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Stabilization of Soft Subgrade Soil with Non-Woven Coir Geotextiles

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Abstract
In this work, the possibility of using non woven coir geotextile in soft subgrade soil was investigated. Flexible pavement have mostly problems like formation of potholes, ruts, cracks and localized depression and settlement. These are mainly due to insufficient bearing capacity of the subgrade. In the CBR method of pavement design (IRC 37-2001), total thickness of pavement increases with decrease in the CBR value of subgrade soil, which in turn increases the cost of construction. To achieve the economy and for proper performance of roads, it is necessary to improve the strength of the soil. In this study, needle punched non-woven coir geotextile material and adhesive bonded non –woven coir geotextile of varying densities were utilized to improve the bearing capacity of subgrade. CBR tests were conducted on soil samples with coir geotextiles of varying densities being interfaced between soft subgrade and unbound aggregate. In order to evaluate the performance, the reinforcement ratio was obtained based on the CBR load- penetration relation of both soft subgrade-gravel and soft subgrade-geotextile-gravel. Comparison of reinforcement ratio showed that the performance of pavement was improved with inclusion of non-woven coir geotextiles.

1. INTRODUCTION

Development of roads is important as it provides access to various places of the country for improvement. Problems in road arises when laid on soft subgrade because of large deformations [2-4], however it may not be a viable option when it comes for low volume roads. In such situation, there is a possibility of utilizing the natural geotextiles instead of geosynthetics, as an economic alternate to overcome the problem.

The coir is a naturally occurring fiber derived from the husk of coconut fruit. It is abundantly available at low cost in India. A large number of coir products are manufactured for various geotechnical applications in the form of grids, textiles, and mats. These applications include filtration and drainage application, reinforcement, erosion control, etc. These products were found to last for as long as four to six years within the soil environment depending on the physical and chemical properties of the soil.[8] When it is used as reinforcement, the coir layers can share the load with soil until its degradation thus increasing the load bearing capacity of the subgrades. The strength of subgrade soil increases in course of time as the soil undergoes consolidation induced by the traffic loads[5-6]. For such applications, where the strength of subgrade increases with elapsed time, the natural reinforcement products are extremely suitable. The application of natural woven coir geotextiles for unpaved roads on soft subgrade performs satisfactorily [9]. The use of blended geotextiles shows an increase in the CBR value as well as gives an even surface without significant marks of subsidence or rutting [1].

2. EXPERIMENTAL PROGRAM

2.1 Materials

Soil

Soil sample obtained from Peelamedu area, Coimbatore is used in the present experimental investigations. The properties of the soil sample are shown in the following table:

Table-1 Properties of sub grade soil

Particulars	Soil
Specific gravity, G	2.69
Liquid limit, w_L (%)	46
Plastic limit, w_P (%)	19
Plasticity index, I_P (%)	27
BIS classification	CI
Optimum moisture content (%)	17
Maximum dry density (g/cm^3)	1.551
California Bearing Ratio (%)	1.4

Aggregate

The gravel aggregate used for the study is subjected to sieve analysis as per IS. The uniformity co-efficient and co-efficient of curvature of the aggregate is 5 and 1.25 respectively. Hence, the aggregate used in the study is classified as well graded gravel (GW).

Geotextile Material

Needle punched non-woven geotextile and adhesive bonded (latex 10%) non-woven geotextile produced from coir fibers are used in this study. The properties of the material are given below:

Table-2 Properties of geotextile material

Sample	Mass per unit area (g/sq.m)	Tensile strength (KN/m)	Thick-ness at 2kpa (mm)	Type of geotextile
A	-	-	-	-
B	600	16.12	8.1	Non-woven adhesive bonded semi needle punched coir geotextile
C	900	21.02	8.4	
D	1000	27.22	8.3	
E	1200	32.03	8.52	
F	700	15.85	8.1	Non-woven needle punched coir geotextile
G	1000	22.32	8.2	
H	1400	30.33	8.4	

Test procedure

The general test procedure for CBR test as described in IS: 2720 – Part 16 was adopted for all the tests. The test was done on CBR mould of diameter 150mm and height 125mm above which collar of diameter 150mm and height 50mm was attached. The overall height of the mould is 175mm. the soft clayey soil was used as subgrade soil and was compacted to the height of 125mm to its optimum moisture content obtained from light compaction test (as per IS: 2270 - Part 7). Well graded gravel was taken as base course for the height of 50mm and was well compacted as shown in the figure 1. The load on the piston is applied in such a way that the penetration rate is about 1.25mm/min. CBR tests were carried out with 50mm plunger on soil-aggregate sample and on all soil-geotextile-aggregate sample systems.

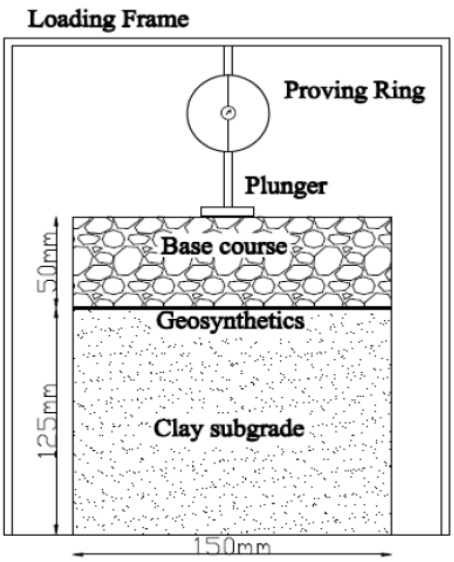

Figure 1. Schematic arrangement of test sample in CBR mould

3. RESULTS AND DISCUSSIONS

The result of various samples obtained from the test is plotted as load versus penetration. The variation of load versus penetration curve of various samples is shown in the following figure:

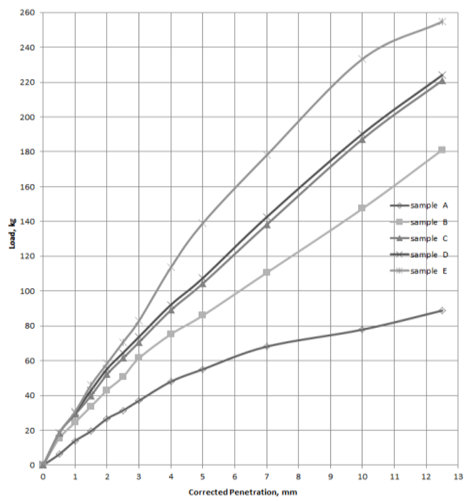

Figure 2. Variation of load-penetration curve of soil-adhesive bonded geotextile-aggregate samples

From the load-penetration curve of figure 2 and 3, it is clearly observed that there is an increase in resistance to penetration, when both adhesive bonded semi needle punched as well as needle punched interfaced between soft subgrade and base aggregate.

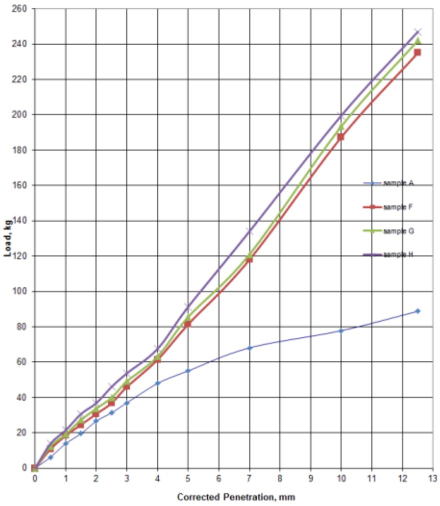

Figure 3. Variation of load-penetration curve of soil-needle punched geotextile-aggregate samples

Further in order to quantify the amount of increase in resistance to penetration, the reinforcement ratio is taken into consideration. The reinforcement ratio at a particular penetration[7] is given by

$$Reinforcement\ ratio = \frac{Load\ with\ geotextile}{Load\ without\ geotextile}$$

$$\begin{pmatrix}\text{Enhanced}\\ \text{CBR}\end{pmatrix} = \begin{pmatrix}\text{Reinforcement}\\ \text{Ratio}\end{pmatrix} \times \begin{pmatrix}\text{Subgrade}\\ \text{CBR}\end{pmatrix}$$

Table 3 shows that reinforcement ratio is more than one throughout the test, which indicates that the introduction of geotextile offers good resistance to penetration. Hence, the use of geotextiles in a road with soft subgrade is more advantageous.

Table-3 Enhanced CBR value of reinforced soil samples

Sample	Reinforcement ratio	Enhanced CBR
B	1.59	2.2
C	1.90	2.6
D	2.03	2.85
E	2.25	3.15
F	1.40	1.96
G	1.45	2.03
H	1.56	2.18

3.1 Design of pavement

IRC 37-2001 has recommended to use the pavement thickness design chart for traffic 1-150 msa based on the CBR value of subgrade soil. Knowing the CBR value of subgrade soil, pavement thickness can be determined from the design chart published.

Thus for designing flexible pavement for soil reinforced with coir geotextile by IRC method, CBR of subgrade soil may be considered to be CBR of subgrade soil obtained after coir geotextile interface.

Design example:

Single lane carriageway width: 3.65m

Traffic in the year 2015 : 120CV /day (in both directions)

Expected year of completion of the project: 2017

Traffic growth rate per annum: 7.5%

Design life: 10 years

Vehicle damage factor: 1.5

As per IRC 37-2001,

Number of commercial vehicles A = P $(1+r)^x$

A = $120(1+0.075)^2$

A = 139

Cumulative no. of standard axles:

$$N = \frac{365[(1+r)^n - 1]}{r} * A * D * F$$

$$N = \frac{365[(1+0.075)^{10} - 1]}{0.075} * 139 * 1 * 1.5$$

N = 1msa

From the design chart, the total pavement thickness is obtained as follows:

Table-4 Total pavement thickness required and approximate cost per m length of road

Sample	Total pavement thickness required (mm)	Total cost per m length (Rs.)
A	810	3636.75
B (600 GSM)	660	3514.75
C (900 GSM)	615	3386.35
D (1000 GSM)	550	3152.36
E (1200 GSM)	550	3199.81
F (700 GSM)	660	3514.75
G (1000 GSM)	660	3591.4
H (1400 GSM)	660	3620.6

*Total cost includes cost of geotextile material and rates of various road materials are taken fromDelhi schedule of Rates 2014,CPWD.

4. CONCLUSION

From the CBR test results, it is observed that the load carrying capacity of the pavement section increases on inclusion of both adhesive bonded and needle punched non-woven geotextile material of varying densities. For adhesive bonded semi needle punched non-woven geotextiles, the percentage increase in the CBR value is upto 115%. Similarly, for needle punched non-woven geotextile, increase is about 56%. This is because of stiffness of adhesive bonded geotextile material is high. Even though there is no much difference in CBR value if density of geotextile varies, CBR value increases as density of material increases.

From the design aspects, it is observed that the thickness of pavement is reduced by 32% on inclusion of 1000 gsm and 1200gsm adhesive bonded non-woven coir geotextile.

From the cost analysis, it is observed that percentage cost reduction is upto 13% for soil-aggregate sample interfaced with 1000 gsm adhesive bonded non-woven coir geotextile.

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