3rd International Conference on New Developments in Soil Mechanics and Geotechnical Engineering,
28-30 June 2012, Near East University, Nicosia, North Cyprus

Effect of the sand layer thickness on the CBR values of two layered subgrade

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KEYWORDS: CBR value, clayey soil, Geosynthetic, sand layer thickness, two-layered subgrade.

ABSTRACT: 72 CBR tests have been conducted on unreinforced and reinforced two-layered samples. Two layered subgrade consists of sand base layer overlying a cohesive soil as subgrade layer. Three reinforcing situations (unreinforced, reinforced with nonwoven geotextile and reinforced with geogrid) at the interface of the two layers, with four compaction moisture contents (cmc) values of subgrade layers are implemented. CBR tests were performed at three thicknesses of the sand base layer for both soaked and unsoaked conditions. The obtained results show that the threshold value of sand layer thickness is dependent on the strength of subgrade clayey soil, which is dependent on the compaction moisture and soaking condition. In some samples threshold value of sand layer can be concluded; samples with 8, 12 and 16% of subgrade cmc in unsoaked condition and samples with 8 and 12% of subgrade cmc in soaked condition. In other samples threshold value for sand base layer thickness can't be seen.

1 INTRODUCTION

In recent decades, one of the ways for decreasing the road layers or thickness of roads is using geosynthetics. More than this advantage, we can use geosynthetics instead of replacing the site materials by soils with higher strength that must be carried from far distances. It seems that combination of soil which is good in compression but poor in tension with a material which is good in tension can be an appropriate option for increasing the strength of soils.

Different investigations have been performed to study the interaction of soils/geosynthetics in recent years. Abu-Farsakh et al. (2007) studied the behavior of a large modeled foundation, placed on reinforced soil. An attempt is made to investigate the change in strength characteristics of different granular base materials reinforced with geogrid to investigate the change in strength characteristics of different granular base materials reinforced with geogrid by Duncan-Williams & Attoh-Okine (2007). Several laboratory model load tests on geogrid -reinforced sand have been published in the literature (Guido and Sweeny, 1987; Khing et al., 1992; Yeo et al., 1993).These model tests were conducted with square or strip foundations on sand. Feng et al. (2008) calculate the ultimate strength of red clay, which was reinforced by geogrid, using pull out test. Many of researches have studied the behavior of soils that were reinforced with geotextile. Bergado et al. (2001) have investigate the mechanism and effects of the different grades of geotextile on the increase in bearing capacity of reinforced unpaved roads over weak subgrade under traffic load .

This paper presents the results of series of bearing ratio tests on a granular soil as a base layer overlaying a cohesive soil as a subgrade layer in three reinforcing situations (unreinforced, reinforced with nonwoven geotextile and reinforced with geogrid) at the interface of the two layers, with four compaction moisture content values (cmc) of the subgrade layers and three different thicknesses of the sand base layer for both soaked and unsoaked conditions. This paper has been investigated the threshold value of the sand base layer for different samples.

2 MATERIALS

2.1 Clayey Subgrade Soil Layer

The underlying subgrade layer was a clayey soil with a plasticity index 13%, classified as CL according to the Unified Soil Classification System (USCS). The optimum moisture content and maximum dry density were obtained as 16% and 18.84 kN/m^3, respectively, according to the B-method of AASHTO T180. For the tests, four compaction moisture content values (cmc) were considered, according to the compaction curve obtained by the B-method of AASHTO T 180. Figure 1 shows the compaction curve, the four compaction moisture content values and the respective dry densities for the subgrade soil used in this investigation.

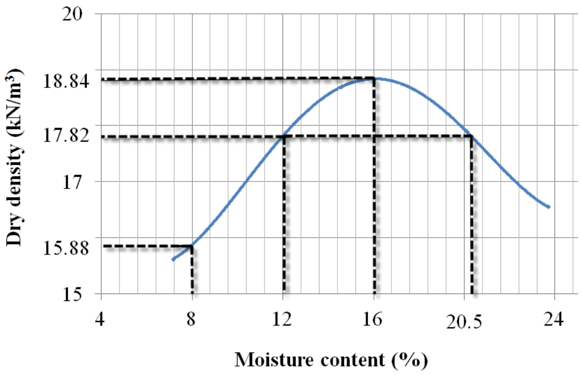


Figure 1. Compaction curve and selected compaction moisture content values for the subgrade layer

2.2 Sand Layer

The base course aggregate was a sandy soil with the particle size distribution shown in Figure 2. The coefficient of uniformity and the coefficient of curvature are 42.92 and 2.33, respectively. The material is classified as SW according to the USCS. The maximum obtained dry density was 21.4kN/m^3 at a water content of 9% (B-method of AASHTO T180).

2.3 Geosynthetics

Two types of geosynthetics were used as the reinforcing element: a nonwoven geotextile, f-300, and a geogrid, ce-161. The properties of these geosynthetics are summarized in Table 1. The size of the geotextile and the geogrid used was 152 mm in diameter.

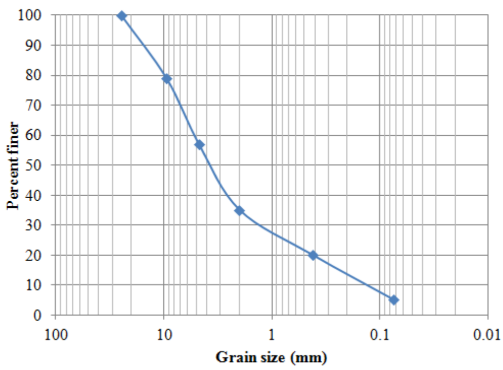


Figure 2. Particle size distribution of the sand base layer

Table 1.Properties of the geosynthetics used for this study

Parameter	ce-161	f-300
Appropriate size (mm)	10×10	6.2×10^{-6}
Material	HDPE	Polymer
Mass/unit area (g/m^2)	700	300
Tensile strength-machine direction (kN/m)	7.6	8
Tensile strength-cross machine direction (kN/m)	7.6	11.1

3 EXPERIMENTAL PROGRAM

3.1 Testing Procedure

To study the behavior of the two-layered soil (granular base overlying cohesive subgrade) with geosynthetic reinforcement at the interface and to find the threshold value series of CBR tests are conducted in both unsoaked and soaked conditions for three different reinforcement conditions, three different thicknesses for the base layer and four different compaction water content values for the clayey subgrade layer. In the soaked condition, the samples were immersed in water for 96 hours.

3.2 Preparation of Samples

The bearing ratio mold was a rigid metallic cylinder with an inner diameter of 152 mm and a height of 178 mm. The mold had a collar fitted on the top with a height of 52 mm to provide the additional height required to study the effect of the compacted sand layer thickness (40, 55 and 70 mm) overlying the clayey soil layer on the bearing ratio. To prepare the samples, oven-dried clayey soil was mixed thoroughly with the required quantity of water (8, 12, 16 or 20.5%). The soil mixed with the selected water content was placed in five layers at the bottom of the mold. Each layer was compacted with automatic CBR compaction by 56 blows of a 44.5-N rammer dropped from a height of 457 mm. The sand layer was compacted at optimum moisture content by using a manual plastic hammer until it reached the target dry density obtained from the B-method of AASHTO T 180. In these tests, the thickness of the compacted cohesive soil was maintained at 116 mm. The geosynthetic layer was placed at the interface of the subgrade and base layer in the reinforced conditions. Figure 3 illustrates the general section of two-layered soil samples with various variables like thickness of sand base layer and type of reinforcement.

For preparation the soaked samples, the mold containing the two-layered sample was immersed in water, allowing free access of water to the top and bottom of the sample, and was allowed to soak for 96 hours (ASTM D1883-05). At the end of this time, CBR test was conducted on the samples.

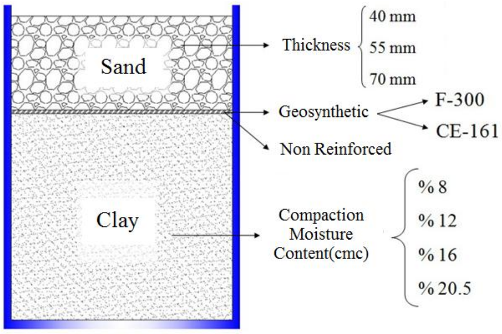


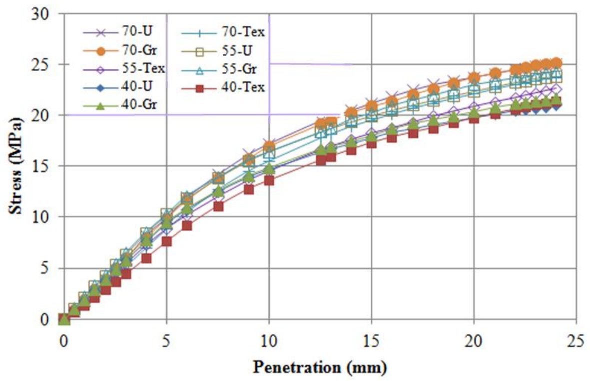
Figure 3. The general section of two-layered soil samples with the variables

3.3 California Bearing Ratio (CBR) Test

To demonstrate the influence of different variables on the bearing ratio of the compacted granular base overlying the cohesive soil, series of bearing ratio tests were carried out on reinforced and unreinforced specimens. The bearing ratio tests were conducted under both unsoaked and soaked conditions according to ASTM D1883-05.

4 RESULTS AND DISCUSSON

California bearing ratio tests were carried out for both reinforced and unreinforced and both unsoaked and soaked samples with different base layer thicknesses and different subgrade compaction water content values. The stress-penetration curves were plotted and corrected according to ASTM D 1883-05. Figure 4 shows a typical stress-penetration curve for unsoaked samples with 12% subgrade compaction water content (cmc).



(a)

Figure 4. Typical load-penetration curves for samples with 12% of subgrade compaction water content for unsoaked condition (U is unreinforced, Gr is geogrid and Tex is geotextile):

Because the studied samples are two-layered and the interaction of the underlying subgrade, the upper base layer and the geosynthetic is more obvious at greater penetration depths, which leads to a better perception of the two-layered soil behavior, CBR values for a penetration depth of 12.5 mm were calculated based on ASTM D 1883-99. In this further penetration (12.5 mm penetration), the included strain in the reinforcement is more. Because of this more strain, interlocking is activated better and the effect of reinforcement in increasing the bearing ratio appears better.

This equation is according to ASTM D1883-99 for CBR value at 12.5mm penetration:

$$CBR = \text{Stress at 12.5 mm penetration} / 17.947 \text{ MPa} \quad (1)$$

In the above equation 17.947 MPa is standard stress at 12.5 mm penetration.

4.1 Unsoaked Samples

4.1.1 8% of Subgrade Compaction Water Content

Fig. 5 shows CBR values versus sand layer thickness for 8% of subgrade compaction moisture content in unsoaked condition. It shows that with increasing the thickness of the sand base layer (regardless of the reinforced conditions) CBR values don't show a great increase.

This figure shows that increasing the base layer thickness from 40 to 70 mm, doesn't have any significant effect on the behavior of two layered soil. With an overall view of the Figure 5 it can be deduction that in the samples that subgrade soil layer has a high strength, using geosynthetics in boundary between two layers and increasing the sand base layer thickness doesn't have any significant effect on the strength of the two-layered subgrad. In these samples we can consider 55mm of sand base layer thickness as threshold value.

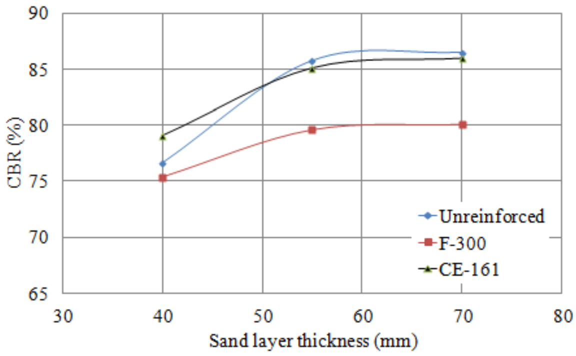


Figure 5. CBR value versus sand base layer thickness with 8% of cmc in unsoaked condition

4.1.2 12% of Subgrade Compaction Water content

Figure 6 shows CBR values versus sand layer thickness for 12% of subgrade cmc in unsoaked condition. It shows that with increasing the thickness of the sand base layer (regardless of the reinforced conditions) CBR values show a little increase. As the thickness of sandy base layer increases up to 70 mm, the two-layered subgrade strength increases 15% approximately.

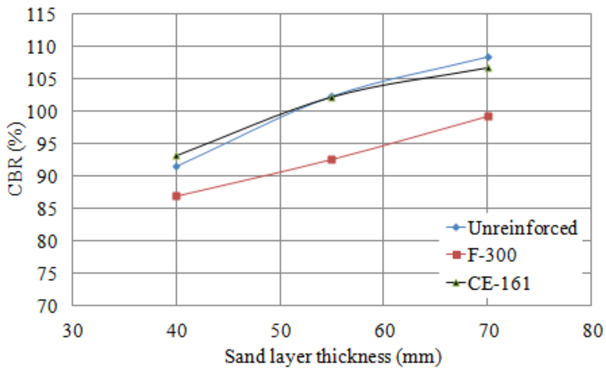


Figure 6. CBR value versus sand base layer thickness with 12% of cmc in unsoaked condition

Here also because of high strength of subgrade soil layer, with increasing the base layer thickness, strength of soil increases a little. In these samples because with increasing base layer thickness there isn't any significant change in CBR values, we can consider 55 to 70 mm of sand base layer thickness as threshold value.

4.1.3 16% of Subgrade Compaction Water Content

In the Figure 7 CBR values versus sand layer thickness for 16% of subgrade cmc in unsoaked condition can be seen. It is obvious that with increasing base layer thickness from 40 to 55 mm, CBR values increase significantly (approximately 25%), regardless of the reinforced conditions; but more than this to 70 mm, has little influence on the CBR values.

For increasing base layer thickness from 40 to 55 mm, it can be observed that increase in strength caused by increasing base layer thickness obviously is more than increase caused by using geogrid.

In these samples 55mm of the sand base layer thickness can be considered as threshold value of sand.

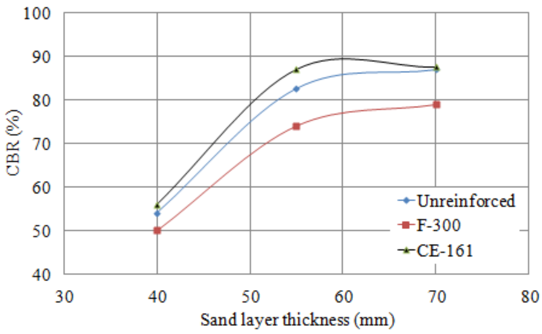


Figure 7. CBR value versus sand base layer thickness with 16% of cmc in unsoaked condition

4.1.4 20.5% of Subgrade Compaction Water Content

Figure 8 shows results of increasing in the sand base layer thickness on the CBR values of samples that subgrade clayey soil is compacted with 20.5% of moisture. Here increase in CBR with increasing in sand base layer thickness is evident (approximately 17% from 40 to 70 mm of thickness).

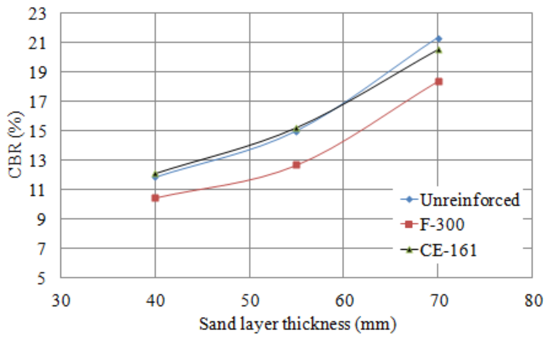


Figure 8. CBR value versus sand base layer thickness with 20.5% of cmc in unsoaked condition

It can be seen that increase in the thickness of the sand base layer, significantly increases CBR values of two-layered subgrade. Because in this samples strength of clay subgrade is low, with increasing in the base layer thickness from 40 to 70 mm in the unreinforced condition, soil strength can be increased approximately 3 times; in this situation it can’t be considered a threshold value for sand base layer.

4.2 Soaked Samples

4.2.1 8% of Subgrade Compaction Water Content

Figure 9 shows CBR values versus sand layer thickness for 8% of subgrade compaction moisture content in soaked condition. It is obvious that with increasing sand base layer thickness from 40 to

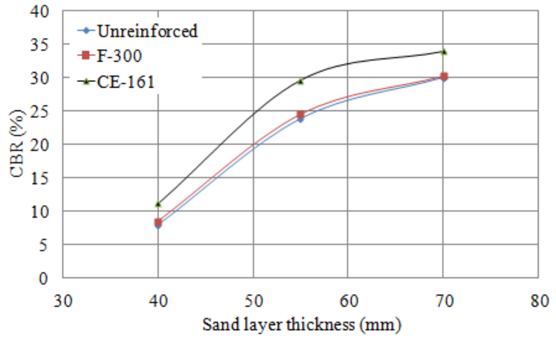


Figure 9. CBR value versus sand base layer thickness with 8% of cmc in soaked samples

55 mm, a significant increase (more that 15%) occurs in CBR value of two-layered subgrade and with further increase in thickness, the slope of increase strength reduced. The percentage of the increase in CBR value of reinforced soil with geogrid compared with unreinforced in 40 mm of base layer thickness is approximately 40%.

In soaked condition, due to low strength of subgrade soil, increasing in sand base layer thickness can improve soil strength. But with thickness more than 55 mm, the slope of increase in strength is reduced and can be stated that with increasing sand base layer thickness more than 70 mm, there isn't any significant increase in CBR values. In these samples it can be deduced that 70 mm thickness is threshold value for sand base layer.

4.2.2 12% of Subgrade Compaction Water Content

CBR values versus sand base layer thickness for 12% of subgrade cmc in soaked samples is shown in Figure 10. This figure is like Figure 9 and because of soaked condition, bearing ratio of clayey subgrade is low and with increasing the thickness of sand base layer, CBR values increases. In the thicknesses more than 55 to 70 mm, curves become closer to the horizontal state, and the effect of thickness on the CBR values of two-layered subgrade (regardless of the reinforced conditions) decreases. In these samples we can state that 70 mm thickness is threshold value for sand base layer.

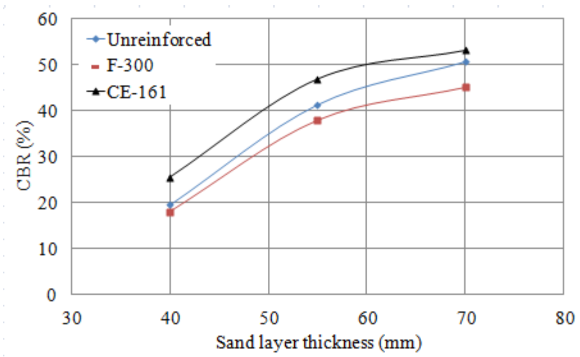


Figure 10. CBR value versus sand base layer thickness with 12% of cmc in soaked samples

4.2.3 16% of Subgrade Compaction Water Content

Figure 11 shows results of increasing the sand base layer thickness in the CBR values of samples that clayey soils are compacted with 16% of moisture. It can be seen that with increasing thickness from 40 up to 70 mm, strength of the samples significantly increases; even doubling the value of CBR at a thickness of 40 mm with increasing up to 70 mm.

It shows that with increasing base layer thickness, CBR values increases and we can't determine a thickness of sand as threshold thickness; regardless of the reinforced conditions.

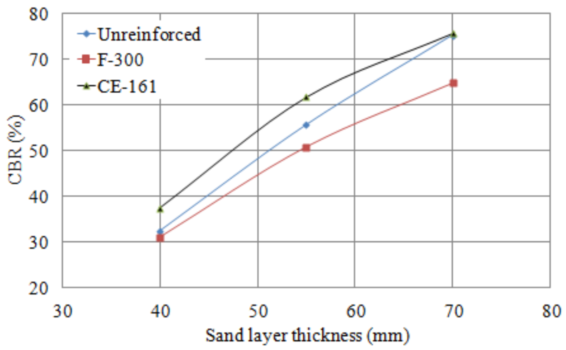


Figure 11. CBR value versus sand base layer thickness with 16% of cmc in soaked samples

4.2.4 20.5% of Subgrade Compaction Water Content

Figure 12 shows effect of sand layer thickness on the CBR values of the samples that their subgrade were compacted with 20.5% of moisture and then being immersed in water for 96 hours. Also, it can be observed that there is a considerable increase in soil strength as the sand base layer increases in depth. In this samples, subgrade clayey soil has low strength and increase in the sand base layer thickness, continuously increases CBR values and we cannot determine a thickness that more than it, CBR values don't show increase. In this sample we can't define a threshold value for sand base layer thickness.

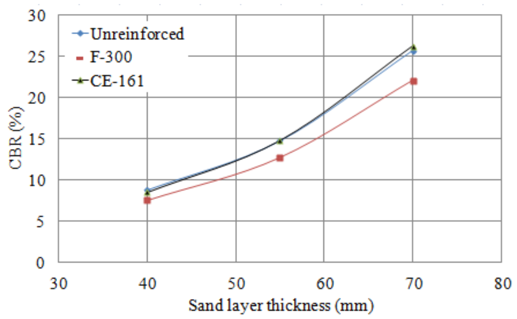


Figure 12. CBR value versus sand base layer thickness with 20.5% of cmc in soaked samples

5 CONCLUSIONS

To investigate the effect of a sand base layer thickness on the CBR values of two- layered subgrade under different moisture and compaction conditions, several CBR tests are conducted. The following conclusions can be drawn from the test results:

- The compaction moisture content (cmc) of the subgrade layer plays a fundamental role in the behavior of the two-layered soil in unsoaked and soaked conditions.
- Thresholds values of sand base layer thickness significantly is dependent on the strength of the subgrade clayey soil , that it's strength is depended on the compaction moisture and soaking condition.
- About the threshold value for sand base layer thickness it should be noted that in some samples this value can be concluded; Samples with 8, 12 and 16% of subgrade compaction moisture content in the unsoaked condition and samples with 8 and 12% of subgrade cmc in the soaked condition.
- In other samples it can't be seen a threshold value for sand base layer thickness. These samples are: Samples with 20.5% of subgrade cmc in the unsoaked condition and samples with 16 and 20.5% of subgrade cmc in the soaked condition.

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