PERFORMANCE EVALUATION ON CBR VALUES OF SOFT SOIL USING COIR AND BAMBOO FOR FLEXIBLE PAVEMENT

[1]Varsha Sahu, [2]Anil Suman

[1]M Tech Student, [2]Assistant Professor,
[1]Civil Department,
[1]SSGI- Faculty of Engineering & Technology, Bhilai, CG, India.

Abstract: India's growing economy needs extension of existing roads, new road routes and rural road developments. Flexible pavement is one of the most widely used highways all over the country. The properties of soil affect the stability and durability of the pavement. Now a days, various kinds of geotextiles are using as a successful application in soil stabilization for improving the subgrade soil properties. The application of geotextiles in structural facilities is mainly concentrated on the raising the strength of structure and also does not address the issue of sustainability of raw materials used. In India, for evaluating the stability of the soil subgrade CBR test is recommended as per IRC 37-2001 design code in designing the flexible pavements. In this work, natural geotextiles i.e. coir and bamboos are interfaced with soft subgrade from two different locations, to evaluate the performance of CBR values. Non-woven Coir and bamboos are interfaced individually at 75% depth from base and also in composite way. Comparison was done for different arrangements of natural geotextiles in subgrade sample. CBR value increases with increase in addition of geotextiles i.e., its value is higher for soil having composite geotextile (soil with non-woven coir + square arrangement of bamboo). It is economical as it can reduce the cost of construction as it reduces the total thickness of the pavement.

***IndexTerms* - Subgrade soil, Soil stabilization, Natural geotextiles, Coir geotextile, Bamboo, CBR.**

I. INTRODUCTION

Bituminous surfaced pavements are most widely used highways in the world. These are constructed in different layers such as base course, binder course and surface course. These layers are constructed by different materials having different functions. Use of bitumen in flexible pavement is advantageous because of its economical production, versatile nature, low melting point and adhesive nature. But these pavements are less durable and have low tensile strength compared to concrete pavement. The existing soil at a construction site is not always suitable for bearing structures so soil stabilization in road construction is thus a common practice in their construction to make the roads more durable and capable of carrying certain traffic loads. So to improve the bearing strength of road either we have to improve the bearing capacity of soil or can increase the thickness of pavement

1.1 ***Flexible pavement***:

A flexible pavement structure consists of series of layers of materials. Bituminous surface course supported over base course and sub-base course. The design of flexible pavement consists of many parameters such as subgrade properties, type of wheel load, traffic intensities, types of terrain and climatic conditions.
The subgrade layer is responsible for distributing the load from top layers to the bottom hence the stability of pavement is greatly influenced by the subgrade strength. Generally they are designed for a period of 15years. For testing subgrade, California Bearing Ratio (CBR) test should be determined as per the IRC: 37-2012(Guidelines for the design of flexible pavement) for Expressways, National Highways, State Highways, Major District Roads and other heavily traffic roads.

1.2 ***Subgrade Soil***:

"Subgrade" is made up of in-situ material and usually in the forms of foundation of pavement on which the pavement structure is supported. Thickness and performance of the pavement widely depends on the subgrade soil strength.

1.3 ***Natural geotextiles***:

Recently various researches have been made for soil reinforcement/ stabilization by using natural geotextiles because of more susceptibility in both technical and economical aspects than the geosynthetics. There are various applications of geotextiles other than the soil stabilization such as erosion control, separation, filtration, drainage etc. Coir, jute, flax, bamboo, sisal, palm leaves are important natural fibres used as geotextiles.

Benefits of natural geotextiles are:-

- Inexpensive, ecofriendly, biodegradable, easily available
- Preservation of load-bearing capacity
- Long lasting separation of the base and sub grade material.
- Ability to extend the life of paved roads

The use of natural coconut fiber has grown rapidly over the past decade due to its 100% biodegrability, effectiveness and non-invasive design. The husk around the coconut seed (Cocosnucifera) is source for extracting coir and is abundantly available in coastal regions of India.

Advantages of coir fibre-

- Problem of erosion can be managed by woven coir geotextiles.
- Resist the moisture absorption and suns radiations.
- Durable, biodegradable and facilitate seed germination.
- Provide good soil support.
- Develops organic manure which is applicable for agricultural crops.

Bamboo is traditionally used as a green building material and easily available in India. It is a 'grass' that is hard, woody, hollowed stem, perennial. It is rapidly grown plant, renewable and biodegradable. Several uses of bamboo are in construction , as food, geotextile, medicine etc. bamboo culm is like a composite material reinforced by cellulose fibres and lignin matrix axially. Bamboo can be used as an alternative to steel as masonry reinforcement because of the proven mechanical properties which gives it high performance, as well as the availability which makes it low cost material

1.4 ***Soil stabilization***:

such as red soil, laterite soil, expansive soil, alluvial soil, laterite deposits, sand dunes, boulders, etc. Out of which expansive soil is one of the problematic soil as per the construction purpose because their stablization is very poor with settlement problem. Behavior of expansive soil is much different as compare to the other soils. And this is just because of its swelling and shrinkage property when it comes in contact with water. Following problems may cause in such type of soil-

- Due to pressure on vertical walls lateral movements may cause on foundations and retaining walls.
- Differential settlement caused in building structures.
- Some failures may occur due to poor stability of soil on roads such as cracks, mud pumping, upheaval and many more on road surface.
- Instability of slopes due to loss of residual shear strength.

What is soil stabilization?

For the above problems soil stabilization is most common method to improve the stability of soil. It is defined as "physical or chemical treatments which are provided to improve or strengthen the stability of soil". Generally soil stabilization is common process used for road construction. Various ground improvement techniques are now available for this purpose such as physical, mechanical, chemical and combined stabilization; for which it is very need to understand the properties of soil.

Geosynthetics?

Geosynthetics are products used to improve the ground stabilization which includes geotextiles, geogrids, geomembranes, geo cells, geonets and geocomposites. By considering the environmental issues nowadays, natural geotextiles are best option to improve the engineering properties of soil. Coir, jute, bamboo, sisal etc are some natural products which can be used as natural geotextiles .

Needs and advantages of soil stabilisation-

- Consumption quarry aggregate may be reduced.
- Construction cost may get reduced.
- Reduce maintenance and repairing work of structures
- Construction time get speed up.

II. Literature Review

Anwar Khatib Aminaton Marto, and Mohd Zain Hj. Yusuf (2005) investigated on the behavior of strip footings resting on sand layer and bamboo-geotextile composite reinforced soft clay. The bamboo-geotextile composite is a method whereby the bamboo is first laid on soft clay and geotextile is then laid on top of the bamboo.They concluded that bamboo arranged in square pattern gives better improvement of bearing capacity than the parallel pattern. Bamboo-geotextile composite could be used as another alternative method in improving the bearing capacity of soft clay.

By using H2M9 type of geotextile **Kundan Meshram, S.K. Mittal, P.K. Jain and P.K. Agarwal (2013)** suggested the possible replacement of CGT in rural roads and studied three cases. Case I represents the CGT placed over subgrade between sand layer of 50mm and layer of selected soil is 300mm. 2nd case represents CGT placed over approved subgrade (i.e., subgrade having CBR 3 to 4%) and a sand layer of 25mm over CGT and the Case III shows, subgrade made with layer of approved soil of 350mm, select soil of 200mm and design CBR will take 5%. Finally they concluded that with the incorporation of coir geotextile below granular subbase layer would be helpful in restricting the movement of upper pavement layers due to seasonal moisture variation in subgrade expansive and shrinkable soil.

Dr M. Joseph and Dr Sheela Evangeline (2015) have done laboratory and field study by using coirgeotextiles with soft subgrade and observed that in CBR test there is an increase in resistance to penetration, when the woven and nonwoven geotextile interfaced between soft subgrade and base aggregate. By visual examination the coir geotextiles reinforced roads are better in performance compared to unreinforced roads. It was observed that a percentage increase of 122% was seen when two layers of coir geotextile was placed at top and half the depth from top of the subgrade.

K S Beena (2016) surveys the improvement in the quality of unpaved roads constructed on silty soils using coir geotextile reinforcement through a number of model tests by performing plate load test and CBR. The result shows that the CBR value of the soil reinforced with coir has upgraded placed at mid depth and also non woven coir shows superior result than the woven coir.

Maisa.Rathnam, Kasireddy and Prathap Reddy (2016) studied on various applications of coir and jute geotextiles in construction of roads on black cotton soil in various establishments for instance, a separator in a streets where the geotextile will be subjected to extreme burdens, toughness is of concern. Permeability ought to likewise dependably be considered in division uses to permit dampness to move uninhibitedly through the framework. This keeps away from inordinate hydrostatic weights which cause soil disappointment.

Mr. S. R Yashas, Mr. S. N Harish and Prof. H. R Muralidhara (2016) determined in their experimental study the effect of CBR value with the various properties of soil by taking 15 soil samples from a road link at every 100m of interval for a distance of 1.5km. They got the relationships between CBR value and various fundamental properties of soil in order to determine which soil property has less or more influence by using mathematical concepts of linear regression, power series and linear series as the value of specific gravity, field density and dry density increases the corresponding soaked value of CBR also increases. As the optimum moisture content, liquid limit, cohesion, internal angle of friction decreases corresponding soaked CBR value increases.

M. Mohamed Ashik (2017) interfaced the soil aggregate sample with 1000Gsm adhesive bonded non-woven coir geotextile and evaluated the performance of pavement by determining the reinforcement ratio. Even though there is no much difference in CBR value if density of geotextile varies CBR value increases as density of material increases.
He also concludes that cost reduction was upto 13%, thickness of pavement got reduced by 32% and the percentage increase in the CBR value is upto 115%.

M. Aroja, K. Nagraj, P. Prashant and S. Rajeshwari (2017) studied in their experiment that the CBR value of soil alone was found to be 4.28%. After addition of 0.25%, 0.5%, 0.75% and 1.0% bamboo fibres by weight of soil is found to 27.74%, 29.20%, 27.74% and 44.77% respectively. i.e., found to be increased. The design thickness of pavement before stabilization is obtained as 450mm and after stabilization obtained as 250mm. The cost of construction is reduced from 4018050Rs/Km to 3721894 Rs/Km.

Vaseem Ahmad Shahnaz and Ameer Ullah Ganai (2019) presents on their paper that the inclusion of coir fibres in clayey soil at different percentages and at varying length increases the unconfined compressive and shear strength characteristics of soil by carrying the Unconfined Compressive and Shear Strength tests. They studied that the increase in percentage and length of the coir fibre can increase the Unconfined Compressive Strength from 2.63 N/cm2(for plain soils) to 7.66 N/cm2 (for reinforced soil) while Shear Strength increased from 2.68N/cm2 (for plain soil) to 75.568 N/cm2(for reinforced soil). Hence the coir layers can share the load with soil until its degradation thus also increasing the load bearing capacity of the subgrades.In this experimental study coir geotextile and bamboo will be used together in different patterns to get the desirable arrangement of them to stabilize the soil subgrade for construction of flexible

III. METHODOLOGY

✓ ***MATERIALS USED:***

- Soil sample was collected from Talpuri Utai Road. Bhilai, which was soft soil having low value of CBR.
- Non-woven coir sheet having thickness of about half inch.
- Bamboo sticks of half inch diameter and lengths 14.5 cm and 10 cm.

✓ ***MATERIALS TESTING:***

- For soil: To determine the general properties of soil specified tests are done by using different parts of IS 2720 which are as under-
  Atterberg's Limit, Specific Gravity, Optimum Moisture Content and Maximum Dry Density etc.
- For coir: Density and Water Absorption determine was done by using parts of IS 15868.
- CBR Tests : IS 2720 PART 16 (1987) was used for determination of CBR value in both unsoaked and soaked (for 4 days) condition. Firstly CBR was done for soil alone. After that, some arrangements are done using geotextiles (Non-woven coir sheet and Bamboo). Individually coir and bamboo was firstly interfaced with soil at depth of about 75% depth from base. Bamboo was used in two ways – Parallel arrangement and Square arrangement. Another arrangement was coir and bamboos which are simultaneously interfaced with soil at $3/4^{th}$ depth from base which was again done in two ways- bamboo was placed in parallel way just above coir and in square arrangement above the coir as shown in figure below:

Fig 1: Coir + Bamboo (Parallel form)

Fig 2: Coir + Bamboo (Square form)

✓ ***DESIGN OF FLEXIBLE PAVEMENT***

Different design procedures are mentioned in code IRC: 37 out of which by using *design catalogues* pavement layers were design. This design catalogue is having five different combinations which are as follows-

a) Granular base and granular sub base
b) Cementitious base and sub base of aggregate
c) Cementitious base and subbase with SAMI at interface layers
d) Emulsion bitumen/ foamed bitumen treated fresh aggregate or RAP
e) Granular sub base and cementitious base with crack relief layer

Here by using first combination i.e., granular base and sub base having plate 1 to 8 for designing the thickness of pavement layers by using CBR and traffic loading in msa.

Traffic should be known for designing the layers of pavement in the cumulative no. of std axles (80 KN) which is to be carried during its life period. Following parameters are required for this:

a) Initial traffic on road after construction in terms of CVPD, A
b) Traffic growth rate in percentage, r
c) Design life in no. of years, n
d) VDF (vehicle damage factor), D
e) LDF (lane distribution factor), F

$$\text{Traffic (msa)}, N = \frac{365 \times [(1 + r)^n - 1]}{r} \times A \times D \times F$$

IV. Result

✓ ***PROPERTIES OF SOIL***

Table 4.1 Properties of soil

Properties	Soil Sample
OMC (%)	12.5
MDD (%)	1.35
Liquid Limit (%)	41
Plastic Limit	30.62
Plasticity Index	10.38
Shrinkage Limit (%)	14.5
Specific gravity	2.36
Colour	Black

✓ ***PROPERTIES OF COIR***

Table 2 Properties of non-woven coir

Properties	Coir Sample
Mass per Unit Area	803.4 gm/cm^2
Water Absorption	93.12 %

✓ ***CBR VALUE***

Penetration test

Calibration factor of the proving ring – 1 Div. = 1.176 Kg

Table 3 CBR value of soil with geotextiles

Soil Condition	Soil	Soil + Coir	Soil + Bamboo (P)	Soil + Bamboo (S)	Soil + Coir + Bamboo (P)	Soil + Coir + Bamboo (S)
Unsoaked	1.72 %	3.13 %	3.26 %	4.51 %	5.24 %	6.05 %
Soaked	1.2 %	2.23 %	2.45 %	3.69 %	4.46 %	5.11%

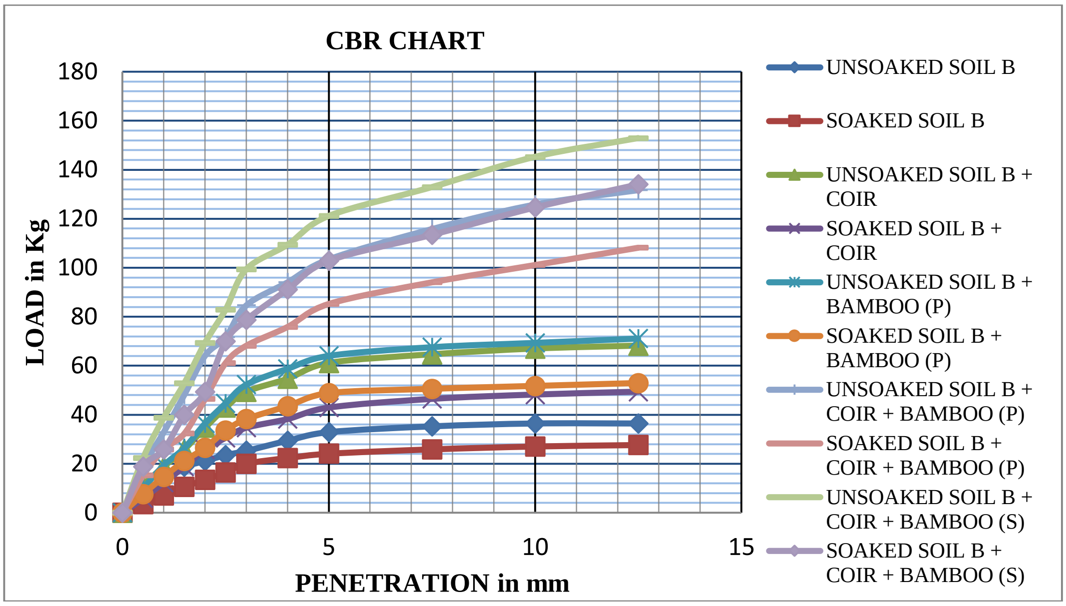


Fig 3: CBR chart for soil with different arrangements of geotextile

✓ ***DESIGN OF FLEXIBLE PAVEMENT***

For the given soil which is from Talpuri-Utai Road data provided as under-
CBR of stabilized soil sample = 6 %

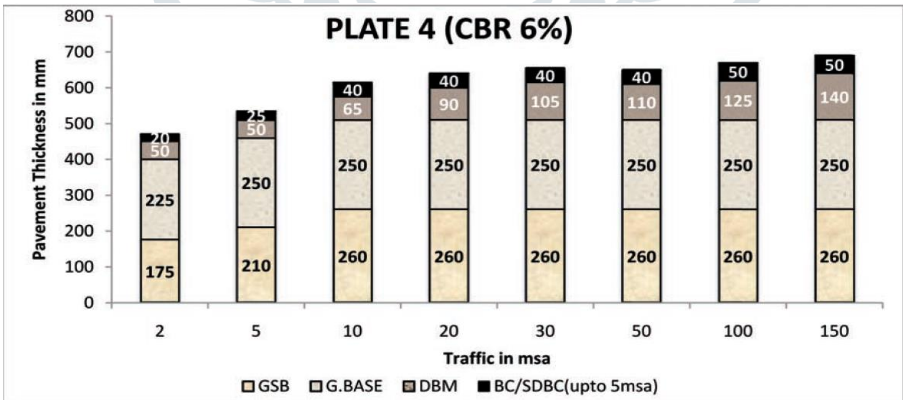
$$\text{Traffic in msa, } N = \frac{365 \times [(1 + r)^n - 1]}{r} \times A \times D \times F$$

Number of commercial vehicles in terms of CVPD, A = 500 CVPD (in both directions)
Traffic growth rate in percentage, r = 5 %
Design life in no. of years, n = 12 years
VDF (vehicle damage factor), D = 3.5
LDF (lane distribution factor), F = 0.50 (Design should be based on 50 % of CVPD for double lane)
Thus,

$$N = \frac{365 \times [(1 + 0.05)^{12} - 1]}{0.05} \times 500 \times 3.5 \times 0.50$$

N = 5110000
N = 5.1 msa ≈ 5 msa

Design Catalogue procedure is adopted here which is provided by IRC: 37-2012 with guidelines was used to design the flexible pavement.



Total thickness of pavement for 5 msa traffic is 535 mm.
Thickness of sub-base material layer = 210mm
Thickness of base material layer = 250mm
Thickness of bitumnous layer = DBM +BC = 50 +25 = 75mm

For unstabilised soil sample CBR = 1.7 %
Total thickness of pavement evaluated is 730 mm.

V. Conclusion

✓ EXPERIMENTAL STUDY

Following conclusions are figured out on the basis of experimental study done of the given soil samples.

- Black cotton soil is generally having low CBR value.
- CBR value gradually increases with the increase in addition of geotextiles.

- The CBR of the soil from alone is 1.72% and it is ascended to 6.05% when stabilized with both non woven coir and bamboo in square pattern.
- Total thickness of pavement decreases for stabilized soil as compared to unstabilized soil which is from 730mm to 535mm.
- Decrease in thickness of pavement may conclude to decrease in cost construction also.

✓ FUTURE SCOPE

Natural fibres are generally used as geotextiles which are available in various kinds such as coir, jute, sisal, bamboo etc. There are various applications of geotextiles other than the soil stabilization such as erosion control, separation, filtration, drainage etc.

- In some applications of geotechnical, level of protection to the natural product resists its decay.
- After degradation of natural geotextiles under subgrade soil it will be useful for us in the form of fossils which is now going to reduced after long years.
- Bamboo can be used as a possible alternative to steel as reinforcement because of the proven mechanical effects which gives it elevated performance as well as the availability which makes it low cost material.
- Thickness of flexible pavement get reduced as compared to unreinforced geotextile pavements and thus cost will also become economical.

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