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Use of Coir Geotextile (CG) over Black Cotton (BC) soil during Rural Road Construction

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Abstract

Transportation adds to a country's overall growth and therefore plays a critical role in its advancement. As India is largely rural in nature, road connections have distinct advantages over other connectivity modes. Economy, time, environmental restrictions, and many other variables, however, make the task of a highway specialist more complex to provide its users with a healthy and cost-effective road network. One of the major problems faced by the engineers during highway construction in rural areas of India is the presence of Black Cotton (BC) soil at ground level. It is inorganic clay having medium to high compressibility, high shrinkage and swelling nature, extremely hard when dry, however lose its strength totally when in wet condition. Because of wetting and drying process, here there is a chance of pavement failure resulting into settlement, unevenness and cracking. The lacuna identified with the traditional approach commands the problem to be tackled at its rudimentary level by rectification of the basic weakness of the formation subgrade and to settle for a strategic solution. Coir Geotextiles (CG) are used to increase the efficiency of roads on such soils, serving as reinforcement. It is noted that with the application of the Coir Geotextile (CG) layer beneath the Granular Sub Base (GSB) layer, due to intermittent changes in moisture content in expansive and shrinkable soil, it will be useful to reduce the time of upper layers of road pavement. A systematic plan for executing the layer thought the construction has been proposed in the paper.

Keywords: *Coir Geotextile (CG), Black Cotton (BC) soil, Subgrade, Granular Sub Base (GSB), Pavement.*

1. Introduction

The Black Cotton (BC) soil is a clayey soil having very high degree of sensation which shrinks and becomes hard in dry weather condition while it is wet during rainy seasons specifically in monsoons. This property of Black Cotton (BC) soil causes problems during highways and roadways construction in rural areas. Due to this highway engineers

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generally avoid to do construction on Black Cotton (BC) soil. For India like developing country, it is impossible to avoid construction on Black Cotton (BC) soil as economy matters a lot. Sometimes it becomes very difficult to build a stable base course over soft soil which leads to introduce the ground improvement techniques on a particular site for road construction. Chemical stabilization using lime or cement, vibration, blasting are different types of techniques used for ground improvements depending on the site condition and financial potential.

Geotextile materials are used in highway construction to fulfill the demand of construction of roads pavements and embankments over soft soil [1, 2]. Geotextiles are synthetic materials which can be woven or non-woven depending on manufacturing type [8, 14]. Geotextiles based materials have wide range of applications in construction including separation, drainage, reinforcement and filtration. Natural geotextiles made of, jute fiber; sisal or coconut fiber can be used as an alternate product of polymeric materials. Coir Geotextiles (CG) are cheap and easily available material used for several applications in highway engineering and pavement design.

2. Coir Geotextile (CG)

2.1 Chemical Composition and Engineering Properties of Coir Geotextile (CG)

The Coir Geotextiles (CG) are manufactured from coir fibers which contain cellulose, hemicellulose, lignin, pectin, water soluble substances and waxes [13, 15]. Cellulose is the fundamental structural element of coir fibers. Hemicellulose consists of sugar chains which comprise a group of polysaccharides bonded together in relatively short branching chains and remains connected with the cellulose after lignin has been removed. Natural fibers get rigidity due to the presence of lignin. In case of coir fiber, 45% lignin is present which gives enough strength as shown in the following Table 1. The outer wall of fibers made of pectin and some other non-structural carbohydrates. In market, Coir Geotextiles (CG) are commercially available in different sizes and textures. Their weight ranges between 400 g/m to 1500 g/m. Depending on site specifications, Coir Geotextiles (CG) are picked up which are easily available in mesh sizes from 0.75 cm to 2.50 cm [12].

2.2 Application of Coir Geotextile (CG)

The Black Cotton (BC) soils cover around 20% area of Indian land which extend over the states of Maharashtra, Gujarat, eastern part of Rajasthan, southern and western part of Madhya Pradesh, southern part of Utter Pradesh and few parts of Andhra Pradesh [6]. They are highly sensitive and exhibit wide range of swelling and shrinkage characteristics. The clay fraction in Black Cotton (BC) soil contains 60% silica, 15% iron and 25% aluminium. Engineering properties like liquid limit, plastic limit, and shrinkage limit as well as plasticity index are very high for this soil leading to objectionable behaviour under different weather conditions. Other than conventional methods of ground improvements, Coir Geotextile (CG) reinforced with soil used to increase the bearing capacity of roadway sections as well as provide the proper drainage and separation between subgrade and sub-base layers [5, 8].

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Table 1. Different types of natural fibers and their chemical composition [11]

Materials	Lignin	Pectin	Cellulose	Hemicellulose
Flax	3	2	81	14
Jute	13	<1	72	14
Hemp	5	1	74	18
Sisal	12	1	73	13
Straw	17	8	40	28
Wood	27	-	45	23
Ramie	1	2	76	15
Cotton	-	-	92	6
Coir	45	4	43	<1

Table 2. Engineering properties of coir fiber [11]

Property	Value
Length (mm)	15-290
Density (g/cc)	1.15-1.40
Diameter (mm)	0.-1.50
Specific Gravity	1.15
Rigidity Modulus (dyn/cm)	1.8924
Young's Modulus (GN/m^2)	4.5
Swelling (%)	5
Breaking Elongation (%)	30

3. Case Study

The Black Cotton (BC) soil has very low bearing capacity where CBR value ranges between 2-4% which furthermore tends to excessive design thickness. The soil sub-base undergoes to compression and tension in the vertical and lateral direction respectively when subjected to traffic loads caused by vehicular movements on road surface. Formation of cracks at the top surface is very common for such soils during dry weather due to alternate drying and shrinkage. Due to capillary action, water starts to rise up in the sub-base during wet weather. Such a sensitive behaviour of Black Cotton (BC) soil pushes the geotechnical engineers to handle the site using ground improvement techniques. But conventionally used techniques are not applicable everywhere because the additives get mixed with the site soil in improper way which reduces the significance of work [3, 9]. To overcome with such problems in roadway construction in rural areas, use of Coir Geotextile (CG) is the best remedy to improve compressive as well as tensile strength of the road pavements. This approach also helpful to solve the permeability related problems during pavement design for rural roads [4, 7]. India produces large quantities of natural geotextiles which can be easily available in the market.

Field experiments on weak subgrades with and without Coir Geotextile (CG) carried out for two sites [10]. The Coir Geotextile (CG) used during construction of the Kumbakkad Chembakulam Road in Trivandrum district of Kerala as well as Vellar Theru Road in Thanjavur district of Tamil Nadu as a reinforcement with sand cushion. The poor subgrade soil covered using Coir Geotextile (CG). It is recommended to spread out the fabric after placing a layer of sand having thickness 10-20 mm. Later, fabric is surcharged

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with the granular materials preferably sand having thickness 30-60 mm which acts as a lower sub-base.

Table 3. Engineering properties of expansive soil

Property	Value
Liquid Limit	50-120%
Plastic Limit	30-60%
Shrinkage Limit	8-18%
Specific Gravity	2.60-2.75
Free Swelling	30-100%
Swelling Pressure	70-1600 kN/ m^2
Optimum Moisture Content	20-30%

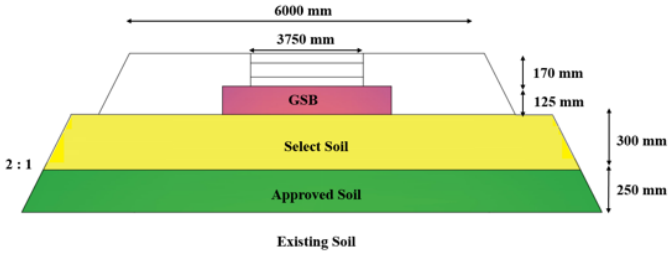

Figure 1. Normal section of road with existing Black Cotton (BC) soil

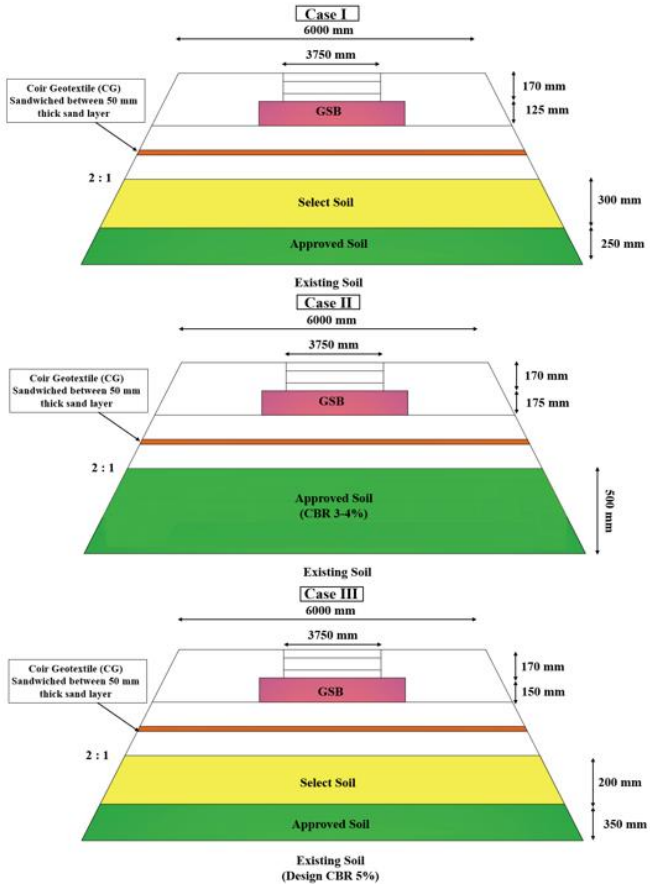

Figure 2. Road section with Coir Geotextile (CG)

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The J Shaped wooden spikes fixed at random locations so as to keep the Coir Geotextile (CG) layer straight during the construction process. The road section having existing Black Cotton (BC) soil without Coir Geotextile (CG) is shown in the following Fig. 1. Application of Coir Geotextile (CG) is recommended in three different ways with different thickness of select and approved soil.

Case I:
The Coir Geotextile (CG) is placed over subgrade between 50 mm thick sand layer. In this case, thickness of select and approved soil are 300 mm and 250 mm respectively.
Case II:
The Coir Geotextile (CG) is directly placed over approved soil. The thickness of approved soil is 500 mm having CBR 3-4%.
Case III:
The Coir Geotextile (CG) is placed over subgrade between 50 mm thick sand layer. In this case, thickness of select and approved soil are 200 mm and 350 mm respectively with design CBR 5%.

From field observations, it is found that Coir Geotextile (CG) gives a satisfactory solution to stability and drainage if laid over the unsuitable and wet sub-grades. Lying of Coir Geotextile (CG) layer and construction of final bitumen layer was done after one year. Overall procedure is closely monitored for any kind of settlements. Concluding remark suggested that no large settlement observed at both sites.

4. Conclusion

Nowadays, to enhance the performance of rural roads on Black Cotton (BC) soil, Coir Geotextiles (CG) are used behaving like reinforcement. They help to reduce the stress intensity on subgrade. Moments of upper layers of road pavements due to moisture changes in Black Cotton (BC) soil get controlled with the inclusion of Coir Geotextile (CG) layer. This technique helps to control the problems like seepage water into subgrade or membrane at the interface of Granular Sub Base (GSB). Coir Geotextile (CG) materials are cheap and easily available in the market which can be used to solve several geotechnical problems with proper design. For India like developing country with 20% Black Cotton (BC) soil, Coir Geotextile (CG) is the best solution to improve the bearing capacity of soil subgrade.

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