

Effect of Utilization of Geosynthetic on Reducing the Required Thickness of Subbase Layer of a Two Layered Soil

R. Ziaie Moayed and M. Nazari

Abstract—This paper tries to study the effect of geosynthetic inclusion on the improvement of the load-settlement characters of two layered soil. In addition, the effect of geogrid and geotextile in reduction of the required thickness of subbase layer in unpaved roads is studied. Considering the vast application of bearing ratio tests in road construction projects, this test is used in present investigation. Bearing ratio tests were performed on two layered soil including a granular soil layer at the top (as the subbase layer) and a weak clayey soil placed at the bottom (as the subgrade layer). These tests were performed for different conditions including unreinforced and reinforced by geogrid and geotextile and three thicknesses for top layer soil (subbase layer). In the reinforced condition the reinforcing element was placed on the interface of the top granular layer and the beneath clayey layer to study the separation effect of geosynthetics. In all tests the soils (both granular and clayey soil layers) were compacted according to optimum water content. At the end, the diagrams were plotted and were compared with each other. Furthermore, a comparison between geogrids and geotextiles behaviors on two layer soil is done in this paper. The results show an increase in compression strength of reinforced specimen in comparison with unreinforced soil sample. The effect of geosynthetic inclusion reduces by increasing the subbase thickness. In addition it was found that geogrids have more desirable behavior rather than geotextiles due to interlocking with the subbase layer aggregates.

Keywords—Bearing ratio, Subgrade, Subbase, Sand layer thickness, Geosynthetic.

I. INTRODUCTION

IN many road projects it may be more reasonable to use geosynthetics instead increasing the road layers or replacing the site materials by soils with higher strength carried from far distances. The combined use of soil (good in compression and poor in tension) and a geosynthetic (good in tension and poor in compression) have made road design better and provided for the development of entirely new application in the field of pavement design in general. The usages of geo-synthetics to improve characteristics of soil have been considered over the last three decades.

Generally, the beneficial influence of geotextile and geogrid reinforcement on the bearing capacity, settlement and subgrade modulus has been recognized for quite some time.

Several laboratory model load tests on geogrid-reinforced sand have been published in the literature (Guido et al. [1], Guido and Sweeny [2], Khing et al. [3], [4], Omar et al. [5], [6], Yeo et al. [7], Das and Omar [8], Huang and Menq [9], Kurian et al. [10], Gabr et al. [11], Wayne et al. [12]). These model tests were conducted with model square or strip foundations on sand. British Rail Research [13] has demonstrated that geogrid inserted in the ballast where tracks lie over soft ground can help extend maintenance intervals. Several case studies describe and illustrate projects in which the geogrids have been successfully used (Tensar International, [14]). The reinforcement mechanisms in geosynthetic reinforced pavement include base course lateral restraint, increase in stiffness of the base course aggregate layer (Bender and Barenberg, [15]), Reinforcement placed high up in the granular layer hinders lateral movement of the aggregate due to frictional interaction and interlocking between the fill material and the reinforcement which raises the apparent load-spreading ability of the aggregate and reduces the necessary fill thickness (Chan et al. [16], Gobel et al. [17], Miura et al. [18], Moghaddas-Nejad and Small [19], Perkins [20]). Alawaji [21] conducted laboratory-model load tests on a circular foundation supported by geogrid-reinforced sand layer underlined by collapsible soil in different stress levels and the dry/soaked loading conditions and concluded that using geogrid-reinforced sand instead of sand alone, savings can be made in sub-base (sand) depth for the same collapse settlement performance. 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 were considered by Bergado, Youwai and Voottipruex [22]. 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 and Attoh-Okine [23]. Haas et al. [24] performed laboratory experiments and demonstrated the importance of variables such as geogrid placement position, base course thickness and subgrade strength. Inclusion of a geosynthetic layer at the interface of a two-layer subgrade improves the load settlement characteristics at a greater footing settlement (Kazimierowicz-

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Frankowska [25]). A full-scale field test on a geosynthetic reinforced unpaved road was carried out, including compaction and trafficking, to investigate the bearing capacity and its performance on a soft subgrade (Hufenus et al. [26]) They implied the reduction of the thickness of the fill layer for specified compaction values and bearing capacities and the reduction in the rut formation as a function of the trafficking, increasing the serviceable life of the track as the benefits of laying a geosynthetic as reinforcing layer between the fill and the subsoil.

This paper presents the results of a series of bearing ratio tests on a granular soil as base layer overlaying a cohesive soil as subgrade layer with geosynthetic reinforcing at the interface of two layers by different thickness of subbase layer.

II. MATERIALS

Underlying subgrade layer is a clay soil classified as CL in Unified Soil Classification System (USCS). Optimum moisture content and maximum dry density were obtained as 16% and 19.20 kN/m³ respectively according to B-method of AASHTO T 180 [27]. To prepare the test sections clay was compacted to 90% of maximum dry density at the optimum water content. The CBR value obtained at this water content and density was 11.13%.

The subbase course aggregate was a sand soil prepared according to AASHTO M 147 [28] (Standard Specification for Materials for Aggregate and Soil-Aggregate Subbase, Base, and Surface Courses) with the particle size distribution shown in Fig. 1. The maximum sand sizes were smaller than 6.3 mm (No. 3 sieve). This satisfies the general requirement that the ratio of the minimum size of the shear box to the maximum size of the soil particle is greater than 6. The material is classified as SW as USCS. Maximum dry density obtained was 21.4 kN/m³ at a water content of 9% (B-method of AASHTO T 180 [27]). The material was compacted to maximum dry density at maximum water content to make the subbase course in all tests. Fig. 2 presents the compaction curves for subbase and subgrade soils obtained using B-method of AASHTO T 180 [27]. Important physical properties of both soil layers are given in Table I.

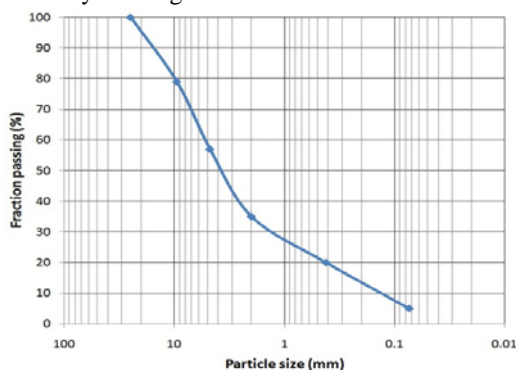


Fig. 1 Particle size distribution of sand subbase layer

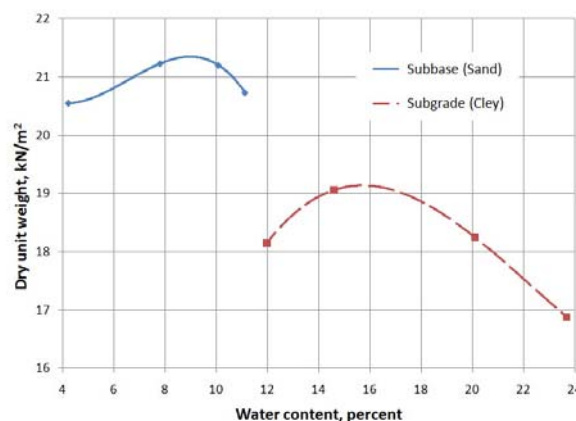


Fig. 2 Compaction curves for subbase and subgrade soils

TABLE I
SOIL PROPERTIES

Property	Soil type	
	Sand	Clay
D ₁₀ (mm)	0.12	-
D ₃₀ (mm)	1.2	-
D ₆₀ (mm)	5.15	-
Coefficient of uniformity (%)	42.92	-
Coefficient of curvature (%)	2.33	-
Liquid limit (%)	-	32
Plastic limit (%)	-	19
USCS group symbol	SW	CL

TABLE II
PROPERTIES OF GEOSYNTHETICS USED FOR THE STUDY

Parameter	CE161	F-300
Aperture size (mm)	10 × 10	6.2 × 10 ⁻⁶
Material	HDPE	Polyester
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

The properties of the non-woven geotextile namely F-300 and the geogrid namely CE-161, which provided by manufacturers are summarized in Table II. The size of the geotextile and the geogrid used was 152.4 mm in diameter.

III. EXPERIMENTAL PROGRAMME AND TEST PROCEDURE

To study the behavior of two layered soil (granular subbase overlaying cohesive subgrade), with geogrid reinforcing at the interface, and to investigate the effect of geogrid inclusion on reducing the required subbase layer thickness to achieve to a satisfactory bearing ratio, a series of bearing ratio tests conducted in both unreinforced and reinforced conditions. The idea of placing the geogrid at the interface is to utilize the semi-separation function of geogrid.

To study the behavior of two layered soil (granular subbase overlying cohesive subgrade), with geosynthetic reinforcing at the interface, and to investigate the different performance of geotextile and geogrid inclusion on reducing the required subbase layer thickness to achieve to a satisfactory bearing ratio, a series of bearing ratio tests conducted in both unreinforced and reinforced conditions. The idea of placing the geosynthetic at the interface is to utilize the separation function of geosynthetic.

Three different thicknesses (40mm, 55mm and 70mm) spotted for subbase layer in this study according to subbase layer thickness at full scale field.

A. Bearing Ratio Test

Bearing ratio is one of the vital parameters used in the design of flexible pavements. To demonstrate the influence of geogrid reinforcement on the bearing ratio of the compacted granular subbase overlying cohesive soil, a series of bearing ratio tests have been carried out for reinforced and unreinforced specimens. The bearing ratio tests are conducted at unsoaked conditions in accordance with ASTM D 1883-05 [29]). The bearing ratio mould is a rigid metallic cylinder with an inside diameter of 152 mm and a height of 178 mm. The mold has a collar fitted on the top with a height of 52mm to provide the additional height required to study the effect of compacted sand layer thickness (40, 55, and 70 mm), over cohesive soil layer, on bearing ratio. A mechanical loading machine equipped with a movable base that moves at a uniform rate of 1.2 mm/min and a calibrated proving ring is used to record the load. The proving ring is attached with a piston, which penetrates into the compacted specimen. The diameter of the piston is 49.6 mm. The loads are carefully recorded as a function of penetration up to a penetration of 24 mm.

To prepare the model cohesive soil subgrade, oven-dried clayey soil is mixed thoroughly with the required quantity of water. The soil mixed with selected water content is placed in five layers at the bottom of the mould. Each layer is compacted by 56 blows of a 44.5 N rammer dropped from a height of 457 mm. The compaction of sand layer is conducted in optimum moisture content by using a manual plastic hammer to hit a graded circular steel plate showing the distance of upper surface of the sand from the upper edge of the mold, which was placed on top of the soil until reaching the target dry density obtained from B-method of AASHTO T 180 [27]. In these tests, thickness of the compacted cohesive soil is maintained as 116 mm and thickness of the overlying compacted sand varied as 40, 55, and 70 mm. The geosynthetic layer placed at the interface of clay and sand soil at the reinforced condition. Prior to CBR testing, a surcharge equivalent to 2.9 kPa was applied on top the compacted sand layer by placing circular steel plates having diameter of 150 mm to stimulate the effects of the thickness of road construction overlying the layers being tested.

IV. RESULTS AND DISCUSSIONS

Bearing ratio tests carried out for reinforced and unreinforced two layered soil for three thicknesses for sand layer. The stress-penetration curves plotted and corrected according to ASTM D 1883-05 [29]. Fig. 3 shows the stress-penetration curves for unreinforced and reinforced conditions for 40, 55 and 70 mm sand thickness.

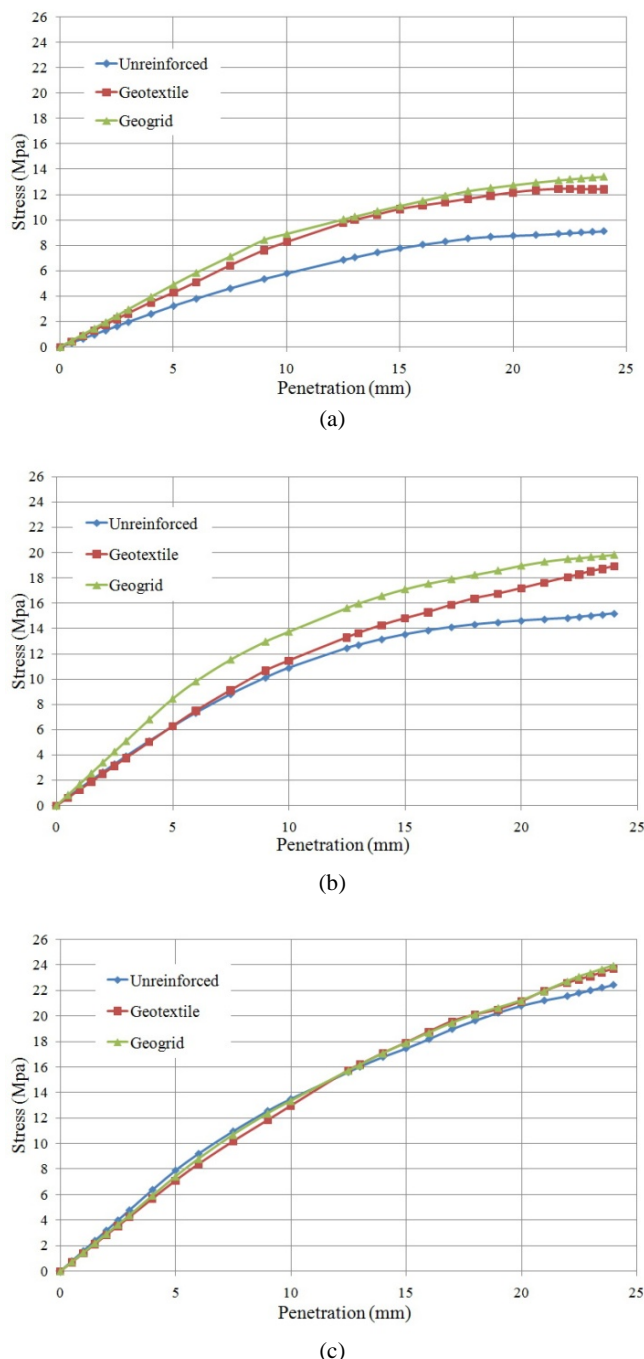


Fig. 3 Stress-penetration curves for different thicknesses of subbase layer (a). 40 mm (b). 55 mm (c). 70 mm

The curves for the unreinforced and reinforced with geotextile and reinforced with geogrid were plotted on the

same graph to enable the comparative analysis to be made. For the thickness of 40 and 55 mm for sand layer it is seen that both geotextile and geogrid have a considerable increasing effect on the bearing ratio of soil section. But as seen for 70 mm thickness of sand layer the effect of geosynthetic inclusion reduces when sand layer thickness increases. By increasing the sand layer thickness the gradient of stress-penetration curves increases because majority of the applied load is distributed by granular soil at a specific penetration but by reducing the sand layer thickness the distributing effect of granular layer reduces at the same penetration thus the curve has a lower gradient.

As the effect of reinforcement inclusion in higher penetrations is more perceptible, the penetration resistance for 12.5 mm was obtained from the curves and the corresponding bearing ratio for samples calculated by dividing the penetration stresses by the standard stress of 17.9 MPa and multiplying by 100. Table III presents the bearing ratio results for unreinforced, reinforced with geotextile and reinforced with geogrid for three sand layer thicknesses. The bearing ratio values obtained from 40 mm sand layer thickness are lower than the 55 mm and these values are lower than bearing ratio values for 70 mm thickness of sand layer and it also applies to both with and without reinforcing conditions. Normally when the sand layer thickness is thinner, the reinforcing has a greater effect on the increasing of the veering ratio values.

TABLE III

BEARING RATIO OF REINFORCED AND UNREINFORCED TWO LAYERED SOIL

Sand layer thickness (mm)		40	55	70
CBR	Unreinforced	37.56	68.12	85.33
	Reinforced with geotextile	53.43	72.69	86.12
	Reinforced with geogrid	55.08	85.41	85.92
% Increase in CBR	Reinforced with geotextile	42.25	6.71	0.93
	Reinforced with geogrid	46.65	25.38	0.69

The relative bearing ratio factors (F_r / F_u) versus the penetration are shown in Fig. 4 for both geotextile and geogrid inclusions. The relative bearing ratio factor (F_r / F_u) was calculated as fraction of the applied stress in reinforced condition (F_r) and unreinforced condition (F_u) at given penetration.

The relative bearing ratio factor can be different depending on the sand layer thickness. As it seen for thinner sand layer thicknesses the relative bearing ratio factor (F_r / F_u) remains the same by increment in penetration. On the other hand for thicker sand layers the relative bearing ratio increases in

higher penetrations. This is more apparent in samples reinforced with geotextile.

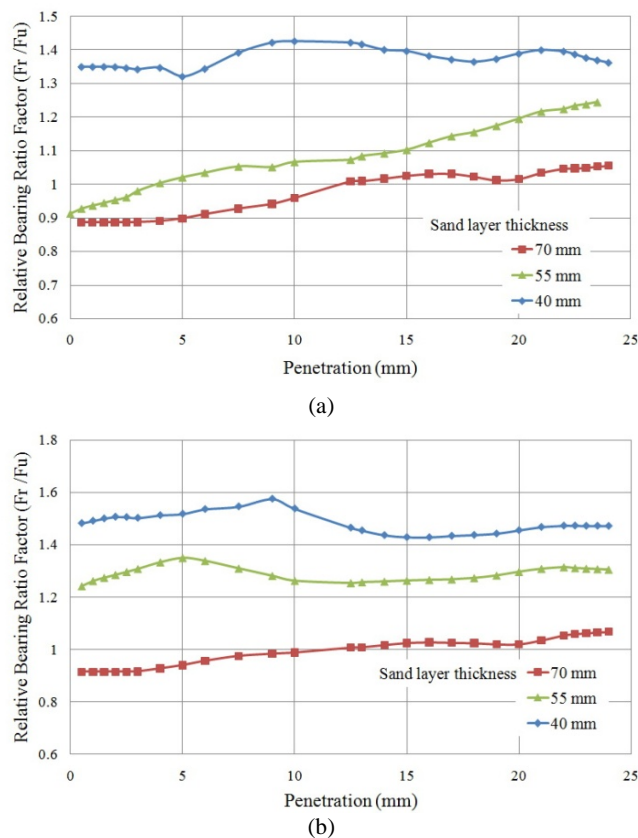


Fig. 4 Relative bearing ratio factor (F_r / F_u) versus penetration (a) Reinforced with geotextile, (b) Reinforced with geogrid

V. CONCLUSION

The aim of the experiment performed under this study was to characterize the performance of geosynthetic material when placed at the interface of a cohesive soil as subgrade and a sand soil as subbase layer subjected to stresses. The experiment can be related to an unpaved road as to whether the geosynthetic material could actually lead to improvement in the strength of the road section and consequently the bearing ratio of the section. The experiment shows that the bearing ratio of two layered soil is enhanced when reinforced with geogrid or geotextile. However utilization of geogrid results more considerable increase in bearing ratio rather than geotextile. In addition the benefit increases as the top layer thickness reduces.

The vertical deformation as a result of the application of load is related to the vertical stress distribution transferred to the soil sample. The geogrid inclusion can improve the shear resistance at the interface because of interlocking and therefore reduce the lateral spread of the soil. The interlocking between sand and geogrid creates an aggregate-geogrid composite. The confinement of the granular particles prevents both lateral and vertical movements, thus improving the load distribution through the geogrid and sand composite. On the other hand geotextile have more separating function and

prevent the sand layer grains to penetrate into the underneath layer and conduct a cohesive interaction with the clayey soil.

The calculated CBR values shows that one can use a thinner sand layer with the geosynthetic reinforcing at the interface except spotting a thicker section without reinforcing.

For thinner sand layers (40 mm for geotextile and 40 and 55 mm for geogrid reinforcement) the relative bearing ratio factor remains almost the same with penetration increment but for thicker sand layers the relative bearing ratio have more values in higher penetrations as the load surface distance from interface layer decreases.

For the sand layer thicknesses more than 70 mm the geosynthetic inclusion has no significant effect on the bearing ratio values of the sample.

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