Chapter 3

Soil improvement on subgrade using Envirotac on clay soils for better roads

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3.1 Introduction

Clay soil always used in construction of road especially in subgrade layer, however this type of soft soil create difficulty in construction due to its properties. This soil experiences a high clay content, which is when their moisture content is increase their potential to swell is high [1]. Clay soil also have low permeability and shear strength and also high compressibility. Among of the problems in the construction when clay soil is used are enormous post construction settlement on excavation and embankment construct, and also an inadequate bearing capacity [2].

One of the methods that can reduce the problems in clay soil in order to have a good road conditions is by soil improvement method. Soil improvement such as chemical stabilization can enhance soil strength and reduced construction cycle. Envirotac is one of the chemical stabilization that act as a soil stabilizer, which is a form of acrylic polymer. Envirotac has a variety of utilization such as for unpaved road improvement, landfill stabilization and also can be used in dust control [3]. The function of these substance in soil are to bind soil particle all together and eventually will produce a hard layer thus can avoid erosion.

This research was conducted to obtain the information about the strength of clay soil with the use of Envirotac chemical as an additional mixture for subgrade layer. Furthermore, is to determine the suitable ratio of Envirotac chemical that is needed to mixture with the soil. By using California bearing ratio test, the performance of the soil with the mixture can be known.
Subgrade layer enact an important role in transmitting structural strength to the pavement structure as it collects loads that produce by road traffic [4]. Generally, a road that is construct on a soft subgrade which is clay soil has created many challenge and problems to the highway construction. This type of soil is known because of the not sufficient strength to hold the loads whether in construction or during the service cycle of the pavement, clay soil also has poor strength and compressibility.

Soil improvement should enhance the stiffness properties and strength of pavement materials, minimize the susceptibility of moisture, improve stability of volumetric, reduce permeability, reduce the thickness of pavement by improving subgrade properties and able to create bound course [5].

3.2 Materials and Methods

The main material that were used in this research are Envirotac and Clay soil that have been taken from Research Center, UTHM. While, testing that was carried out in this research is California Bearing Ratio (CBR) test.

3.2.1 Envirotac

Envirotac is a form of acrylic polymer that act as a soil stabilizer. Envirotac commonly in liquid form and it is white colour. This emulsion binds the soil particle all together during drying process by producing a clear plastic and resin bond. In addition, Envirotac also confirmed as non-toxic, non-hazardous, environmentally safe dust control which is concentrated liquid format and finally cured in solid state [6]. Despite all that, Envirotac is still examined as a new material in the construction sector. Figure 1 shows Envirotac, soil stabilizer in liquid form.
3.2.2 Soil sample preparation

All of the soil sample preparation for this research are compiled to [7] and ASTM D1997 Standards. Generally, the clay soil sample will be mixed with different percentages of Envirotac and different curing period. This sample undergo several tests to determine its effectiveness and performance of stabilised clay soil. Table 1 shows sample preparation data.

Table 1 Sample preparation data

<table>
<thead>
<tr>
<th>Type of soil</th>
<th>Additives</th>
<th>Number of samples (Unsoaked and soaked)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0 days</td>
</tr>
<tr>
<td>Clay Soil</td>
<td>100% clay soil</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>95% soil + 5%</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Envirotac</td>
<td></td>
</tr>
<tr>
<td></td>
<td>90% soil + 10%</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Envirotac</td>
<td></td>
</tr>
<tr>
<td></td>
<td>85% soil + 15%</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Envirotac</td>
<td></td>
</tr>
</tbody>
</table>
Atterberg limit are used to determine the water content corresponding to different state of soil. In this research, Atterberg limit test are only carried out for original clay soil. The testing that conducted for this study is moisture content (MC), liquid limit (LL) plastic limit (PL) and the Plasticity index (PI).

Proctor compaction test are used to obtain or evaluate the properties of soil compaction especially in determining the optimal water content whereas soil can reach its maximum dry density.

CBR test is used to evaluate the strength soil involve with load-deformation curve of soil according to clause BS 1377: Part 4: 1990. Generally, at given rate CBR test will penetrate cylindrical plunger with standard cross-sectional on the sample. Generally, CBR test is conducted in 2 conditions which is soaked to represent wet condition and unsoaked condition to represent dry condition. Figure 2 shows the CBR test on the sample.

![CBR test on the sample](image)

**Fig. 2 CBR test on the sample**

### 3.3 Results and discussion

Soil sample was classified as per USCS based on the index properties of the soil. Based on the results of the tests conducted in the laboratory, it
is found that the moisture content of the soil is 27%. While the plastic limit value is 29.27% and liquid limit is 50.9% as shown in Table 2 and Figure 3. From the data, soil sample can be classified as clay due to its high value of liquid limit and plastic limit along with its plasticity index which is 22% that is more than 17%. Based on USCS classification of soil at RECESS UTHM was high plasticity clay (CH). [8]

Table 2 Results of plastic limit test

<table>
<thead>
<tr>
<th>Sample</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of Can + Moist Soil, M&lt;sub&gt;cw,s&lt;/sub&gt; (g)</td>
<td>63.84</td>
<td>64.08</td>
</tr>
<tr>
<td>Mass of Can + Dry Soil, M&lt;sub&gt;c,s&lt;/sub&gt; (g)</td>
<td>61.51</td>
<td>61.51</td>
</tr>
<tr>
<td>Mass of Can M&lt;sub&gt;c&lt;/sub&gt; (g)</td>
<td>53.33</td>
<td>52.96</td>
</tr>
<tr>
<td>Mass of Dry Soil, M&lt;sub&gt;s&lt;/sub&gt; (g)</td>
<td>8.18</td>
<td>8.55</td>
</tr>
<tr>
<td>Mass of water, M&lt;sub&gt;w&lt;/sub&gt; (g)</td>
<td>2.33</td>
<td>2.57</td>
</tr>
<tr>
<td>Water content, w (%)</td>
<td>28.48</td>
<td>30.05</td>
</tr>
<tr>
<td>Plastic limit (%)</td>
<td>29.27</td>
<td>29.27</td>
</tr>
</tbody>
</table>

Fig. 3 Liquid limit value

For determining optimum moisture content and maximum dry density, water at 15%, 20%, 25% and 30% were added with the soil sample and then compacted. This test was carried out on the original soil only. As shown in Figure 4, the optimum moisture content (OMC) of Recess clay
soil was determined to be 24% and maximum dry density was found to be 1.40mg/m$^3$.

![Graph showing DRY DENSITY VS MOISTURE CONTENT](image)

Fig. 4 Optimum moisture content value

3.3.1 Analysis of California Bearing Ratio with Envirotac for unsoaked condition

CBR test was performed on the original clay soil sample and the cured clay soil sample with different percentages of stabilizer which are 5%, 10% and 15% Envirotac and were cured for 0, 7 and 14 days curing period at unsoaked and soaked condition.

Figure 5 shows a graph between CBR and different percentage of Envirotac at 0, 7, 14 days. Based on the result, the CBR value for untreated soil and stabilized soil on 5%, 10% and 15% Envirotac were determined and have found the higher CBR value is on unstabilized clay soil (without Envirotac) which is 16.1%, And then followed by 5% Envirotac with 14 days curing period with CBR value 14.26%. CBR value for untreated soil is greater than stabilized soil. Initial observation show that the Envirotac treatment seem not to work well with clay soil.

From Figure 6, it can be concluded, the CBR strength increase if the Dry density of the soil increase. This is because the higher the dry density of the soil the denser the soil thus more strength. From the graph it can be
seen that at 0%, 5%, 10% and 15% Envirotac on curing period 0, 7 and 14 days, 0% Envirotac which is 100% of clay soil has the highest CBR and dry density value which is 16.1% and 1.27 gm/cm$^3$ respectively.

**Fig. 5** Relationship between CBR and Envirotac at different curing period for unsoaked samples.

**Fig. 6** Relationship between CBR and dry density of unsoaked samples
3.3.2 Analysis of California Bearing Ratio with Envirotac for soaked condition

Figure 7 shows a graph plotted between CBR and different percentage of Envirotac at 0, 7 and 14 days. Based on the result at 0 days, the CBR value for untreated soil and stabilized soil on 5%, 10% and 15% were determined and found to be 2.41%, 3.33%, 2.76% and 1.33% respectively. While at 7 days, the strength of CBR for stabilized soil decrease at 5% and 10% which is 2.6% and 2.07% respectively compare to 0 days. Then at 14 days the strength of CBR for stabilized soil slightly increases compare to 0 days and 7 days. It can be concluded that, the higher CBR value is on 5% Envirotac which is 3.48%, then followed by 10% Envirotac which is 3.11%, the stabilizes soil on 5% Envirotac also produces a higher CBR value than the pure clay soil. This shows that the Envirotac is suitable to be use as a stabilizer in clay soil for soaked condition.

Meanwhile form figure 8, it can be concluded that the CBR strength are higher on 5% Envirotac at 14 days curing period which are 3.48% at 1.06 gm/cm$^3$ dry density. The data also shows that, the dry density of stabilized soil is decrease as the percentage of Envirotac added on the soil increase.

![Fig. 7 Relationship between CBR and Envirotac at different curing period for soaked samples.](image-url)
3.4 Discussion on the results

Table 3 shows the summary result of CBR for soaked and unsoaked condition, with different percentage of Envirotac and curing period. Unsoaked CBR samples gives higher value compared to soak CBR soil. For unsoaked condition, 5% and 10% Envirotac CBR value achieve the minimum CBR value for subgrade layer requirement according to JKR standard. While for soaked condition, only 5% Envirotac is achieve the minimum requirement. However, for soaked condition the CBR value at 5% is higher than 100% soil (unstabilized soil), it can be seen that with the presence of water Envirotac had a little bit improvement on soil. The strength of CBR also increase when the amount of Envirotac used are less thus, for unsoaked condition the clay soil (without Envirotac) produces a higher CBR value than the soil with Envirotac.

Overall summary from the test conducted at 0, 7 and 14 days, it can be seen that the strength of CBR increases more when the curing time is longer which is at 14 days. In addition, the strength of CBR also increase when the amount of Envirotac used are less which is 5%. Thus, the clay soil (without Envirotac) produces a higher CBR value than the soil with Envirotac. Hence, the unstabilized clay soil performs better in the test. This shows that the Envirotac is not suitable to be use in clay soil, in other words Envirotac does not mix well with the clay soil as stabilizer in subgrade.
This can be explained from the test observation and other scientific research. The strength of CBR for Pure Clay soil is higher than Envirotac mix with clay, this is because of the moisture content, the higher the moisture content, the lower the CBR value. By visual observation during laboratory work, shows Envirotac clump together at soil thus leaving random voids in the clay soil. The voids make the CBR value decrease as it is easier to penetrate the clay.

Another reason that cause the CBR result affected is by the application method. In this research, the application of clay soil mixed with Envirotac is by using mixing method, however according to Federal Highway Administration a mixed in application are less susceptible than sprayed-on application, this can affect the CBR strength. For Envirotac or also can be called acrylic polymer, a spraying method on a surface of soil is the effective method. In addition, Envirotac or Acrylic Polymer emulsion also take approximately 30 days to cure completely and develop their full strength [9]. While, in this research the maximum curing time is only 14 days, which is less than the recommended curing time, thus the ultimate strength cannot be determined.

Table 3 Summary of CBR value for unsoaked and soaked condition

<table>
<thead>
<tr>
<th>Mixture percentage</th>
<th>CBR value (%)</th>
<th>CBR value (%) according to JKR standard</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unsoaked</td>
<td>Soaked</td>
</tr>
<tr>
<td>100% soil</td>
<td>16.1</td>
<td>16.1</td>
</tr>
<tr>
<td>95% soil + 5% Envirotac</td>
<td>9.2</td>
<td>9.46</td>
</tr>
<tr>
<td>90% soil + 10% Envirotac</td>
<td>3.8</td>
<td>3.91</td>
</tr>
<tr>
<td>85% soil + 15% Envirotac</td>
<td>1.22</td>
<td>1.38</td>
</tr>
</tbody>
</table>

A minimum CBR for subgrade layer is 3 – 5%.
3.5 Conclusions

From the test and analysis, some conclusions have been:

i. It is found that the soil at RECESS, UTHM can be classified as high plasticity clay due to its high moisture content, liquid limit and plasticity index.

ii. The suggested suitable ratio of mixture is, 95% soil + 5% Envirotac as the result is the closest to the minimum requirement from JKR which is 3-5% of CBR rating. The study also showed that the CBR value reduced by increment amount of Envirotac in the clay soil mixture thus lowering the strength of soil.

The value of CBR soil mix Envirotac increase with curing time but decrease with the increment amount of Envirotac added into the clay soil. In conclusion, clay soil does not work well with Envirotac as the result shows the CBR values is much higher on unstabilized soil (without Envirotac) than stabilized soil (with Envirotac).

References