Design of Geotextile Reinforced Rural Roads by U.S Army Corps Engineer's Method

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***Abstract* - A well connected road network is one of the basic infrastructure requirements which play a vital role for the fast and comfortable movement of inter-regional traffic in our country. This research paper presents a design procedure for predicting the thickness of base course layer for geosynthetic reinforced road systems. The design method developed takes into consideration the worst type of natural subgrade soil, usually in the form of soft, saturated clays exhibiting low values of cohesion under undrained conditions. This research also gives the base course thickness for very weak subgrade soils which have CBR value less than 2 %. The research aims at providing an effective design procedure based on simple laboratory evaluation of equivalent CBR of the composite layered system namely, the geotextile sandwiched between the base course material and the soft subgrade soil.**

***Index Terms* - Geosynthetic reinforced road systems, Base course layer, California Bearing Ratio (CBR), Geotextile**

I. Introduction

In order to achieve higher growth rates of economic development in India, the quality and level of service provided by the roads should improve. A well connected road network is one of the basic infrastructure requirements which play a vital role for the fast and comfortable movement of inter-regional traffic in our country. The above objectives are being met with a missionary zeal by our national planners under the direction of ministry of road transport and highways, Government of India.

This research paper presents a design procedure for predicting the thickness of base course layer for geosynthetic reinforced road systems. The design method developed takes into consideration the worst type of natural subgrade soil, usually in the form of soft, saturated clays exhibiting low values of cohesion under undrained conditions. In other words, paper addresses a design method which enables the engineer to calculate the required thickness of the base course layer and make the proper selection of the Geotextile or Geogrid to be used. As there are no readily available design catalogues, developed by Indian Roads Congress for Indian conditions, for determining the composition as well as the thickness of the pavement, when reinforcement is used, this research helps us to determine the thickness as well as composition of the pavement, when a Geotextile, in particular, is used as reinforcement at the interface of the base course layer and the soft subgrade soil.

II. MATERIALS AND METHODOLOGY

The aim of this project is to connect the rural roads to improve the economy and decrease the maintenance cost of roads. Geosynthetic is very costlier to use in road works, as basis raw material is not provided. Hence, discarded geotextile bags (Cement) is used in the place of geosynthetic. Using this geotextile in construction of roads, we can reduce the thickness of the base course, by placing the geotextile in between subgrade and base course. Therefore, the design of geotextile bag is done by plunger push test, for knowing tensile strength using CBR & also method reported by (Sudhaker 2005) and (Krishnaswamy 2011). At last, the values which obtained using geotextile as reinforced is compared with P.K. Sikdar (2001), the changes in design procedure is explained.

According to ASTM 4439, the geotextile is defined as: *"A permeable geosynthetic comprised solely of textiles. Geotextile are used with foundation, soil, rock, earth, or any other geotechnical engineering-related material as an integral part of human-made project, structure, or system"*. The prefix of geotextile, 'geo' means 'earth' and 'textile' means 'fabric'. The name geotextile was proposed by *Prof. J.P. Giroud President* of International Geotextile society, USA.

The most common type of Geosynthetic is *Geotextile *Geomembranes *Geonets *Geopipes *Geogrid

<u>Types of Geotextile:</u> Depending upon the mode of manufacturing the fabrics, they are classified as,
*Woven Geotextile *Non-woven Geotextile *Knitted Geotextile *Composites

<u>Classifications of Geotextile:</u> Geotextile are classified based on,
*Form & Construction geotextile *Constituent polymer *Weight & Thickness *Engineering functions * Engineering properties

<u>Application of Geotextile:</u>

**Geotextile as Separators*	*Separates subsoil from the Granular sub-base
**Geotextile as Soil Reinforcement*	*Base-Course Reduction Ratio (BRR) *Traffic Benefit Ratio (TBR)
**Geotextile in Filtration & Drainage*	*Prevent soil fines from pumping up through aggregates

III. THEORETICAL DISCUSSION

Theoretical model assumptions
***Friction coefficient** of the base course layer is large and the base course layer does not fail in shear.
***Bearing capacity** of subgrade soil governs the solution.
***Wheels** are assumed to travel always along the road in the same track.
***Dual tire contact area** is assumed to be **circular**.
*Applies only to purely **cohesive subgrade soils** (*representing the worst scenario*)

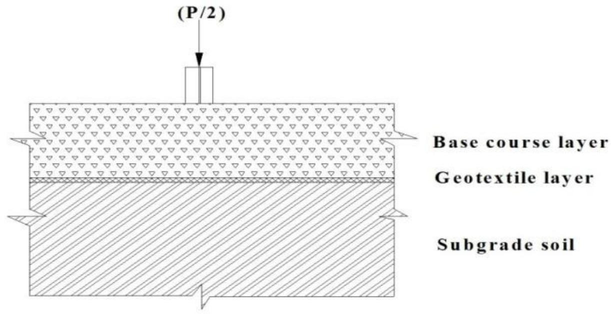


Figure 1: Cross section of the two layered road system

IV. METHODOLOGY

This study is aimed at providing a design procedure based on simple laboratory evaluation of equivalent California Bearing Ratio (CBR) of the composite layered system namely, the Geotextile sandwiched between the base course material and the soft subgrade soil.

Various parametric studies are also carried out to study the behavior of the two layered.
**Geotextile reinforced soft soil subgrade *Base course* system.

CBR tests have been undertaken primarily with the view to study the effect of certain key parameters in the behavior of the reinforced soil subgrade system. The following are the parameters:
*Height of subgrade soil in standard CBR mould
*Height of subgrade soil in modified CBR mould
*Diameter of the reinforcement in the modified CBR mould

***MATERIALS USED**

1. Subgrade Soil

*For the research work locally available clayey soil is used.

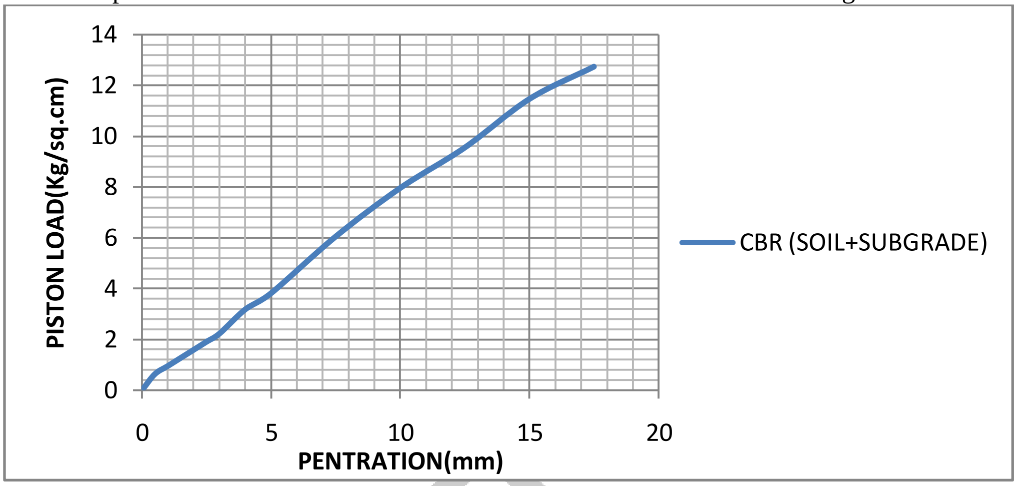
Table 1: Properties of the clayey soil

Sl No	Parameter	Value
1	Plasticity Index	25.91%
2	Liquid Limit IS:2720 (Part 5)-1985	56.50%
3	Plastic Limit IS:2720 (Part 5)-1985	30.59%
4	Maximum dry density (kN/m^3) IS:2720 (Part 7)-1980	16.50%
5	Optimum moisture content IS:2720 (Part 7)-1980	25.30%

***CBR value of the Soil Subgrade** (Without Geotextile)

Result CBR Value for 2.5mm = (2.00/70) x 100 = **2.857%**

Graph 1: Piston load vs Penetration to determine the CBR value without geotextile



2. Base Course Layer

*Primarily have to bear the stresses occurring on the roads.
*Resist wear due to abrasive action of traffic.
*Basic strength of base course comes from good interlocking and compactness, which depends on gradation.
*Consists of crushed stone passing through 10 mm

3. *Reinforcement*

a) Geotextile is used in this study (discarded cement bags)

Table 2: Properties of the Geotextile

SL No.	Type of Geotextile	Thickness (mm)	Mass/Area (g/m^2)	Stiffness (g-mm)	Secant Modulus (K) (kN/m)	Ultimate Tensile Strength (kN/m)
1	Woven Geotextile	0.275	200	17.695	62.4	6.24

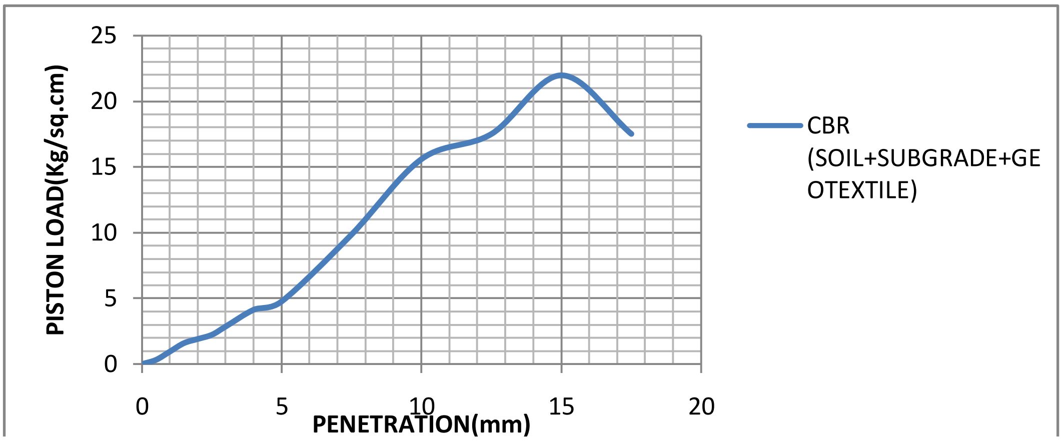
Table 3: Properties of the Subgrade soil

Sl No	Parameter	Value
1	Specific Gravity	2.22
2	Liquid Limit (%)	56.50
3	Plastic Limit (%)	30.59
4	Plasticity Index	25.91
5	CBR (%)	1.571
6	Optimum moisture content (%)	25.30
7	Maximum dry density (kN/m^3)	16.50
8	Shear strength (kN/m^3)	44.824

***CBR value of Composite Layer (Soil Subgrade + Base Course) (**With Geotextile)

Result CBR value for 2.5mm = (2.3/70) x100 =3.28%

Graph 2: Piston load vs Penetration to determine the CBR value with geotextile



V. DESIGN METHODS - U.S. ARMY CORPS OF ENGINEERS MODIFIED CBR

It's possible to arrive at a *Reinforcement Ratio* provided by the geotextile. Using a CBR mould that has been modified to hold a geotextile at the interface between the soil subgrade and the crushed stone, repeat the test with the geotextile in position and record the data.

Using U.S. Army Corps of Engineers Modified CBR Design Methods formula, with CBR < 2%

$$\mathbf{t = [3.24 \log C + 2.21] \times [P_1 / 36.CBR' - A_c / 2030]^{1/2}}$$

Where

CBR of subgrade soil =**1.57%**

t= the design thickness,

C= the traffic in terms of coverage=**7500 MSA**

P_1= the equivalent single-wheel load=**80 kN**

A_c= the tire contact area

P_c= Tyre inflation pressure=620kpa=$\mathbf{620x10^3\ N/m^2}$

A_c=P/4Pc= $(80x10^3)/[4x(620x10^3)]\ N/m^2$ = $\mathbf{0.0322\ m^2}$

CBR'= CBR of subgrade soil * Reinforcement ratio

Reinforcement Ratio

For 2 layers geotextile = 3.28/2.85=**1.15**

h= $[3.24.\log (7500) + \{[(80x10^3) / (36xCBR')]*[0.0322/2030]\}^{1/2}$

*Thickness of base course for subgrade soil, whose CBR=1.57

h_0' = $[3.24.\log (7500) + 2.21] \times \{[(80x10^3) / (36x1.57)] - [0.0322/2030]\}^{1/2}$ **= 555.27mm.**

*Thickness of base course for same subgrade soil, with geotextile reinforcement

h'= $[3.24.\log (7500) + 2.21] x\{[(80x10^3) / (36x1.57x1.15)] - [0.0322/2030]\}^{1/2}$ **= 517.82mm.**

*The savings in base course (Δh) afforded by using a geotextile

$\Delta h = h_0' - h'$= 555.27-517.82 **= 37.45mm.**

Pavement cross section is valid in this case since the subgrade CBR < 2.The combination of different materials is chosen to maximum durability and economy on the pavement. Thus, the total reduction in thickness of base course layer is equally distributed in WBM Grade 2, WBM Grade I and Sub base, to obtain the benefit of durability and economy.

Table 4: Total reduction in base course layers

Parameter	Without Geotextile	With Geotextile	Reduction (mm)
W.B.M Grade 2	75	69.09	5.91
W.B.M Grade 1	100	92.12	7.88
Sub Base	300	276.35	23.65
Total reduction in thickness of base course, using geotextile			**37.44**

VI. CONCLUSIONS

Based on the results obtained from the present experimental investigations, the following conclusions can be made regarding geotextile reinforced road subgrade.

*The proposed design methodology involving US Army Corps Method can be adopted to consider the effect of traffic passes in the same manner as recommended by Sikdar (2001).
*The prohibitive cost of commercially available geotextile in India can be overcome by the extensive use of discarded and used cement bag fabrics.
*The discarded cement bags can be joined together either by stitching or by thermal bonding and the same can be used as an alternative component instead of commercially available Geotextile.
*The thickness of the base course layer can be reduced when a geosynthetic reinforcement layer is included between the soft subgrade soil and the base course layer.
*This project has come out with the idea of productive use of discarded and used cement bag fabrics as a geotextile in the construction of rural roads.
*The properties of the cement bag fabrics for the efficient use in the construction of rural roads have been explored and are found to be suitable.
*The above mentioned project will indirectly help in bringing down environmental pollution caused by indiscriminate disposal of plastic wastes, particularly discarded and used cement bags.
*The implementation of this project will be giving a big boost to the construction of rural roads and consequent increase in the volume of rural employment.
*The reduction in the base course thickness results in substantial savings in the total cost of the project.

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