

Improvement in Soil Subgrade Reinforced with Natural Fibers



Engineering

KEYWORDS : soil; subgrade; coir fiber; jute fiber ; sisal fiber; bamboo fiber; compaction; california bearing ratio; unconfined compressive strength;

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ABSTRACT

important factor in the design and construction of pavement is the behavior of underlying subgrade. Large deformations in the subgrade will lead to a continuous deterioration of the paved surface, as the subgrade soil is too weak to bear the load. Engineering solutions such as geo reinforcement using geo-synthetics and additives are earlier studied and such solutions are not eco-friendly. This paper deals with the effectiveness of solutions using Natural fibers (Coir, Jute, Bamboo & Sisal) for strengthening the subgrade and for designing the pavement. In this study, Proctor's compaction tests, UCS tests and CBR tests are conducted on locally available soil reinforced with natural fibers. The soil identified for this study has a CBR value of only 1.5%. The behavior of this soil with the addition of natural fiber is studied. A series of laboratory soaked and un-soaked CBR tests are conducted on randomly oriented natural fiber reinforced and un-reinforced soil specimens compacted at OMC and MDD. Test results indicate that Unsoaked and Soaked CBR value of soil increases with increase in fiber content. It is also observed that increase in CBR value of reinforced soil is substantial at fiber content of 1 % for coir fiber and at 0.75% for jute and sisal fiber and at 1.25% for bamboo fiber. The significant increase in CBR value of soil due to natural fiber reinforcement will thus substantially reduce the thickness of pavement subgrade

INTRODUCTION

Availability of good subgrade soil is of primary concern in the design and construction of highway projects. Indian Roads Congress (IRC: 37-2001) specifies that the subgrade soil should have a California Bearing Ratio (CBR) of minimum two per cent. Also, where the California Bearing Ratio of the subgrade is less than two per cent, a capping layer of 150mm thickness of material with a minimum CBR of ten per cent shall be provided in addition to the sub base layer.

Ground improvement is a general term used for the modification of soil to enhance the strength and other engineering properties. One of the methods, which got momentum in recent years, is the concept

of reinforced soil. The modern concept of reinforced soil was however coined by Henri Vidal in 1963.

Reinforced soils can be obtained either by providing continuous reinforcement within a soil mass in a defined pattern or by mixing discrete fibers randomly with a soil fill. Randomly distributed fiber-reinforced soils have recently attracted increasing attention in geotechnical engineering.

The availability and low cost of natural fiber, make it an eco-friendly material, which suits geotechnical applications. A number of published works are available which deal with different types of geosynthetics being used for separation, filtration, reinforcement, etc. But the data related to natural fibers is only very limited. Hence there is a need for conducting studies to exploit the potential use of natural fibers as a highway construction material.

In this project Coir, Jute, Bamboo and Sisal fibers are used as reinforcing material, in subgrade of flexible pavement system. Any pavement design is based on the properties of the subgrade. The main parameter in the analysis of subgrade is evaluation of California Bearing Ratio. Soil is analysed for its various physical, engineering and strength properties. Proctor's compaction tests, UCC tests and CBR tests. Soil reinforced with various percentages of natural fibers is analysed to study the improvement in various properties. The results obtained are compared. The design of pavement with and without natural fiber reinforcement is done to compare the reduction in thickness of pavement.

MATERIAL

SOIL

In this work, a location on Kalapatti Road, Coimbatore is selected and the soil samples from this location is analysed for its various physical, engineering and strength properties. The properties of soil is shown in the following table

**TABLE 1
PROPERTIES OF SOIL**

Properties	Results
Specific Gravity	2.75
Percentage of Gravel	0.3%
Percentage of Sand	17.7%
Percentage of Silt	22.1%
Percentage of Clay	59.9%
Soil Classification	CH
Optimum Moisture Content	24.9%
Maximum Dry Density	1.495 g/cc
Unconfined Compressive Strength	0.132N/mm ²
Cohesion	0.066N/mm ²
CBR (Unsoaked Condition, 2.5 mm penetration)	5.4%
CBR (Soaked Condition, 2.5 mm penetration)	1.5%
CBR (Unsoaked Condition, 5 mm penetration)	4.4%
CBR (Soaked Condition, 5 mm penetration)	1.2%

NATURAL FIBERS

Coir fibers are procured from Thuran Mills, Pollachi near Coimbatore. Diameter is in the range of 0.1- 1.5mm. The coir is cut into pieces of length 1.5cm to 2cm. Jute fiber is procured from Shri nandini pvt.ltd, Tiruppur. These fibers are generally available in the threaded form. Diameter is 1mm. In order to protect them from microbial attack & degradation Bitumen is used for coating the jute fiber. Then the threads are further cut in the small pieces of length equal to 2 cm. Bamboo and Sisal fibers are purchased from local market. Diameter is 0.5mm and cut into pieces of length 1.5cm.

EXPERIMENTAL PROGRAM

GENERAL

The experimental study involves Standard Proctor's Compac-

tion tests, Unconfined Compressive Strength test, and California Bearing Ratio tests on unreinforced and reinforced soil with varying percentage of natural fibers (0.25%, 0.5%, 0.75%, 1%, 1.25%, and 1.5%). All the tests are conducted with light energy of compaction.

STANDARD PROCTOR'S COMPACTION TEST Standard Proctor compaction test is done to assess the amount of compaction and water content required for the sample. The test is conducted as per IS 2720 (Part 7). The test provides relation between the dry density and the water content. The tests is conducted on soil with Coir, Bamboo and Sisal fibers to determine the optimum moisture content and maximum dry density of soil sample. The bitumen treated Jute fiber does not make any appreciable trend on the result of optimum moisture content and maximum dry density, so that the Proctor's compaction tests are done only for soil reinforced with Coir, Bamboo and Sisal fibers. The OMC obtained for different natural fiber mixes is given in the figure 1.

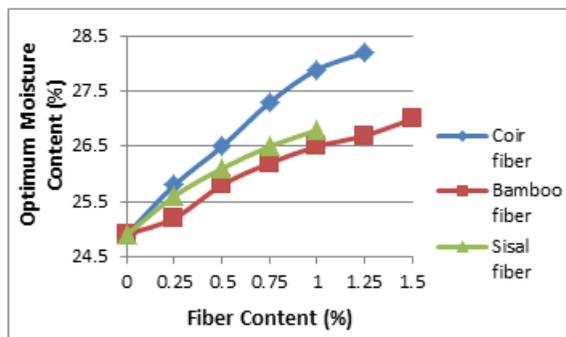


Fig. 1:OMC for different natural fiber mixes

UNCONFINED COMPRESSIVE STRENGTH TEST

The Unconfined Compressive Strength and Cohesion is obtained by conducting Unconfined Compressive Strength test. The test is conducted as per IS 2720(Part 10): 1991. The test is conducted on soil samples reinforced with natural fibers in order to determine the optimum fiber content. The UCS value for different natural fiber mixes is given in the fig 2.

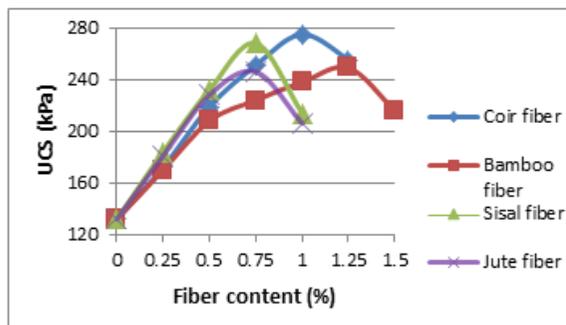


Fig. 2:UCS Test results for different natural fibers mixes

CALIFORNIA BEARING RATIO TEST

The CBR tests are conducted as per IS 2720(Part 16) -1987. The CBR test is conducted for both unsoaked and soaked condition. The test is conducted on soil samples reinforced with varying percentage of natural fibers in order to determine the optimum fiber content. The CBR value obtained as a result of both unsoaked and soaked CBR test is given in the following graphs.

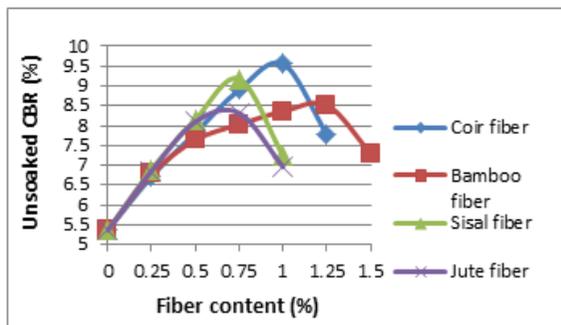


Fig. 3:Unsoaked CBR Test results for different natural fibers mixes

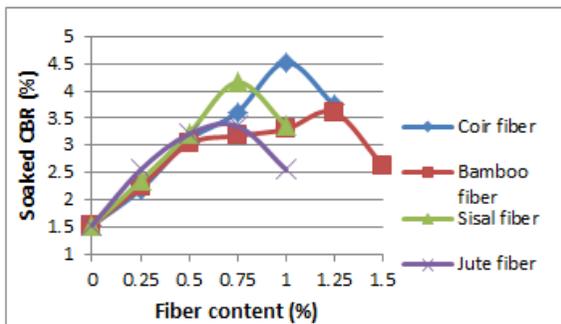


Fig. 4:Soaked CBR Test results for different natural fibers mixes

RESULTS AND DISCUSSION

It is clearly observed that both unsoaked and soaked CBR value of soil and UCS value increases as the natural fiber content increases. The optimum fiber content is obtained based on the results of CBR tests and UCC tests.

The optimum Coir fiber content and Bamboo fiber content that gives maximum value of CBR is obtained as 1% and 1.25 % respectively. The optimum Jute & Sisal fiber content that gives maximum value of CBR is obtained as 0.75 %.

The maximum increase in CBR value corresponding to the optimum natural fiber content is given in the table 2.

TABLE 2
COMPARATIVE RESULTS-CBR

Description	Maximum Percentage improvement in CBR (%)
Coir reinforced subgrade	196.1
Jute reinforced subgrade	119.6
Bambooreinforced subgrade	135.9
Sisal reinforced subgrade	171.9

DESIGN OF PAVEMENT

INPUT DATA:

- i) Two-lane single carriageway
- ii) Traffic growth rate per annum =7.5%
- iii) Design life =15 yrs
- iv) Vehicle damage factor =3.5
- v) Distribution factor (from IRC code para 3.3.5) =0.5
- vi) Initial traffic at the year of construction =1200 CV/day
- vii) CBR value of unreinforced subgrade =1.5%
- viii) CBR value of optimum content of Coir reinforced subgrade =4.53%
- xi) CBR value of optimum content of Jute reinforced subgrade =3.4%
- xii) CBR value of optimum content of Bamboo reinforced sub-

grade =3.6%

xiii) CBR value of optimum content of Sisal reinforced subgrade =4.16%

DESIGN CALCULATION:

Cumulative number of standard axles to be catered for design

$$365 \{ (1+r)^n - 1 \} \times D \times A \times F$$

N =

R

N = Cumulative number of standard axles to be catered for in design in terms of million standard axles – msa

A = Initial traffic,

D = Lane distribution factor ,

F = Vehicle damage factor,

n = Design life in years,

r = Annual growth rate of commercial vehicles

For CBR value 1.53% and N=25 msa

- Referring IRC: 37-2001 Thickness of the pavement required = 890 mm
- For Coir fiber reinforced subgrade Total pavement thickness for design CBR = 719 mm
- For Jute fiber reinforced subgrade, Total pavement thickness for design CBR = 776 mm
- For Bamboofiber reinforced subgrade Total pavement thickness for design CBR = 764 mm
- For Sisalfiber reinforced subgrade Total pavement thickness for design CBR = 734 mm

CONCLUSIONS

This paper investigates the effect of introducing four different types of natural fibers as solutions to strengthen the weak subgrade. Based on the laboratory tests, experimental studies and pavement design carried out in the above study the following conclusions are drawn.

Subgrade soil used in this test is classified as clay of high plasticity. The CBR value of soil collected is very less and it provides an opportunity to be improved.

The increment in CBR is due to reason that randomly distributed fiber incorporated into soil mass improves its load deformation behaviour by interacting with the soil particles mechanically through surface friction and also by interlocking.

The strength and stiffness of reinforced soil increases with the increase in fiber content and may be due to this reason also the

CBR value of reinforced soil was observed to be greater than that of unreinforced soil

The optimum Coir and Bamboo fiber content is 1% and 1.25% respectively. The optimum Jute and Sisal fiber content is 0.75%, based on CBR and UCS test.

It is concluded that there is a considerable reduction in the thickness of pavement for natural fiber reinforced subgrade compared to unreinforced subgrade.

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