UITS Journal of Science & Engineering ❖ **Volume: 7, Issue: 1**
ISSN: 2521-8107, January-2020

An Experimental Study to Improve the Subgrade Soil of Flexible Pavement by Using Geosynthetic Materials

Md. Sanaullah Shamim[1]

ABSTRACT: Weaker soils are generally clayey and expansive in nature, which are having lesser strength characteristics. The load bearing capacity of these soils is very low and hence improvement is required for these types of soil. Soil improvement with geotextile is a new idea that can increase the stiffness and load bearing capacity of the soil through frictional interaction between the soil and geotextile material. The vehicular load coming on the road subgrade is transferred to the underlying soil. If the road subgrade supporting the vehicular load is weak, the subgrade thickness of road increases, which leads to the more cost of construction. To achieve the economy and for proper performance of road, it is necessary to improve the subgrade soil. Synthetic low cost non-woven geotextiles were placed at different depth of subgrade mould and the improvement in soil load bearing capacity are checked by Californian Bearing Ratio (CBR) value. In the present investigation locally available sub-grade soil of the road is modified by addition of geotextile material and placed on mould in different layers such as at top level, at 3 cm from top, at 6 cm from top and at 9 cm from top level of subgrade mould. Test result shows that single layer of geotextile reinforcement at 6 cm from subgrade level has better performance than those samples without geotextile and with the provision of geotextile layer at other depths. The CBR value of geotextile reinforced subgrade soil at 6 cm depth from top of mould increases about 54.00% and 35.00% for unsoaked and soaked conditions, respectively comparing to unreinforced soil.

Keywords: Subgrade soil, Improvement of soil, Geotextile, CBR, Bearing Capacity.

1. INTRODUCTION

Currently, soil reinforcement is most commonly performed with geosynthetics, leading to an increase in the strength and a decrease in the compressibility of the composite material. In other words, the addition of

[1] Lecturer, Department of Civil Engineering, UITS.
Email: sanaullah.shamim.bd@gmail.com

geosynthetic reinforcement in regions of tensile strain helps to inhibit the stresses in the soil, thereby increasing the shearing characteristics of the composite material. The common usage for soil-geosynthetic reinforcement includes the construction of roads, retaining walls, foundations and embankments. The current research focused on the application of geosynthetic reinforcement in the flexible pavements. Geosynthetic reinforced base course and subgrade layers enhanced pavement performance. While geosynthetics have been used in pavements for the past few decades, there is still a lack of test methods to quantify the benefits of geosynthetics and the variables governing their design. This research includes a re-evaluation of existing design methodologies, a process that involved obtaining data to quantify the performance response of geosynthetic reinforced soil subgrade. The overall goal of this research is to identify the mechanism governing geotextile reinforced flexible pavement.

The upper layer of the embankment whether in cut or fill is termed as subgrade. The strength of the subgrade is a basic factor in determining the thickness of pavement and is evaluated by means of CBR tests. The thickness of sub-grade normally should not be less than 30cm. The thickness of pavement will vary due to Californian Bearing Ratio (CBR) value of subgrade [1]. At locations with adequate subgrade bearing capacity or CBR value, a layer of suitable granular material can improve the bearing capacity to carry the expected traffic load. But at sites with CBR less than 2% problems of shear failure and excessive rutting are often encountered.

The ground improvement techniques such as excavation and replacement of unsuitable material, deep compaction, chemical stabilization, and geotextiles are often used at such sites. In pavement construction, geotextile reinforcement has been applied to improve their overall strength and service life. The stabilization of pavements on soft ground with geotextiles is primarily attributed to basic functions of separation of base course layer from subgrade soil.

2. RESEARCH OBJECTIVES

Traditionally natural soil is used as road subgrade. When there is low bearing capacity soil under the pavement, the soil needs to improve its quality. The CBR is a measure of resistance by which the strength of soil can be determined. The low CBR value indicates the lower strength of soil. In this study, it is tried to improve the CBR value of subgrade soil by reinforcing with geotextiles.

The specific objectives of this study are as follows:

1. To determine the CBR value of subgrade soil without reinforcement and with reinforcement by geotextile.
2. To determine the percentage increase of CBR value due to reinforcement.
3. To calculate the approximate pavement thickness and percentage reduction of pavement thickness above subgrade soil due to reinforcement by International Residential Code (IRC) CBR method.

3. GEOTEXTILE IN PAVEMENTS

A flexible pavement has mainly four layers named as subgrade, sub-base, base and wearing surface. A typical flexible pavement system is shown in Figure 1.

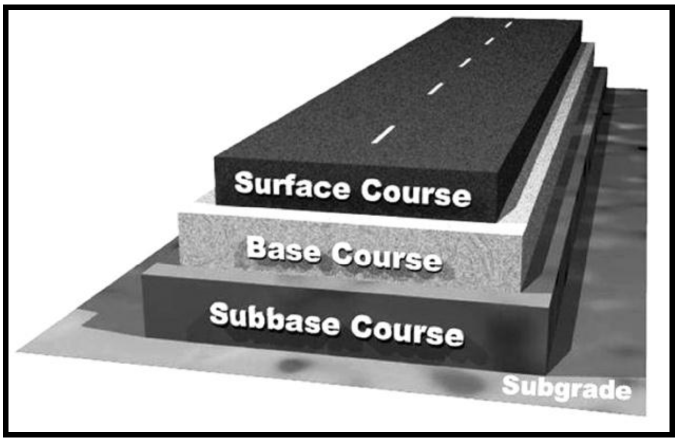

Figure 1: Crosssection of flexible pavement system.

There are two main benefits of using geosynthetics in the form geotextiles in the base course and subgrade layers of flexible pavements [2]. For a given cross-section of the pavement, addition of geosynthetic leads to an increase in serviceability life and reduction in the maintenance cost of the pavement. This alternative is feasible when the maintenance and replacement costs during the service life of the pavement are offset by the high initial cost of using the geosynthetic for a given project.

Geotextile and its classifications

Geotextiles can be defined as planar products manufactured from polymeric material, which are used with soil, rock or other geotechnical engineering related material as an integral part of a man-made project, structure or system. A geotextile is defined as a permeable geosynthetic made of textile materials. Woven geotextiles are manufactured by adopting techniques which are similar to weaving usual clothing textiles. The majority of low to medium strength woven geo synthetics are manufactured from polypropylene which can be in the form of extruded tape, silt film, monofilament or multifilament. A typical woven geotextile is shown in Figure 2.

Figure 2: Woven Geotextile.

Figure 3 shows a typical non-woven geotextiles can be manufactured from either short staple fibre or continuous filament yarn. The fibers can be bonded together by adopting thermal, chemical or mechanical techniques or a combination of techniques.

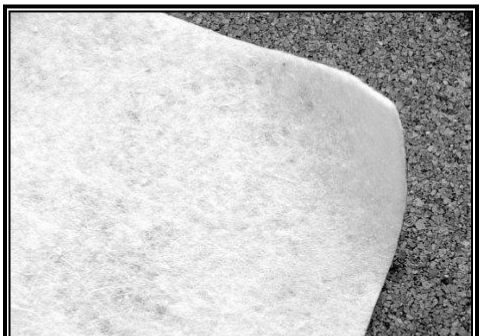

Figure 3: Non-woven Geotextile.

Functions of geotextile

The primary functions of geotextiles used for pavement applications have traditionally included separation, filtration, drainage, and reinforcement [3]. A brief overview of functions typically performed by geotextiles in pavement applications is discussed below.

Separation: Separation is the introduction of a flexible porous geotextile placed between dissimilar materials so that the integrity and the functioning of both materials remains intact for the life of the structure or is improved [4]. In pavement applications, separation refers to the geotextile's role in preventing the intermixing of two adjacent layers. Figure 4 shows the separation function in road pavement by geotextile.

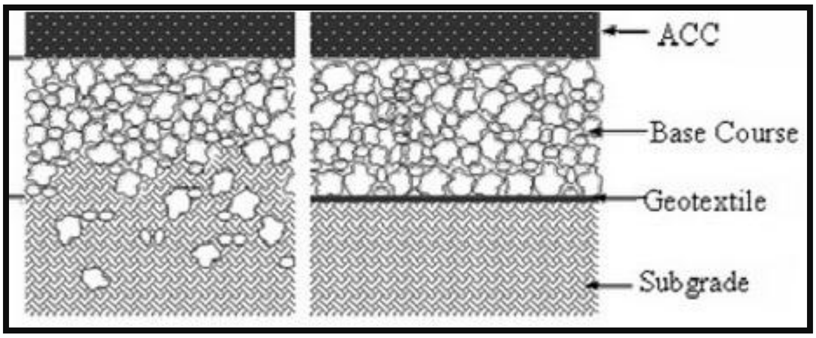

Figure 4: Separation function of a geotextile placed between base aggregate and soft subgrade.

Filtration: Filtration is defined as the equilibrium of a geotextile-soil system that allows for adequate liquid flow with limited soil loss across the plane of the geotextile over a service lifetime compatible with the application under consideration [4]. Figure 5 shows a common application illustrating the filtration function is the use of a geotextile in a pavement trench drain.

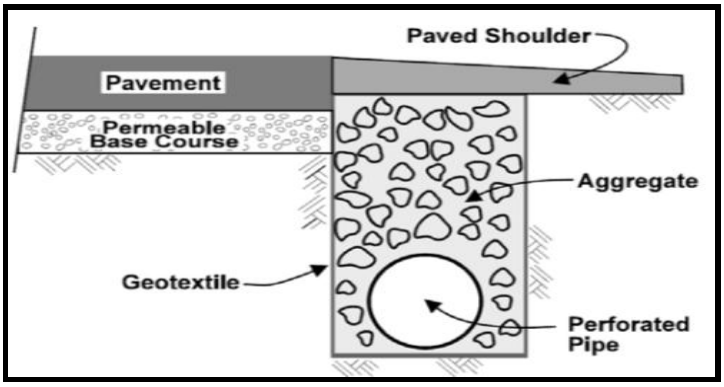

Figure 5: Filtration function provided by a geotextile in a pavement trench drain.

Drainage: Drainage refers to the ability of geotextiles (typically thick, nonwoven geotextiles) to provide an avenue for flow of water through the plane of the geotextile. Figure 6 shows the drainage function provided by geotextile.

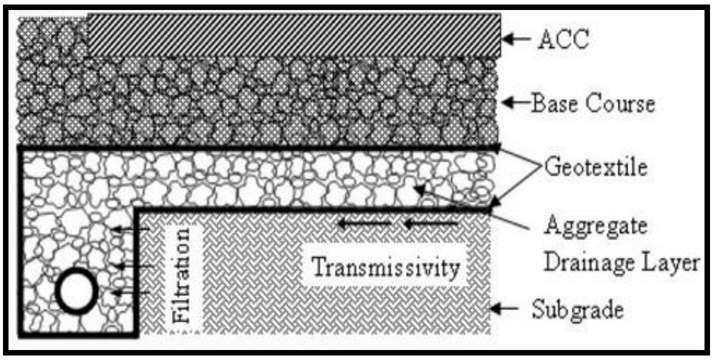

Figure 6: Drainage function provided by a geotextile.

Reinforcement: A geotextile with good frictional capabilities can provide tensile resistance to lateral aggregate movement. The reinforcement mechanism is illustrated in Figure 7.

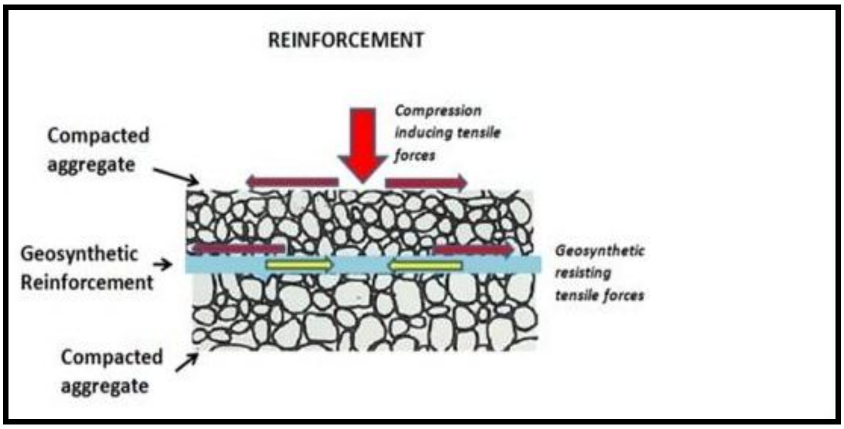

Figure 7: Reinforcement mechanisms induced by a geotextile.

4. CALIFORNIA BEARING RATIO

The CBR test was developed by the California division of highway as a method for classifying and evaluating soil subgrade and base course material for flexible pavement. The CBR is a measure of resistance of a material to penetration of standard plunger under controlled density (Table 1) and moisture condition. The CBR value is calculated from the following formula.

$$\text{CBR}(\%) = \frac{\text{Unit load carried by soil sample at defined penetration level}}{\text{Unit load carried by standard crust stones at above penetration level}} \times 100$$

Table 1: Standard load values for different penetration level.

Penetration (mm)	Standard Load (kg)	Unit Standard Load (kg/cm^2)
2.5	1370	70
5.0	2055	105

The standard CBR test was selected so that a comparative analysis between the reinforced condition with geotextile and unreinforced condition test results without the use of geotextile could be interpreted.

5. RESEARCH METHODOLOGIES

The experimental set up was developed with reference to the same samples preparation for California Bearing Test, CBR Test of single layer of geotextile with the soil subgrade. The tests are performed in a steel cylindrical mold of volume $\frac{1}{30}$ ft^3 (943.3 cm^3). The tests were conducted immediately after compaction for unsoaked case as well as after soaking it in water for 4 days for soaked case.

The following arrangements of CBR test were conducted to find out the variation in load carrying capacity for both reinforced and unreinforced soil subgrade.

1. Soil sample without geotextile (Unsoaked and Soaked Condition)
2. Soil sample with geotextile at top (Unsoaked and Soaked Condition)
3. Soil sample with geotextile at 3cm from top (Unsoaked and Soaked Condition)
4. Soil sample with geotextile at 6cm top (Unsoaked and Soaked Condition)
5. Soil sample with geotextile at 9cm from top (Unsoaked and Soaked Condition)

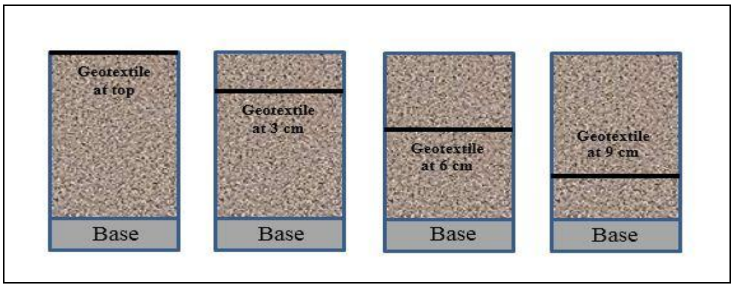

Figure 8: Location of Geotextile at different layers.

The tests were carried out on plain soil and by placing the geotextile at various positions of the sample in the mold as shown in Figure 8.

Experimental procedure

The water content of soil was kept constant in all tests and equal to 12.80%. To achieve this, the existing water content of soil was fully dried before each test and the water content was mixed accordingly. For uniform compaction of soil, the modified proctor hammer was used whose weight is 10 lb (4.54 kg) and height of drop is 18 in. The mold was filled with four layers. The layer fills are 3 cm, 6 cm, 9 cm, full length respectively. Each layer was compacted with 70 blows uniformly. In case of unsoaked condition, the mold was tested immediately after compaction. And in case of soaked case, it was tested after four days soaked in water. Testing was carried out on Universal CBR Testing Machine.

Engineering properties of Tested Geotextile Sample

There is no guideline to use the geotextile with pavement subgrade but the geotextile thickness and boundary effect can have influence on the outcome, but any change of in condition, will make it difficult for comparative analyses. Therefore, the current values can be treated more as relative measurements. Small size of the CBR test apparatus limits the size of the geotextile sheet. Table 2 shows the properties of geotextile used in this research.

Table 2: Properties of Geotextile.

Mass per unit area	456.75 (gm/m^2)
Thickness (under 2kpa pressure)	3.34 mm
Strip Tensile Strength Test	38.89 KN/m
Grab Tensile Strength Test	2456 N

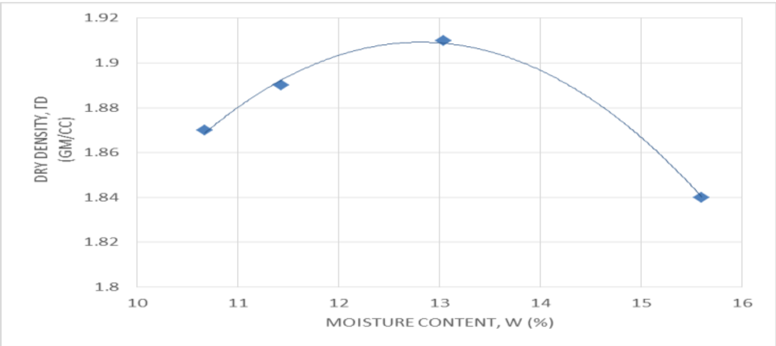

Figure 9: Dry density vs. moisture content plot.

Figure 9 shows the dry density vs. moisture content graph. By plotting the dry density (gm/cc) in Y-axis and moisture content (%) in X-axis, the optimum moisture content found to be 12.80 %. The CBR test was conducted on each soil sample as close to the optimum moisture content as possible.

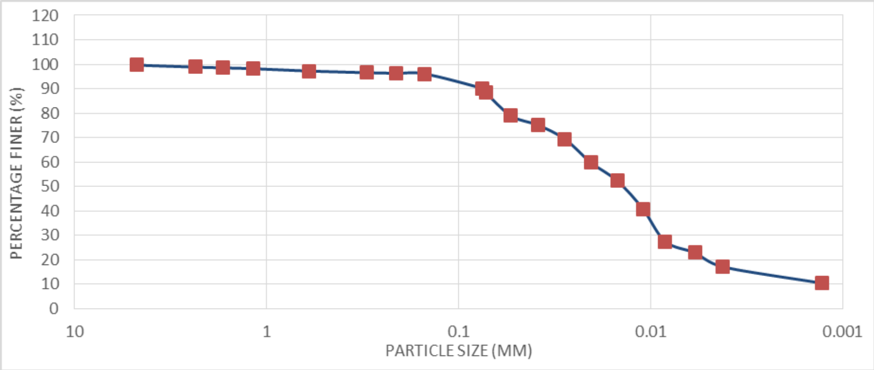

Figure 10: Particle Size Distribution curve-Sieve Analysis & Hydrometer Analysis **.**

The Figure 10 shows the particle size distribution curve obtained by analyzing both the sieve analysis and hydrometer analysis. As the collected soil sample was clayey type. From particle size distribution curve, it is observed that the soil sample near to well graded.

6. DATA ANALYSIS AND RESULTS

CBR test results on unsoaked soil with geotextile at different layers

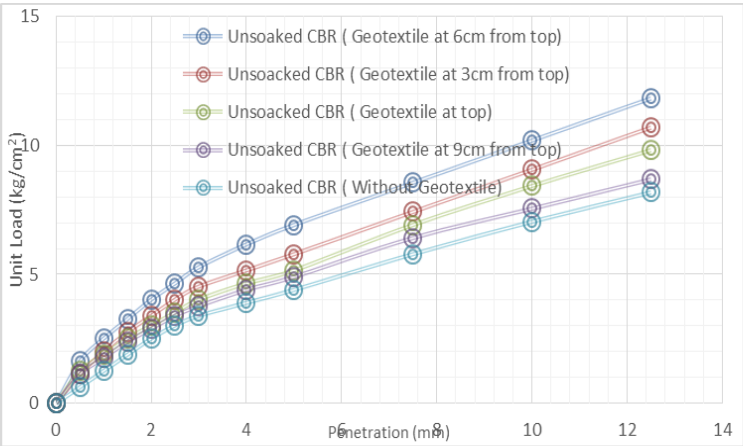

Figure 11: Load vs. Penetration plot for unsoaked soil sample without geotextile and with geotextile at different layers.

Figure 11 shows load vs. penetration plot for unsoaked soil sample without geotextile and with geotextile at different layers. From this figure it is clear that the CBR value is maximum for the provision of geotextile at 6 cm depth from top which gradually decreases and becomes minimum for soil sample without geotextile.

CBR test results on soaked soil with geotextile at different layers

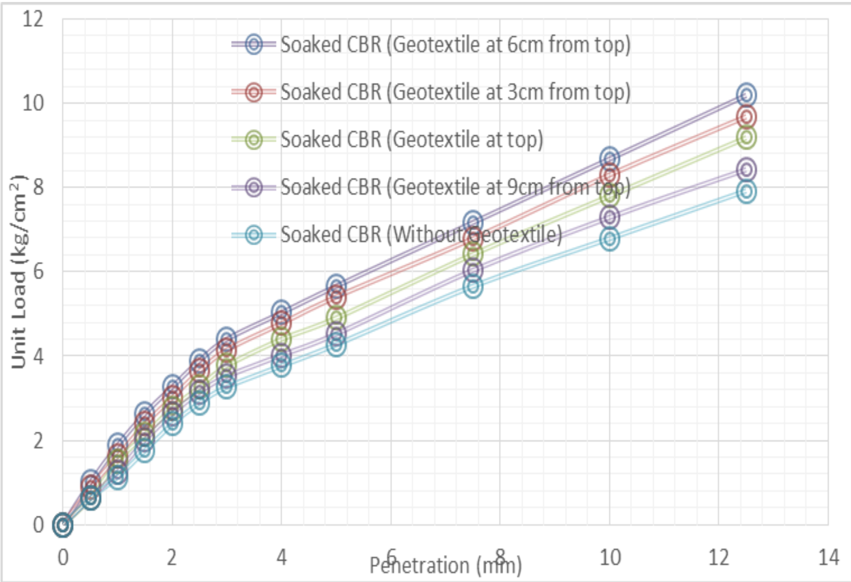

Figure 12: Load vs. Penetration plot for soaked soil sample without geotextile and with geotextile at different layers.

Figure 12 indicates load vs. penetration plot for soaked soil sample without geotextile and with geotextile at different layers. From this figure it is clear that the CBR value is maximum for the provision of geotextile at 6 cm depth from the top layer which gradually decreases and becomes minimum for soil sample without geotextile.

Table 3 and Table 4 show the calculated CBR value of the normal subgrade and subgrade with geotextile at various positions in unsoaked case and soaked case respectively. From the two Tables, it is seen that the maximum CBR value is that of subgrade soil with geotextile at 6cm from top.

Table 3: Variation of CBR value of unsoaked soil due to provision of geotextile.

Soil sample	CBR value (%)	Increase of CBR value	% increase of CBR value
Without geotextile	4.31	--	--
Geotextile at top layer	5.03	0.72	16.71
Geotextile at 3cm from top	5.76	1.45	33.64
Geotextile at 6cm from top	6.64	2.33	54.06
Geotextile at 9cm from top	4.86	0.55	12.76

Table 4: Variation of CBR value of soaked soil due to provision of geotextile.

Soil sample	CBR value (%)	Increase of CBR value	% increase of CBR value
Without geotextile	4.13	--	--
Geotextile at top layer	4.67	0.54	13.08
Geotextile at 3cm from top	5.21	1.08	26.15
Geotextile at 6cm from top	5.57	1.44	34.87
Geotextile at 9cm from top	4.49	0.36	8.72

Variation of Pavement Thickness according to CBR value

IRC Method [5] is widely used in India and in our country for the design of flexible pavement. CBR method which considers traffic in terms of commercial vehicles per day determines the CBR curves are recommended for design in Figure 13. The thickness of different layers of sub-base, base and surfacing can be determined by repeated use of these curves and duly taking into account the minimum thickness and compositional requirements. The following Table 5 shows the approximate traffic conversions which may be used to decide the minimum thickness and composition of various layers.

Table 5: Traffic Classification curve according to vehicle number.

Traffic, CVPD	CBR Design Curve Applicable
0-15	A
15-45	B
45-150	C
150-450	D
450-1500	E
1500-4500	F
Exceeding 4500	G

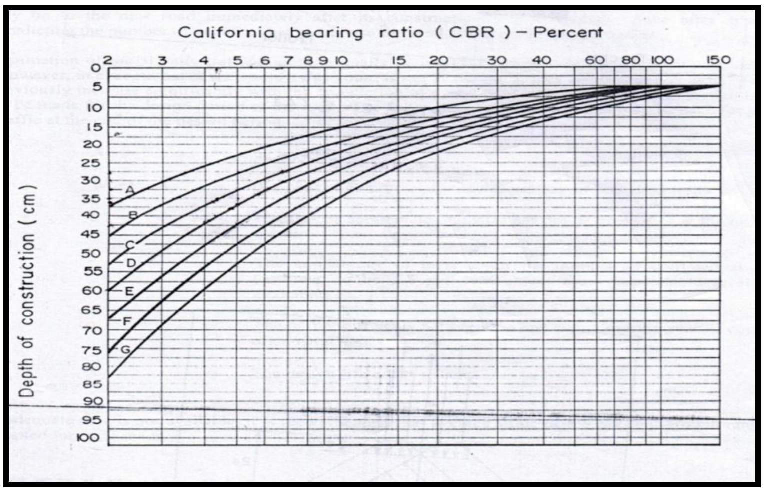

Figure 13: CBR curve for flexible pavement design, as adopted by IRC.

Pavement Thickness Design By IRC

In this study, the commercial vehicle per day was projected as 420 VPD. So from the curves provided, our design curve was D. The design thickness of the pavement could be picked up from the Figure 13.

IRC recommended pavement thickness for curve D (Unsoaked Condition)

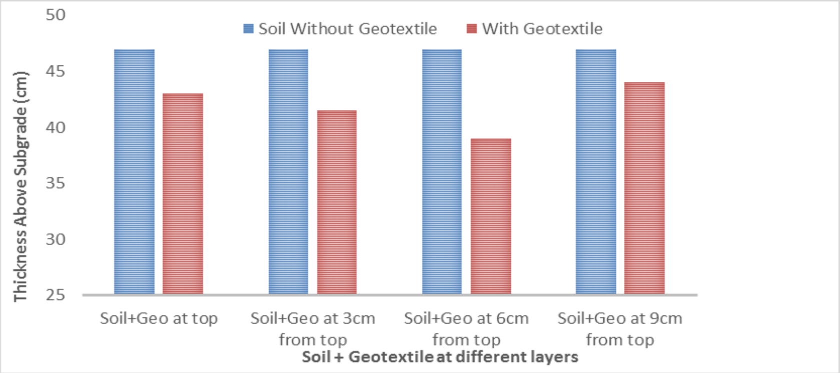

Figure 14: Variation of reduction in pavement thickness for D curve due to provision of geotextile at different layers (Unsoaked Condition).

In case of unsoaked conditions, Figure 14 represents total pavement thickness in cm for sample subgrade soil reinforced with geotextiles at different positions. It shows a minimum pavement thickness of 30.50cm for geotextile placed at 6cm from top of the mould and maximum 41cm for subgrade soil without geotextile.

IRC recommended pavement thickness for curve D (Soaked Condition)

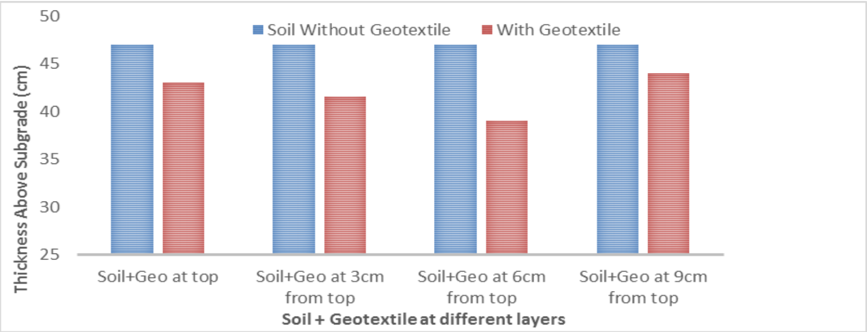

Figure 15: Variation of reduction in pavement thickness for D curve due to provision of geotextile at different layers (Soaked Condition).

On the other hand, in case of soaked conditions Figure 15 represents total pavement thickness in cm for sample subgrade soil reinforced with geotextiles at different positions. It shows a minimum pavement thickness of 34.50cm for geotextile placed at 6cm from top of the mould and maximum 42cm for subgrade soil without geotextile.

7. DISCUSSION

The CBR value for unsoaked soil is 4.31% and with insertion of geotextile at top of the mould is 5.03%, at 3 cm from top of mould is 5.76%, at 6 cm 6.64% and at 9 cm 4.86%. There is an increase in CBR value when geotextile is placed at the top is 16.71%, at 3 cm is 33.64%, at 6 cm is 54.06% and at 9 cm is 12.76%. In case of unsoaked condition according to IRC CBR method, there is a reduction in pavement thickness when geotextile is placed at the top is 9.76% ; at 3 cm the reduction is 17.07%; at 6 cm the reduction is 25.61%; and at 9 cm it 7.32% for D Curve.

The CBR value for soaked soil is 4.13% and with insertion of geotextile at top of mould is 4.67%, at 3 cm from top of mould is 5.21%, at 6 cm 5.57% and at 9 cm 4.49%. There is an increase in CBR value when geotextile is placed at the top is 13.8%, at 3 cm is 26.15%, at 6 cm is 34.87% and at 9 cm is 8.72%. In case of soaked condition according to IRC CBR method, there is a reduction in pavement thickness when geotextile is placed at the top is 9.52%; at 3 cm the reduction is 13.09%; at 6 cm the reduction is 17.85%; and at 9 cm it is 7.14% for D Curve.

Therefore, there will be an increase of CBR value due to insertion of geotextile and consequently the reduction of pavement thickness will occur.

8. CONCLUSIONS

It can be concluded from the above discussions that due to provision of Geotextile, CBR value increases up to 6 cm depth from top and then reduces gradually. At 6 cm depth, CBR value increases about 54% and 35% for unsoaked and soaked condition respectively by reinforcing soil. Pavement thickness above subgrade also decreases with the increase in CBR value. As for example, According to IRC CBR method, at 6 cm depth from top of the CBR mould maximum reduction of thickness of a flexible pavement is about 26% and 18% for unsoaked and soaked condition respectively.

9. RECOMENDATIONS

From this research work a major finding is that geotextile can be used with the natural subgrade to improve the soil quality. A further future research work may be performed by adding building wastes from demolition works with subgrade along with geotextile to know the performance of subgrade soil. Geotextiles can also be provided in multiple layers rather than using single layer whether it gives a higher value or not.

ACKNOWLEDGEMENTS

This research work has been done in the Laboratories of the Department of Civil Engineering of Rajshahi University of Engineering & Technology, Bangladesh. We are grateful to our honorable teacher Professor Dr. Syed Abdul Mofiz sir for his unconditional support and guidance.

REFERENCES

[1] Road Pavement Design Manual, (1999), pp. 16-17, LGED, Bangladesh.

[2] Sivapragasam C et al., (2010) Study on Synthetic Geotextiles for Road Pavements, Indian Geotechnical Conference, GEO trendz, December 16–18.

[3] Zornberg J G, Thompson N, (2012) Application Guide and Specifications for Geotextiles in Roadway Applications, A Project of Texas Department of Transportation, pp. 107-112.

[4] Koerner R M, (1986) Designing With Geosynthetics, Prentice–Hall, Eaglewood Cliffs, New Jersey, vol.1.

[5] Guidelines for the Design of Flexible Pavements, (2012) IRC, SP: 37, New Delhi, India.