Effect of Geogrids on Compressive Strength and Elasticity Modulus of Lime/Cement Treated Soils

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ABSTRACT

Appropriate function and behaviour of improved soil strata would really affect the superstructure or pavement behaviour, safety and stability due to loading or other conditions. Lime/cement stabilized soils have been used widely for pavement base or sub-base materials or structural foundations. But not many research studies have been performed to investigate the effects of geogrids on the behaviour of lime/cement treated soils. This study has been performed on compressive treated soil samples with or without geogrid layers. The results for each sample have been mentioned through the paper and discussed. Finally the effects of geogrids have been concluded.

KEYWORDS: soil stabilization, granular soil, cylindrical samples, unconfined compressive test, stress-strain behaviour.

INTRODUCTION

Various soil stabilization methods have been used extensively during the centuries all around the world. The stabilization methods would comprise physical, chemical and mechanical methods. Too many stabilizer agents such as lime, salts, cement, bitumen, lime/ fly ash, geosynthetics and etc. are used to approach stabilization aims. Wide studies have been done on soil stabilization methods. In this study an experimental study has been performed on lime/cement stabilized soil reinforced with polypropylene geonet in order to make the effects of reinforcement on geotechnical properties of stabilized soil more obvious.

Lime soil stabilization has been used so widely since ancient time in Roman and Iranian civilizations. Lime affects geotechnical properties of soil apparently. It would improve plasticity, strength, durability and fatigue characteristics of stabilized soil. In recent century too many
studies and laboratory experiments have been performed on this case. Investigation of lime stabilized contaminated soils, J.M. Reid and A.H. Brooks (1999) [1]; Effects of partial substitution of lime with ground granulated blast furnace slag (GGBS) on the strength properties of lime-stabilized sulphate-bearing clay soils, S. Wild et al. (1998) [2]; Sludge ash/hydrated lime on the geotechnical properties of soft soil, Deng Fong Ling et al. (2007) [3]; Effect of polypropylene fiber and lime admixture on engineering properties of clayey soil, Yi Cai et al. (2006) [4]; Chemical stabilization of sandy-silty illite clay, J. Ninov et al. (2007) [5]; Useful lifetime and suitable thickness of soil-lime mixture, T. Lopez-Lara et al. (2005) [6]; are some of the researches samples.

Cement would really change the behavior and geotechnical characteristics of the soil such as temporary and permanent strength, susceptibility to water, durability against freezing and thawing, workability of cohesive soil and etc. Some of recent studies on cement treated soils would be mentioned as: Influence of soil type on stabilization with cement kiln dust, G. A. Miller and S. Azad, (2000) [7]; Stabilization of residual soil with rice husk ash and cement, E.A. Basha et al. (2005) [8]; Stabilization of clayey soils with high calcium fly ash and cement, S. Kolias et al. (2005) [9]; Mechanism of stabilization of Na-montmorillonite with cement kiln dust, S. Peethamparan et al. (2009) [10]; and Curing time effect on behavior of cement treated marine clay, H.W. Xiao and F. H. Lee (2008) [11].

During past decades, application of geosynthetics for soil stabilization has become wider and wider. Various types of synthetics are used right now in different cases of soil improvement like geotextiles, geogrids, geonets, geofibers and etc. There have been wide efforts on reconnaissance of geosynthetic application effects on geotechnical properties of reinforced soil such as: Constitutive modeling of geosynthetics, S. W. Perkins (2000) [12]; A case study of geosynthetic reinforced wall with wrap-around facing, K.K. Frankowska (2005) [13]; Geosynthetic reinforcement application for tsunami reconstruction: evaluation of interface parameters with silty sand and weathered clay, P.V. Long (2007) [14]; Effect of reinforcement form on bearing capacity of square footings on sand, G. Mahdavi Latha and A. Somwanshi (2009) [15]; A study on the coefficient of friction of soil/geotextile interface, A. A. Mahmood and N. Zakaria (2000) [16]; Studies on geotextile/soil interface shear behavior, A.A. Mahmood et al. (2000) [17]; Design and test methods for geosynthetic reinforced structures, A. Nernheim (2005) [18]; Strength characteristics of sand reinforced with coir fiber and coir geotextiles G. Venkatappa Rao et al. (2005) [19]; and Pullout behavior of geogrid in red clay and prediction of ultimate resistance, X. Feng et al. (2008) [20].

However, too many studies performed on different types of soil stabilization techniques but no serious effort is done on geogrid reinforced lime/cement treated soil. Therefore, this study has been carried out on the case. The study is performed in order to find out the effects of geogrids application on the geotechnical behavior of lime/cement treated soils used as base, sub-base or structural foundation materials.

In this study cylindrical soil samples stabilized with lime and cement, by different mix designs, were made with and without geogrid layer. The layer was chosen as polypropylene geogrid because of lime application, in order to prevent corrosion in reinforcing agent. Unconfined compressive test performed on each sample to obtain compressive strength and modulus of elasticity for each mix design in the case of presence or lack of geogrid layer. In following, the article will go through the materials used, mix designs, sample production and curing method, compressive test results, discussion and conclusions.
MATERIAL USED

As the study is carried out for base, sub-base and foundation strata materials, the soil alternated for the study due to the provisions of ASTM [21] for concrete materials and Iranian National Code of Pavement for base materials [22]. The particle distribution curve (ASTM D 422-88) is given in figure 1.

![Particle distribution curve of used materials](image)

**Figure 1:** Particle distribution curve of used materials

Hydrated high calcium lime and Portland cement type II have been used as stabilizer agents. Hydrated lime has been used because of its high effect in soil stabilization and is really easy to use and mix with soil due to its fine particle size. Portland cement type II is mostly used in foundation soil stabilization because of the sulphate attack risk.

Polypropylene geogrid seems to be a good reinforcement for granular materials, because of its large void which would allow the grains to be stuck with in the voids. Polypropylene synthetics are corrosion resistant against acid and alkaline conditions. The geogrid used in the study is shown in figure 2.

![Applied polypropylene geogrid](image)

**Figure 2:** Applied polypropylene geogrid
MIX DESIGN

Stabilization mixtures have been designed in order to achieving different compressive strength and modulus of elasticity for the firm soil gradation condition. Therefore, various amounts of lime and cement were alternated such as given in table 1. The amount of lime varies between 4.5, 5.6 and 6.8 and the amount of cement varies between 4.5 and 5.6 percent of dry soil weight.

The water volumes used for mixture compaction in special wares were obtained from compaction tests for each mix design and obtaining optimum compaction moisture content to achieve the mixture maximum dry density. The amount of applied water is given in table 1 for each mix design as the percentage of dry mixture weight.

Table 1: Stabilization mix design information

<table>
<thead>
<tr>
<th>Mix Design</th>
<th>Cement Ratio</th>
<th>Hydrated Lime Ratio</th>
<th>Moisture Content</th>
<th>L/C Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-1</td>
<td>4.5</td>
<td>4.5</td>
<td>8.23</td>
<td>1</td>
</tr>
<tr>
<td>A-2</td>
<td>4.5</td>
<td>5.6</td>
<td>8.98</td>
<td>0.8</td>
</tr>
<tr>
<td>A-3</td>
<td>5.6</td>
<td>4.5</td>
<td>8.98</td>
<td>1.25</td>
</tr>
<tr>
<td>A-4</td>
<td>4.5</td>
<td>6.8</td>
<td>9.44</td>
<td>0.66</td>
</tr>
<tr>
<td>A-5</td>
<td>5.6</td>
<td>6.8</td>
<td>9.61</td>
<td>0.82</td>
</tr>
</tbody>
</table>

SAMPLE PRODUCTION AND CURING METHOD

Cylindrical samples were made by compaction of the mixture in special wares which led to cylinder stabilized soil samples by the dimensions of 10cm in diameter and 20cm in height. The samples were compacted in 5 layers by the means of 22 impacts of 10.542 (N.m) as the energy of each pulse. Figure 3 shows three samples which were made by this method.

Figure 3: Picture of produced samples

Two samples series was made for tests. Three samples produced for each mix design without any geogrid layers and three samples with one geogrid layer. The first series are named as “A” and the second ones are named as “B”. The samples curing were done for 50 days in a completely wet condition under plastic covers as is shown in figure 3.
UNCONFINED COMPRESSIVE TEST RESULTS

Unconfined compressive tests ASTM D 2166-87[22] have been performed on cylindrical samples. By the means of the tests, the compressive strength and modulus of elasticity were obtained for each mix design as given in Table 2. The modulus of elasticity was calculated for the stress range of 6 to 20 (kgf/cm²), because all samples had linear behavior in this range.

Table 2: Summary of compressive tests results

<table>
<thead>
<tr>
<th>Mix Design</th>
<th>L/C Ratio</th>
<th>Compressive Strength (kgf/cm²)</th>
<th>Modulus of Elasticity (kgf/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-1</td>
<td>1</td>
<td>57.37</td>
<td>1767.45</td>
</tr>
<tr>
<td>A-2</td>
<td>0.8</td>
<td>46.86</td>
<td>1674.4</td>
</tr>
<tr>
<td>A-3</td>
<td>1.25</td>
<td>71.91</td>
<td>2032.7</td>
</tr>
<tr>
<td>A-4</td>
<td>0.66</td>
<td>43.47</td>
<td>1992.35</td>
</tr>
<tr>
<td>A-5</td>
<td>0.82</td>
<td>58.78</td>
<td>1990.15</td>
</tr>
<tr>
<td>B-1</td>
<td>1</td>
<td>55.33</td>
<td>2512.5</td>
</tr>
<tr>
<td>B-2</td>
<td>0.8</td>
<td>54.55</td>
<td>1856.8</td>
</tr>
<tr>
<td>B-3</td>
<td>1.25</td>
<td>71.92</td>
<td>2460.05</td>
</tr>
<tr>
<td>B-4</td>
<td>0.66</td>
<td>56.56</td>
<td>1984.9</td>
</tr>
<tr>
<td>B-5</td>
<td>0.82</td>
<td>55.15</td>
<td>2146.7</td>
</tr>
</tbody>
</table>

Stress-strain diagrams were printed for all samples. Some of diagrams are given in figure 5. Figure 6 shows unconfined compressive test for cylindrical samples.
DISCUSSION

The first thing would flash in mind that the increment in compressive strength of samples would not follow a regular procedure. Some of the samples would even show decrement in compressive strength as the geogrid layer has been added to. Let’s first look at the mechanism of reinforcement working in unconfined compressive condition.

It has been learned from the material mechanics that whenever an element carry over an unconfined compressive stress, it would spall on its sides, see figure 7.
The amount of this deformation would be calculated by equations (1) [23] and (2):

\[ v = -\frac{\varepsilon_{2,3}}{\varepsilon_{\text{axial}}} \]  

\[ v = -\frac{\varepsilon_{2,3}}{\sigma_1/E} \Rightarrow \varepsilon_{2,3} = \frac{\sigma_1}{E} \times v \]  

In which the \( \varepsilon_{2,3} \) is the strain on other sides, the \( \sigma_1 \) is the compressive stress, the \( E \) is the modulus of elasticity, and the \( v \) is Poison ratio.

By studying the equations (1) and (2), it would get clear that as the modulus of elasticity increases, there would appear a significant decrease in side deformation. The Poison ratio is almost dependent on the cohesion produced by pozzolanic reaction of cement and lime. The more strength, the more cohesion produced by reaction, therefore the poison ratio would decrease obviously due to the phenomena. Moreover, when the L/C ratio decreases the poison ratio decreases and modulus of elasticity increases significantly, there for the sides deformation would be less and less by decrement in L/C ratio. The deformation of cylinder samples is shown schematically in figure 8.

**Figure 7:** Side deformation of compressive cubic element

**Figure 8:** Schematic view of cylindrical samples deformation
When a layer of reinforcement locates in the middle of the sample, the spall deformation produces tensile stress in the reinforcement layer. The tensile stress in reinforcement layer would work as a confining force on the mid-belt of the sample. This force and confinement would help the samples to carry over more compressive pressure, see figure 9.

![Figure 9: Schematic deformation view of cylindrical samples including reinforcement](image)

Therefore, as the amount of L/C ratio decreases in stabilized samples, the effect of geogrid reinforcement layers would decrease too. Moreover, the geogrid layer ductility would make problems during the compaction procedure. This phenomenon would be observed in “B” series samples. In this case the fracture had happened on the top side of geogrid layer in compressive tests especially in “B-3” and “B-5” samples and led to less compressive strength compared to the same in “A” sample series. Figure 10 shows the diagram of compressive strength improvement ratio against the samples modulus of elasticity.

![Figure 10: Improved strength against modulus of elasticity](image)

**CONCLUSION**

Appropriate behavior of improved foundation soil strata or pavement base and sub-base layers due to external loads, would lead to safety and durability of super structures. Moreover, any unexpected phenomena may cause general collapses or intensive damages. Therefore, the behavior characteristics of any improvement methods must become clear.

The study has been performed on the lime/cement stabilized soil reinforced with polypropylene geogrid layer, under the unconfined compressive condition. Cylindrical stabilized samples including reinforcement and without reinforcement layer were made by compacting in special wares. Unconfined compressive test performed on the samples and following results have
been concluded.

How much the sample stiffness gets higher, the less positive effect would be shown by propylene geogrid reinforcement application. When there is an increment in modulus of elasticity and the cohesion, produced by pozzolanic reaction, the side deformation of the cylinder decreases. Therefore, the tension produced in reinforcement and the confinement forces would decrease too.

Moreover, when a ductile reinforcement layer is used within the stabilized soil, it would make some problems during compaction procedure and lead to a less dry density. Therefore, the compressive strength would really decrease at the upper soil layer of the sample located on geogrid layer.

In order to have an appropriate interaction between lime/cement stabilized soil and polypropylene geogrids, alternated mix design should comprise enough ductility and side deformation. Therefore, great L/C ratio must be selected and total amount of applied cement must be lower than 5 percent.

REFERENCES


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