# Performance Evaluation of Coir Geotextile for Stabilization of Subgrade and Subbase Soil in Rural Roads Construction

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*Abstract*— Considerable length of roads planned to be constructed in India under various programmes require construction over poor subgrade soils. The performance of a road largely depends on properties of the subgrade soil. One such subgrade soil often encountered is the black cotton (BC) soil. It is inorganic clay of medium to high compressibility, high shrinkage and swelling property, very hard when dry, but lose its strength completely when in wet condition. As a result of wetting and drying process, vertical movement takes place in the soil mass leading to failure of pavement, in the form of settlement, heavy depression, cracking and unevenness. In order to improve the performance of roads on such soils Coir textile has scope as reinforcement. It is expected that with the inclusion of coir geotextile layer below Granular Subbase (GSB) layer would be helpful in restricting the movement of upper pavement layers due to seasonal moisture variation in subgrade expansive, shrinkable soil. A pilot project plan for implementing the idea has been proposed in the paper.

***Keywords:*** Black Cotton (BC) soil, Coir Geotextile (CGT), Subgrade, Granular Subbase (GSB), Rural RoadS

## I. INTRODUCTION

The roads laid on BC soil bases develop undulations at the road surface due to loss of strength of the sub-grade through softening during monsoon. BC soil is a highly clayey soil and problem for highway engineers. In dry state it shrinks and becomes so hard that the clods cannot be easily pulverized for treatment for its use in road construction. However, when it is wet during rains, it swells as well as loses strength and poses serious problem with regard to subsequent performance of the road. All this results cracking in roads and for this is the reason that the road engineers do not prefer to construct roads on BC soil but have no option as black cotton soil is available in about one third part of the country, particularly in Madhya Pradesh. It is often impossible to build a stable base course over soft subgrade, without loosing expensive base material which penetrates into the soft sub grade soil and hence a ground improvement method has to be resorted to. There are many methods of ground improvement such as cement stabilization, lime stabilization, chemical stabilization etc. [Mathur et al 2012, Neeraja, D., 2010]. But these additives do not mix properly with soil. Geotextiles form one of the largest groups of geosynthetics. One of the most popular applications of Geotextiles is in the construction of pavements and embankments on soft soil. They are indeed textiles in the traditional sense, consisting mainly of synthetic fibers, though natural fibers are also used for manufacturing. They can be Woven or Non-woven type [Subaida et al 2009]. There are enormous specific application areas for geotextiles. Generally the fabric performs at least one of the four discrete functions viz., separation, reinforcement, filtration, drainage [IRC: SP: 59-2002]. The low cost of natural fibers, the growing concern over the impact of the use and disposal of synthetic materials has recently led to a renowned interest in the possible advantages of natural geotextiles [Ravi Shankar et al 2012]. Natural geotextiles made of coconut fiber, jute fiber; sisal, etc. can be used as an alternative to polymeric geosynthetic materials [Ling, Hoe I. and Liu, Zheng 2001]. Coir net is readymade material, cheap, easy laying in field and biodegradable. Coir geotextiles find application in a number of situations in geotechnical/ highway engineering practice. Coir geotextiles can be used as an overlay or interlay, the former protecting the surface from runoff and the latter performing the functions of separation, reinforcement, filtration and drainage.

## II. PROPERTIES OF COIR

1) Coir fiber: The components of natural fibres are cellulose, hemicellulose, lignin, pectin, waxes and water-soluble substances. The cellulose, hemicellulose and lignin are the basic components of natural fibres.
2) Cellulose: Cellulose is the basic structural component of all plant fibers.
3) Hemicellulose: Hemicellulose is made up of chains of sugars. They comprise a group of polysaccharides (excluding pectin) bonded together in relatively short, branching chains and remains associated with the cellulose after lignin has been removed.
4) Lignin: Lignin is the compound that gives rigidity to the fiber. Natural fibers could not attain rigidity without lignin. It is very high among all other natural fiber shown in Table 1.
5) Pectin: Pectin is the basic structural component of all plant fibers. The outer cell wall is porous and consists also of pectin and other non-structural carbohydrates. The pores of the outer skin are the prime diffusion paths of water through the material.

The principal chemical constituents of fibres from various plant fibres are shown in Table 1.

| S.N | Material | Cellulose | Hemicellulose | Lignin | Pectin |
|---|---|---|---|---|---|
| 1 | Flax | 81 | 14 | 3 | 3 |
| 2 | Jute | 72 | 13 | 13 | <1 |
| 3 | Hemp | 74 | 18 | 4 | 1 |
| 4 | Sisal | 73 | 13 | 11 | 1 |
| 5 | Cotton | 92 | 6 | - | - |
| 6 | Ramie | 76 | 15 | 1 | 2 |
| 7 | Wood | 45 | 23 | 27 | - |
| 8 | Coir | 43 | <1 | 45 | 4 |
| 9 | Straw | 40 | 28 | 17 | 8 |

Table 1: Chemical composition of various natural fiber [Verma and Sharma2012]

The Engineering properties of coir fiber given in Table 2

| Property | Value |
|---|---|
| Length (mm) | 15 – 280 |
| Density (g/ cc) | 1.15 – l.4 |
| Breaking elongation (%) | 30 |

| | |
|---|---|
| Diameter (mm) | 0.1 -1.5 |
| Rigidity modulus (dynes/cmL) | 1.8924 |
| Swelling in water (%) | 5 |
| Moisture at 65% RH (%) | 10.5 |
| Specific gravity | 1.15 |
| Young's modulus (GN/m$^2$) | 4.5 |
| Tenacity (g/tex) | 10 |
| Specific heat | 0.27 |

Table 2: Engineering properties of coir fiber [Ravi Shankar et al. 2012]

Coir Geotextile: Coir nettings / geotextiles are produced in ten specifications [$H_2M_1$ to $H_2M_{10}$] as per the Bureau of Indian Standards, which vary in weight from 400 to 1400 g/meter and mesh sizes from 0.75 cm to 2.5 cm respectively. The open weave coir netting is manufactured in the following grades based on the mass [Sharma& Anita Das Ravindranath 2012]

1) Grade I – 400 g/m$^2$ ($H_2M_6$)
2) Grade II– 700 g/m$^2$ ($H_2M_2$, $H_2M_5$, $H_2M_8$)
3) Grade III – 900 g/m$^2$ ($H_2M_9$)

## III. Use of Coir Geotextile in Expensive Soil Subgrade

The Black cotton soils of India are typical highly expansive soils which occupy about 20 percent of total area of country. They exhibit a wide range of shrinkage and swelling characteristics and give rise to cracks of 7 to 15 cms wide and up to 3 meter deep on drying. These soils cover about 0.8x10$^6$ km$^2$ area which is more than one-fifth of the country and extend over the states of Maharashtra, Gujarat, Southern part of Utter Pradesh, eastern part of Rajasthan, southern and western part of Madhya Pradesh, and few parts of Andhra Pradesh and Chennai [Arvind Kumar et al 2007]. The composition of the black cotton soil considerably varies with different depth horizons. The clay fraction of the black cotton soil is very rich in silica 60% and iron 15% with only aluminium about 25%. Typical ranges of Expensive soils are given in Table 3[Anirudh Rathore 2012]. Properties of BC soils, like Liquid limit, Plastic limit, Plasticity index and Shrinkage limit, are very high and CBR is very less. So the soil behavior is objectionable. There are many methods of soil stabilization, like lime stabilization, cement stabilization, mechanical stabilization, chemical stabilization etc., for improvement of expensive soils. But they do not pulverize in actual field condition. Now-a- days, CGT-reinforced soil may be used as a soil- improvement technique, with respect to embankment, subgrade/subbase, and other problems. Improvement from CGT implies an increase in the bearing capacity of roadway sections as well as providing separation and drainage between the subgrade and subbase layers.

## IV. Field Study

Sharma and Ravindranathan [2012] explained the field experiments on weak sub-grades with and without coir geotextile. Also discussed two case study first, the construction of a village road namely, Kumbakkad-Chembakulam Road at Varkala Block in Trivandrum district Kerala and Second, Vellar Theru Road at Orthanadu Block in Thanjavur district Tamilnadu using H2M6 coir geotextile as a reinforcement with sand cushion. Coir netting is spread directly over the roughly leveled poor sub-grade soil (agrarian soil). In the case of clayey sub-grades it is recommended to spreading the fabric after placing a layer of sand of 10mm to 20mm thickness. The fabric is then surcharged with granular material preferably sand of 30mm to 50 mm thickness to act as a lower sub base. The fabric over the sub-grade may be spiked, if necessary, by use of J shaped wooden spikes driven at random as necessary to keep the netting in place during construction and rolling.

For unsuitable and wet sub-grades, coir netting provides a satisfactory solution to stability and drainage. The coir geotextiles placed in this location is $H_2M_6$. Lying of Geotextiles and construction of bitumen layer was done after one year. After that monitoring of settlement is noted continuously, No large settlement is noticed.

| S. No. | Characteristics | Normal range of values |
|---|---|---|
| 1 | Mechanical Analysis: | |
| | Gravel | 0-10% |
| | Sand | 15-25% |
| | Silt | 15-30% |
| | Clay | 25-70% |
| 2 | Consistency Limits: | |
| | Liquid limit | 50-120% |
| | Plastic limit | 30-60% |
| | Plasticity index | 20-60% |
| | Shrinkage limit | 8-18% |
| 3 | Soil Classification: | |
| | Indian Standard | CI, CH, MI, MH |
| | HBR System | A-7 Group |
| 4 | Specific Gravity | 2.60-2.75 |
| 5 | Natural moisture content | 20-40% |
| 6 | Free Swelling | 30-100% |
| 7 | Differential Free Swell (DFS) | 40-180% |
| 8 | Swelling Pressure | About 70 kN/m$^2$ to over1600 kN/m$^2$ |
| 9 | Volumetric Shrinkage on the basis of Dry volume | 200-300% |
| 10 | Proctor Dry Density (kN/m$^3$) | 12.5-16.0 |
| 11 | OMC | 20-30% |
| 12 | Shear Strength Parameters: | |
| | Ø | 10°-18° |
| | Cu | 20-100 kN/m2 |
| 13 | Compression Index | 0.25-0.5 |
| 14 | CBR in Soaked condition | 2-4% |

Table 3: Typical Engineering Properties of Expensive Soil

## V. Need of the Study

BC soil has very low bearing capacity, high swelling and shrinkage characteristics and it is a very poor subgrade material for road construction. Soaked laboratory CBR values of Black Cotton soil is generally found in the range of 2 to 4 percent. Due to very low CBR values, it results in excessive design thickness of pavement. Under the traffic loads, the soil sub-base is subjected to compression in the vertical direction accompanied by tension in the lateral direction. Also, during dry weather conditions, cracks develop at the soil surface due to tensile stresses induced as a result of drying and shrinkage. During wet weather conditions, water starts to rise in the sub-base by capillary action from soil sub-grade. Materials like coir, lime etc. are needed to improve the compressive as well as the tensile strength and the permeability characteristics of the sub- base for a better performance of the pavements. Other methods of stabilization like lime stabilization, cement stabilization, fly ash stabilization etc. are not suitable because the additives (lime, cement etc.) do not proper mix with soil in field [Pothal et al 2008, Chauhan et al 2008, Neeraja, D. 2010]. Now-a-days, geotextiles are widely used in highway engineering, to solve a variety of problems related to drainage, separation and reinforcement of pavement structure. Geotextiles made of natural fibres such as coir, jute etc., are emerging as alternatives to polymeric geotextiles. Coir net is readymade material, cheap, easy laying in field and biodegradable. Coir nettings have long life of at least 5 years [Sharma and Ravindranathan 2012]. The coir-geotextile reinforcement is a superior solution for the construction of roads on weak subgrade soils. The use of natural geotextiles has not gained popularity though India produceslarge quantities of coir geotextile and their use for geotechnical and highway engineeringapplications is possible.

## VI. Placement of Coir Geotextile in Rural Roads

It is suggested to possible placement of CGT in Rural Roads is shown Case- I to Case- III, in which Case-I represents the CGT place over Subgrade between sand layer of 50 mm and layer of select soil is 300mm. In Case-II Subgrade made with total approved soil having CBR 3 to 4 %. CGT place directly placed over approved soil, then laying of CGT and a sand layer of 25 mm over it. The Case-III shows, subgrade made with layer of approved soil of 350 mm, select soil of 200mm and design CBR will take 5%. The $H_2M_9$ type of geotextile use in pilot project. The normal section of rural road is given in fig. 1

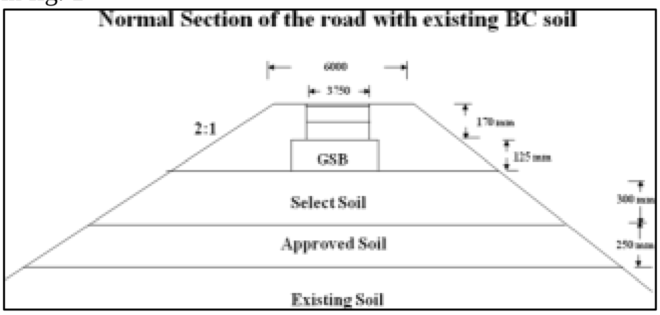
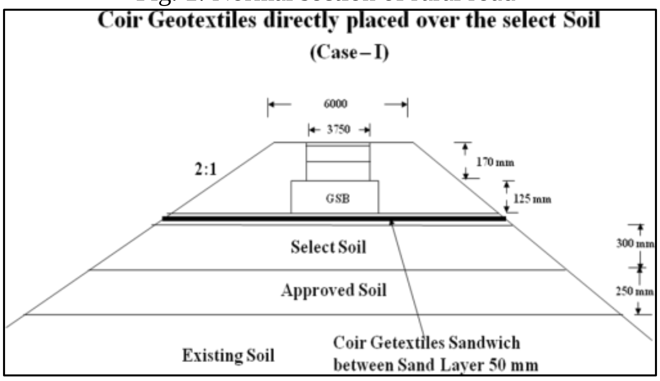
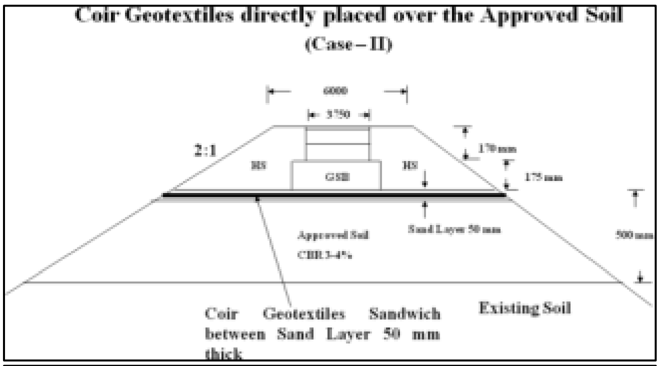
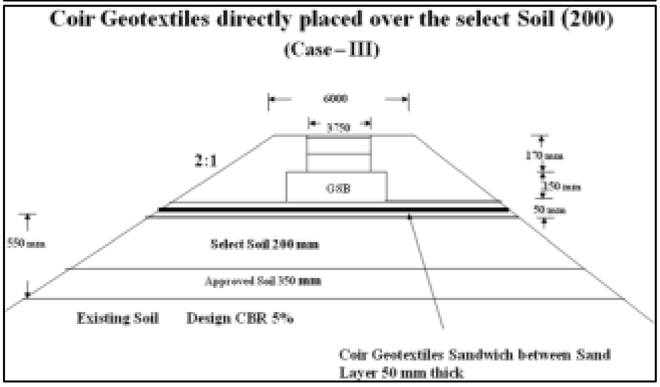



Fig. 1: Normal section of rural road




## VII. Conclusion

The following conclusions have been drawn from the study conducted on BC soil:

1) There is a need for improving the engineering characteristics of BC soil for road construction.
2) Incorporation of CGT between sub-grade and sub-base layer is an emerging technology. It not only stops seepage of water but also brings reduction in thickness. The ingress of seepage water into the sub-grade is stopped by introducing the geotextile layer or membrane at the interface of Granular Sub-base layer (GSB) and sub-grade which retains the intrusion of sub-grade soil into the interstices of granular sub-base layer, and this enables proper function of GSB as drainage layer.
3) It is reducing intensity of stress on subgrade
4) Utilisation of non conventional material, like CGT, in construction of roads can provide cost effective and eco friendly solution for road by reducing the consumption of other conventional materials.
5) The geosynthentic offers wide variety of products to solve may geotechnical problems being non-biodegradable and costly. Their use should be restricted the natural materials like coir geotextile can be an option to improve the poor sub-grade soil.

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## References

[1] Anirudh Rathore, “Behavior of Stone Columns in Expansive Soils” M. tech. thesis, Deptt. Of Civil Engg,,

Maulana Azad National Institute of Technology Bhopal, 2012.
[2] Arvind Kumar, Baljit Singh Walia and Asheet Bajaj, "Influence of Fly Ash, Lime, and Polyester Fibers on Compaction and Strength Properties of Expansive Soil", Journal of Materials in Civil Engineering, ASCE, 2007, pp. 242-248.
[3] A.U. Ravi Shanker, A. Chandrashekhar and H. Prakash Bhat, "Experimental Investigation on Lithomargic Clay Stabilized with Sand and Coir", Indian Highways, 2012, pp.21-31.
[4] B.M. Das, E.C. Shin and M.T. Omar, "The Bearing Capacity Surface Strip Foundations on Geogrid-Reinforced Sand and Clay – A Comparative Study", Geotechnical and Geological Engg., Vol. 12, 1994, pp 1-14.
[5] D. Neeraja, "Influence of Lime and Plastic Jute on Strength and CBR Characteristics of Soft Clayey (Expansive) Soil", Global Journal of Researches in Engineering, Vol. 10, Issue 1, 2010, pp- 16.
[6] Dennes T Bergado, Pham V. Long and B.R. Srinivasan Murthy, "A laboratory study of Geotextile-Reinforced Embankment on Soft Ground", Geotextiles and Geomembranes, vol. 20, 2002, pp. 343–365.
[7] E.A. Subaida, S. Chandrakaran and N Sankar, "Laboratory performance of unpaved roads reinforced with woven coir geotextiles", Geotextiles and Geomembranes, Vol. 27, 2009, pp. 204–210.
[8] Goutam Kumar Pothal and G. Venkatappa Rao, "Model Studies on Geosynthetic Reinforced Double Layer System with Pond Ash Overlain by Sand", Electronic Journal of Geotechnical Engg., Vol. 13, 2008, pp.1-13.
[9] Hoe I. Ling and Zheng Liu, "Performance of Geosynthetic- Reinforced Asphalt Pavements", Journal of Geotechnical and Geoenvironmental Engineering, Vol. 127, No.2, 2001.
[10] Indian Roads Congress, "Guidelines for use of Geotextiles in Road Pavements and Associated Work", Special Publication: 59, 2002.
[11] J.G. Zornberg, & R. Gupta, "Geosynthetics in pavements: North American contributions", 9th International Conf. on Geosynthetics, Brazil, 2010.
[12] K.K. Babu, K.S. Beena, and A.K. Raji, "Estimation of CBR of Coir Geotextile Reinforced Sub grade", Highway Research Journal, 2011, pp. 41-47.
[13] M. Sudhakaran Pillai & Christy Fernandez, "Coir an Effective Component For Consolidation", Proc. of Geosynthetics Asia 2000-GA 2000 (Kaula Lumpur 29th to 31st May 2000), Vol. 2, 2000, Page 207-212.
[14] Mahipal Singh Chauhan, Satyendra Mittal and Bijayananda Mohanty, "Performance evaluation of Silty Sand Sub grade Reinforced with Fly Ash and Fibre", Geotextiles and Geomembranes, Vol. 26, 2008, pp. 429–435.
[15] P. Senthil Kumar, and R. Rajkumar, "Effect of Geotextile on CBR Strength of Unpaved Road with Soft Sub grade", Electronic Journal of Geotechnical Engg., Vol. 17, 2012, pp.1355-1363.
[16] Sanjay Kumar Shukla, and Sarvesh Chandra, "A Study of Settlement Response of a Geosynthetic- Reinforced Compressible Granular Fill- Soft Soil System", Geotextiles and Geomembranes, Vol.13, 1994, pp. 627-639.
[17] Sarika B. Dhule, S.S. Valunjkar, and S.D. Sarkate, "Improvement of Flexible Pavement with Use of Geogrid", Electronic Journal of Geotechnical Engg., Vol. 16, 2011, pp. 269-279.
[18] Sudhir Mathur, R.K. Swami, and Uma Arun, "Lime/Cement Stabilisation for Soil and Granular Materials", National Workshop on Non – Conventional Material/ Technologies, NRRDA, NEW DELHI, 2012.
[19] U.K. Guru Vittal, "Use of Marginal Materials & Fly Ash in Road Works", National Workshop on Non – Conventional Material/ Technologies, NRRDA, NEW DELHI, 2012.
[20] U.S. Sharma, and Anita Das Ravindranathan, "Application of Coir Geotextiles in the Construction of Roads on Agrarian Soils", National Workshop on Non – Conventional Material/ Technologies, NRRDA, NEW DELHI, 2012.
[21] Uday Kumar Verma and U.S. Sharma, (2012, June 26), "Application of Coir Geotextiles in Rural Roads", http://ieca.crhosts.com.
[22] Vimal Kumar, "Overview of Fly Ash for Use in Rural Development", National Workshop on Non – Conventional Material/ Technologies, NRRDA, NEW DELHI, 2012.