Experimental Study of Geotextile Effect on Improving Soil Bearing Capacity in Aggregate Surfaced Roads

Mahdi Taghipour Masoumi, Ali Abdi Kordani, Mahmoud Nazirizad

Abstract**—**Geosynthetics utilization plays an important role in the construction of highways with no additive layers, such as asphalt concrete or cement concrete, or in a subgrade layer which affects the bearing capacity of unbounded layers. This laboratory experimental study was carried out to evaluate changes in the load bearing capacity of reinforced soil with these materials in highway roadbed with regard to geotextile properties. California Bearing Ratio (CBR) test samples were prepared with two types of soil: Clayey and sandy containing non-reinforced and reinforced soil. The samples comprised three types of geotextiles with different characteristics (150, 200, 300 g/m^2) and depths (H= 5, 10, 20, 30, 50, 100 mm), and were grouped into two forms, one-layered and two-layered, based on the sample materials in order to perform defined tests. The results showed that the soil bearing characteristics increased when one layer of geotextile was used in clayey and sandy samples reinforced by geotextile. However, the bearing capacity of the soil, in the presence of a geotextile layer material with depth of more than 30 mm, had no remarkable effect. Furthermore, when the two-layered geotextile was applied in material samples, although it increased the soil resistance, it also showed that through the addition of a number or weights of geotextile into samples, the natural composition of the soil changed and the results are unreliable.

Keywords**—**Reinforced soil, geosynthetics, geotextile, transportation capacity, CBR experiments.

I. Introduction

THE main usage of unpaved roads are in low volume traffic and accessing roads [1]. Basically, in agricultural countries, low volume roads play a very important role in the rural economy. When these types of roads with soft foundation soils are constructed, there is the possibility for large deformations to occur, which increases maintenance cost and lead to interruption of traffic service [2]. The use of geotextile for reinforcement to improve weak soil is currently a popular method. The tensile strength of geotextile and the soil-geotextile interaction are the major factors that influence the improvement of soil. Change in fine content within the sand can change the interface behavior between soil and geotextile [3]. This shrinking and swelling movement is the consequence of irregular road surface and road deterioration, resulting in a need for premature rehabilitation of the pavement road. Recently, there are profuse of technologies to enhance the mechanical properties and performance of soil using geotextile materials [4]. Recently, there has been considerable interest in the use of natural fibers for soil reinforcement [5], [6], [2] as well as its use a separator in the construction of paved and unpaved roads [7]-[12]. Geotextiles have pervaded almost all the branches of geotechnical engineering with almost infinite number of applications [13]. One of the most common uses of geotextiles is in road construction and soil stabilization, where soft and low-strength soil conditions prevail. In this application, the geotextile is generally used in conjunction with locally available aggregate, such as crushed stone, gravel, or seashells, to develop a structural supporting layer. For example, roads that surfaced only with aggregate are continually being built to provide access to and around construction sites, logging operations, mining and quarrying operations, and as planned stage construction for higher type of roads. Experience with these types of support systems has shown that geotextiles can be cost effective, and may substantially reduce the quantity and possibly the quality of aggregates used [14]. Geotextiles have pervaded almost all the branches of geotechnical engineering with almost an infinite number of applications [13].

Regarding with its usage as a separation in the unpaved roads, the purpose of its application is to provide the separation or reinforcement to the soil which is degraded by time passes and stabilize the soil. The durability of jute within the soil depends upon nature, pH, moisture content throughout the year, and composition of the soil [15]. Soils with low plasticity are more resistant in comparison with soils with high plasticity due to the cohesion of the reinforced sample. On the other hand, increasing the number of geotextile layers is the other way of to compensate for this problem [16]. In another study [17], researchers used a series of direct shear tests on highly plastic cohesive soil to evaluate and compare the behavior of woven and non-woven geotextiles on the behavior of clay. The behavior of reinforced clay was tested in triaxial compression tests under both static and cyclic loading conditions [18]. The field experience illustrated that where the geotextile was used had the little subsidences or rutting after 18 months. However, where the road constructed without geotextile, 5-35 mm deep ruts were observed. Long term CBR tests showed a 67-73% improvement in the road due to the use of jute–HDPE blended geotextile than that obtained for the part of the road where geotextiles were not used [19]. In a study conducted by [20], the results demonstrated that the use

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of non-woven geotextiles improved the load-carrying capacity of the sabkha by up to four times than without geotextile. In another research [21], the effect of using jute fabric in road construction applications, especially when dealing with clayey subgrades, was studied. Thus, a series of laboratory experiments were conducted using unconfined compression and California-bearing ratio (CBR) tests on samples compacted with and without fabric layers under saturated and unsaturated conditions. It was found that the jute fabric increased the CBR value and the stability of the soil, improved the bearing capacity and reduced the settling of subgrade soil.

Although the main goal using geotextile in early road constructions was separation, the laboratory tests under an axisymmetric loading condition using nonwoven, needle-punched geotextiles illustrated that its application between the sub-base and sub-grade can significantly increase the bearing capacity of soft subgrades [22].

In another study [23], the effects of nonwoven needle-punched geotextile reinforcement with granular soils with different grading applied in three different subgrade layers were compared with the bearing capacity of soil with and without geotextile reinforcement under axisymmetric loading condition. The result of these tests showed that the bearing ratio of reinforced granular soils with geotextile increased.

A researcher [24] tried to investigate the profits of applying geotextile for base reinforcement. By applying 5 types of geotextile as reinforced materials, saturation was performed on the reinforced and non-reinforced soils in CBR base experiment. As a result of the reinforced performance, efficient major cutting tensions could be seen among the joint area between the base layer, geosynthetic and base.

Another researcher conducted several CBR experiments on weathered and soft clay covered with pressed sand. The samples were reinforced by geotextile with different rigidity between clay and sand. The results showed that applying geotextile in soil increased soil transportation capacity. By increasing the speed of loading, the geotextile rigidity innuendo and the amount of power increases in a definite strain (the amount of CBR increased) [25].

II. Scope and Objectives

The aim of this study was to investigate the role of non-woven geotextile in the bearing capacity of two types of soils. Three types of geotextiles in different weights per square meter (150, 200, 300) were used in 5 definite depths of layers in clayey and sandy soil samples, and two sheets of geotextiles between the layers were also used as shown in Fig. 1. CBR (California Bearing Ratio) ASTM D1883 testing program was performed to evaluate the bearing capacity of samples. The specific objective of this study was to investigate the number and types of geotextile layers on the bearing resistance of samples reinforced by geotextile.

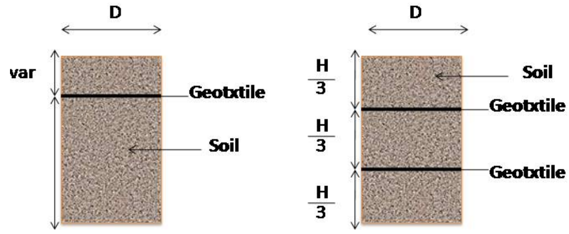

Fig. 1 The arrangement of geotextile in different samples

III. Materials and Experimental Testing

A. Aggregates and Soil Collection

In this study, clay soil was used as a subgrade and sand was placed as surface aggregates. The aggregates were obtained from a quarry that is adjacent to Sahand dam project located in Hashtrrud area, which is posited 20 km away from Hashtrud-Maragheh road. Table I shows the physical properties of both clayey and sandy aggregates. The density curves of the aggregates are shown in Figs. 2 and 3, and Table II.

TABLE I
Clay and Sandy Soil Characteristics

Amount	Standards	Description	Soil Type
	ASTM D 4318	Smooth limit	25.6%
	ASTM D 4318	Dough limit	17.7%
Clay	ASTM D 4318	Dough index	7.9%
	ASTM D1557	Optimization humidity	15%
	ASTM D1557	Maximum dryness(g/cm^3)	1.78
	ASTM D 2862	D 10 (mm)	74
	ASTM D 2862	D 30 (mm)	34.4
	ASTM D 2862	D 60 (mm)	39.5
sand	ASTM D 2862	Coefficient Uniformity (CU)	47
	ASTM D 2862	Coefficient Curvature (CC)	175
	1557 ASTM D	Optimization humidity	10%
	1557 ASTM D	Maximum dryness(g/cm^3)	2.03

TABLE II
Density Amount for the Studied Materials

Material	Clay	Sand
Gs(ASTMD 854) g/cm^3	2.62	2.68

B. Geotextile

The reinforcement material used is a non-woven geotextile with three different values in weights per square meters (150, 200 and 300) from PAMCO. The properties of geotextiles are shown in Table III.

IV. Testing Program

One of the commonly used tests, that is, California Bearing Ratio (CBR) test, was applied to determine the bearing capacity of the soil layers.

A. Test Procedure

The CBR (California Bearing Ratio) ASTMD1883 is one of the most common tests in the world used to investigate the mechanical strength of soil layers, such as sub-grades, sub-base and base. It involves penetration of the soil mass with standard circular piston at the rate of 1.25 mm/min (Fig. 4).

The soil was placed in three layers in mold, and each layer was compacted by a rammer dropped from a distance of 304 mm with 56 blows. The non-woven sheet of each type of geotextile was located in a definite depth of 5, 10, 20, 30, 50 and 100 solely, and in doubles, between the interface of layers in sandy and clayey soils. Subsequently, the penetration resistance for 2 and 5 mm were gained from the stress penetration curves and finally, related CBR for specific cases of both reinforced and without reinforcement samples were determined by dividing the penetration stresses by the standard stresses of 1000 Psi (6900 kPa) and 1500 Psi (10300 kPa), respectively and multiplying by 100. The CBR values of the samples were calculated using the following equation:

$$CBR = \frac{Stress(kPa)}{Standard\ Stress(kPa)} * 100$$

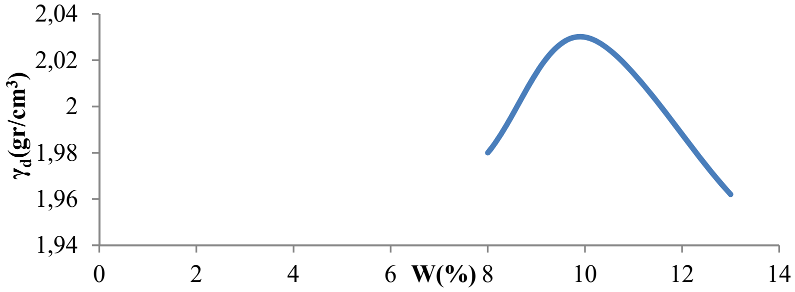

Fig. 2 Sand compression curve diagram

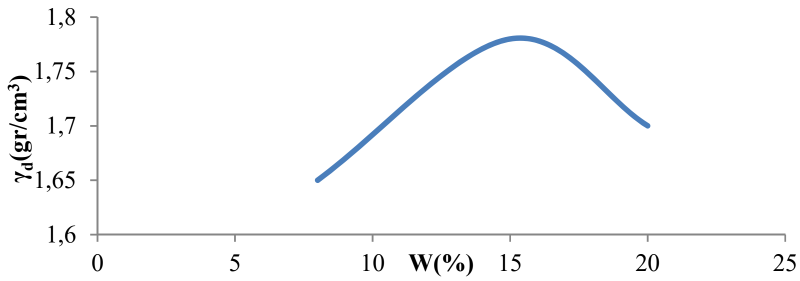

Fig. 3 Clay compression curve

TABLE III
SELECTION OF GEOTEXTILE CATEGORY BASED ON PERFORMANCE CONDITIONS

specification	unit	Test	direction	150-g/m	200-g/m	300-g/m
Mass per unit area	g/m	DIN EN 29073/1		150	200	300
Thickness	mm	DIN EN 29073/2		1.9	2.6	3.4
Max. Tensile Stength	kN/m	DIN EN 29073/3	liner	6.7	11	19
Elongation at max. Tensile strength	%	DIN EN 29073/3	liner	50	55	55
Hole size cone drop test	mm	EN 918		24	20	14
CBR puncture Resistance	kN/m	DIN EN ISO12236		1.6	2.5	3.4
Opening size	um	DIN EN ISO12956		102	93	93
Vertical Water permeability	10 m/s	DIN EN ISO11058		2.8	2.4	2.4
Grab Tensile Strength	N	ASTM D 4632	liner	510	820	1220
Elongation at max. Grab Tensile Strength	%	ASTM D 4632	liner	62	62	59
trapezoid tearing strength	N	ASTM D 4533	liner	200	290	395
index puncture resistance	N	ASTN D 4833		265	370	560

V. RESULTS AND DISCUSSION

A. One Layer Geotextile

1. CBR Values of 150 g/m^2 Geotextile

In Fig. 5, the first geotextile type (150 g/m^2) indicated that the maximum amount of CBR was obtained at 10 mm depth for clayey aggregates and 20 mm in sandy aggregates, indicating that the geotextile had the most influence on bearing capacity, when it was placed near the surface of the sample. Moreover, the amount of CBR reduced, by increasing the depth of the geotextile for clayey and sandy aggregates by 10 and 30 mm, respectively and consequently, the CBR amounts remained constant. It can be concluded that the increasing depth had no significant impact on the CBR amounts.

2. CBR Values of 200 g/m^2 Geotextile

As shown in Fig. 6, due to the bond of aggregates in clayey soil, the CBR amounts of the soil were greater as compared with those of sandy aggregates. As previously mentioned, in this type of geotextile, there is an increase in the amount of CBR in the surface adjacent layers. In this study, by increasing the placement depth, the CBR approximately remained permanent.

3. CBR Values of 300 g/m^2 Geotextile

Fig. 7 shows the CBR values of sandy soil samples, having greater amounts than the clayey samples. This can be attributed to the impact of geotextile thickness and its compatibility with soil in increasing the CBR values in the vicinity of the layer surface. Moreover, the maximum CBR was assigned to sandy soil with 5 mm depth, which is 2.31 and 2.41 times greater than those of 150 and 200 (g/m^2) geotextiles.

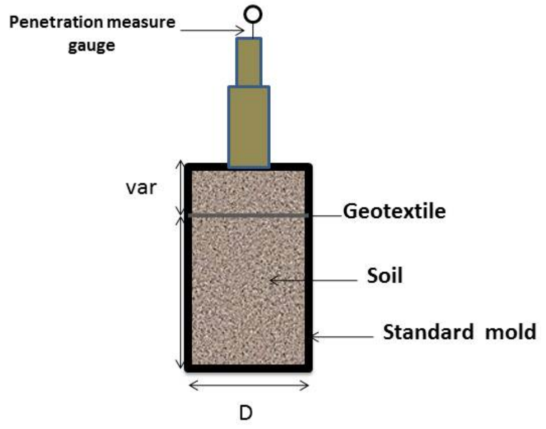

Fig. 4 Schematic arrangement of the Soil-Aggregate in the CBR mold with geotextiles

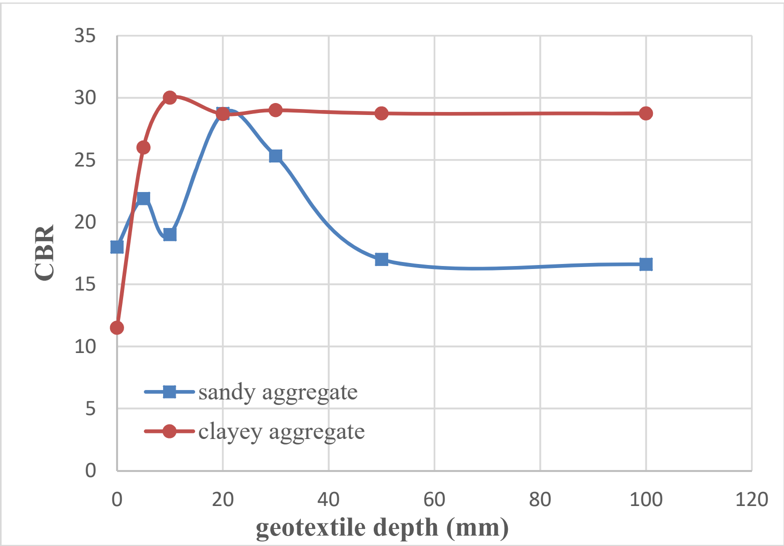

Fig. 5 CBR vs. geotextile (150 g/m^2) in different depths for the reinforced soil in no and one layer cases

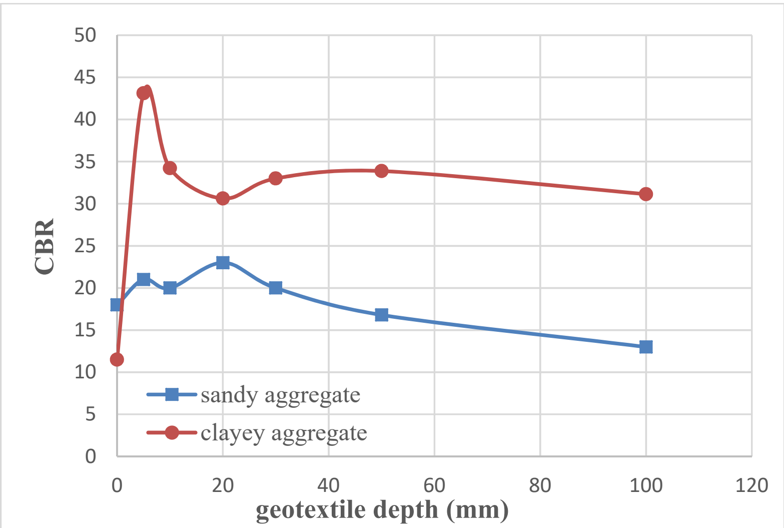

Fig. 6 CBR vs. geotextile (200 g/m^2) in different depths for reinforced soil in no and one layer cases

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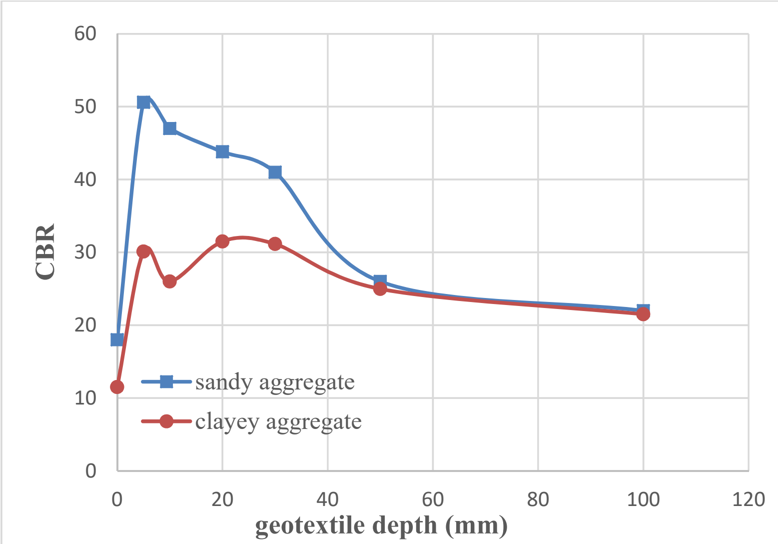

Fig. 7 CBR vs. geotextile (300 g/m^2) in different depths for reinforced soil in no and one layer cases

4. CBR Values of All Types of Geotextiles for Sandy Soil

The CBR curves of all types of geotextiles for sandy aggregates are shown in Fig. 8. As shown in the figure, 300 g/m^2 geotextile was the most applied CBR value as compared with the two other types. Thus, this can be attributed to its remarkable bearing characteristics under loading conditions. By increasing the depth in all types of geotextiles, the CBR values reduced due to low radius effect.

5. CBR Values of All Types of Geotextiles for Clayey Soil

Fig. 9 shows the CBR curves of clayey soil for all types of geotextiles. The maximum amount of CBR was assigned to 200 g/m^2 geotextile with depth of 5 mm. Therefore, it can be concluded that CBR was high when geotextile was implemented near the surface of the samples. The reduction of CBR in 300 g/m^2 geotextile may be related to the nature of the clay and its incompatibility with this type of geotextile.

B. Two Layer Geotextile

The CBR results of two types of soils for two layers with geotextiles are shown in Fig. 10. As shown in this figure, the maximum CBR value was ascribed to 150 g/m^2 geotextile in both sandy and clayey soils and this can be attributed to the strong interaction of soil with geotextile in the interface of layers. Moreover, the difference in CBR values between control samples and samples reinforced with 150 g/m^2, clearly shows the effect of geotextile in increasing the bearing capacity of soil.

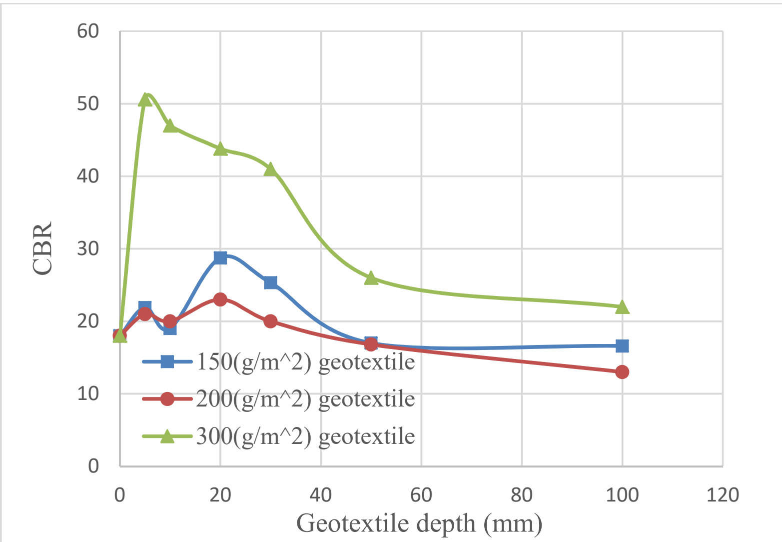

Fig. 8 CBR vs. geotextile types in different depths for reinforced sand soil in no and one layer cases

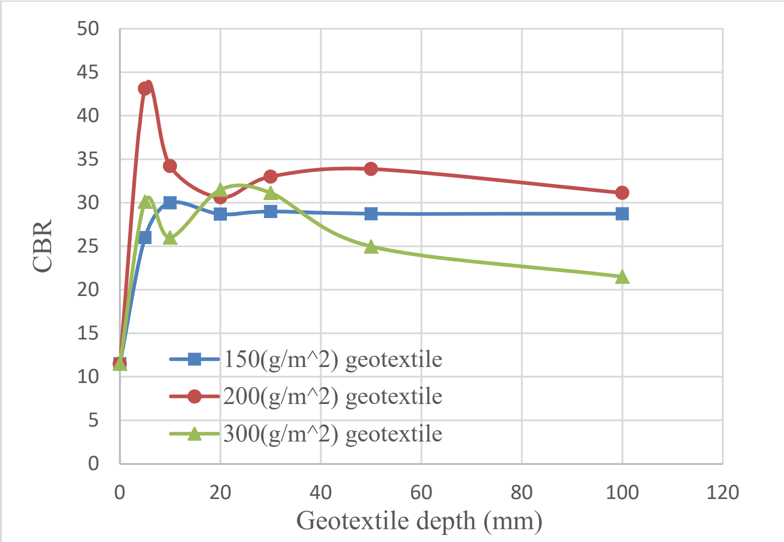

Fig. 9 CBR vs. geotextile types in different depths for reinforced clay soil in no and one layer cases

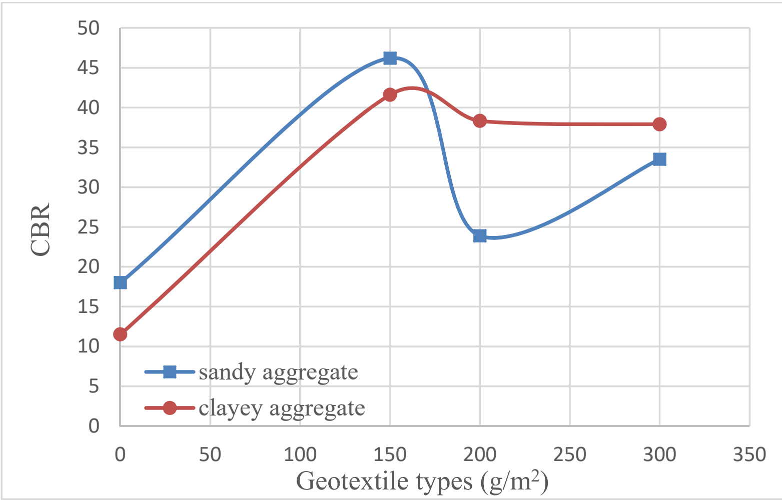

Fig. 10 CBR vs. layer geotextile types for reinforced soils in no and two layer cases

To sum up, the maximum CBR values are approximately related to 5 mm depth placement; however, under practical conditions, it may be impossible to implement geotextile in such depth. Indisputably, the best depth that can be used in filed circumstances is 20 mm for sandy and 10 mm for clayey soils according to the figures.

VI. Conclusions

The aim of this study was to evaluate the effectiveness of one and two layer application of geotextile in the bearing capacity of road soil layers. The following conclusions were drawn based on the test results:

1. All test results generally showed that with the utilization of geotextile in the states of one and two layers, the resistance of samples against loading increased appreciably.
2. With regards to the CBR test results, the CBR values of 150 and 200 g/m^2 geotextile in clayey soil indicated better responses under loading conditions; however, the reverse was the case for 300 g/m^2 geotextile.
3. The application of geotextile in two layers showed that it increased the CBR values and the maximum amount was ascribed to 150 g/m^2 geotextile application. However, it causes a change in the inherent behavior of soil due to its discontinuity of aggregates.
4. CBR test results confirmed that the 300 g/m^2 geotextile showed the most bearing resistance as compared with the two other types and at the adjacency of surface capacity was the maximum amount.
5. Based on the CBR results, the CBR values increased with the application of one layer geotextile, the maximum CBR values in clayey and sandy soils were approximately 3 and 2.6 times greater than those without reinforcement.

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