table>

Therefore, the overall range of shear strength parameters for sedimentary residual soil in Malaysia founded by earlier researchers is between 0 - 39 kPa for c’ value while Ø’is 23˚- 44˚. The range of shear strength parameters in this study is between 20 - 22.5 kPa and 30˚- 32˚ for c’ and Ø’value effectively. It can conclude that the results recorded are within the range of shear strength parameters.

CONCLUSIONS

Shear strength parameters is the important value in designing any geotechnical structure. These parameters are not constant for every soil type even with same depth of soil collected. Residual soil as mention by many researchers is known as one of the soil with heterogenities and unpredictable effects.

Result of CD triaxial test for 38 mm diameter and 50 mm diameter of sedimentary remoulded residual soil shown there is a significant effect in different size of sample during isotropic compression test. In shearing stage, the smaller size sample recorded higher friction angle and shear strength. Accordingly, using the results of smaller size sample could lead to higher slope stability analysis and falsely higher factor of safety in designing retaining structure. In the other words, testing the larger size sample will get better result that will representing of field shear and deformation behavior. This study also showed that, both effective shear strength parameters recorded are within the range of effective shear strength parameters founded by earlier reseacher of Malaysian sedimentary residual soil.

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