Structural Performance of Coir Geotextile Reinforced Rural Roads

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***Abstract* - Coir geotextiles can be effectively used as stabilizer and reinforcement in paved and unpaved roads. It improves the mechanical characteristics of roads, yielding to significant increase in road life span and reduction in maintenance cost. In the 1920's the State of South California used cotton textiles to reinforce the underlying materials on a road with poor soil properties. Experimentation done for several years has proven that the natural geotextiles are good in workable conditions. The reinforcement can also reduce pavement thickness between 20% to 50%. The natural products like coir geotextiles make the construction cost effective and eco-friendly. Field tests were conducted for evaluating structural performance of road reinforced with coir geotextiles. Three roads were undertaken for this study. The Benkelman beam Deflection Technique was used for this purpose. The comparison between deflection values obtained for coir geotextile reinforced and unreinforced roads are reported in this paper.**

I. INTRODUCTION

India is the second largest populated country and one of the largest rural and urban road networks in the world. Our country's agricultural and economic development mainly depends on its transporting net work. India has a rural oriented economy with 74% of its population living in villages and about 3,300 out of the 25,000 village habitants were without any all-weather road access. Rural road connectivity is a key component of rural development by promoting access to economic and social services and thereby generating increased agricultural incomes and productive employment opportunities. It also plays a key role in the reduction of poverty.

Geosynthetic materials have been used to stabilize soils in road construction and have proved in several cases to be successful. The geotextiles used are mainly polymeric materials. They perform the function as reinforcement, separation and drainage. But the high cost of geosynthetic materials and stringent environmental protection requirement make it important to explore alternate natural product as cost efficient and eco-friendly. Natural geotextiles like coir and jute is good alternative to geosynthetics due to its low cost, easy availability and eco-friendliness.

This paper presents a study on the structural performance of un-reinforced and woven coir geotextile reinforced roads by Benkelman Beam Deflection Technique.

II. LITERATURE REVIEW

The major problems faced by rural roads are, they are built in weak subgrade. To strengthen these types of subgrade, it can be reinforced by laying geosynthetics in between subgrade and sub base / base course. Major functions of geotextile materials include filtration, separation and reinforcement. The geotextile as a tensioned membrane serves to reduce the vertical stress acting on the subgrade (Giroud and Noiray, 1981). The placement position of reinforcement is the main factor affecting the bearing capacity of reinforced granular soil and higher bearing capacity has been observed when the depth of placement of reinforcement is decreased (Sankariah and Narahari, 1988). The reinforcement can also yield to reductions of pavement thickness between 20% and 50% with obvious favourable economical repercussions. Benefits of reducing base coarse thickness are realized if the cost of the geosythetics is less than the cost of the reduced base coarse materials (Anderson and Killeavy, 1989). In developing countries like India, cost and availability of geosynthetics are the major constraining factors for the construction of reinforced soil structures. It is also concluded that the use of geosynthetic reinforcement is particularly effective when the subgrade is weak. It is well known that the natural materials will decompose overtime, which limits its use to short term applications only. Since an unpaved road on soft subgrade gets stabilized by soil consolidation due to passage of vehicles, till the time geotextiles supports it. It is expected that consolidation of the soft subgrade soil will make reinforcement unnecessary in the long term (Fannin and Sigurdsson, 1996). The presence of the reinforcement layer increases lateral restraint or passive resistance of the fill material, increasing the rigidity of the system and reducing the vertical and lateral pavement deformation (Ajitha and Jayadeep, 1997; Cancelli and Montanelli, 1999; Perkins, 1999 a & b; Som and Sahu, 1999). Reinforcement placed high up in the granular layer hinders lateral movement of the aggregate due to frictional interaction and interlocking between the fill material and the reinforcement which raises the apparent load-spreading ability of the aggregate and reduces the necessary fill thickness (Perkins, 1999).

Coir is the agricultural fibre obtained from the husk of the coconut fruit which surrounds the base shell. It provides the raw material for the coir industry. Coir fibres are of different types and are classified according to varying degree of colour, length and thickness. Length of coir varies from 50mm to 150mm and diameters vary from 0.2mm to 0.6mm. The fibre is of two types depending on the process of extraction, white fibre and brown fibre. White fibre is extracted after retting mature coconut husks for 9 to 12 months, followed by beating of the retted husks with mallet manually for thrashing out the coir pith. Brown fibre is extracted by mechanical means after soaking the husks for a short period in water. The brown fibre is relatively inferior in terms of quality. Brown coir is mainly used for ropes, rubberized coir and in upholstery. The extracted fibres are then spun into yarn of different weights. The yarn is classified in terms of type of fibre, colour (natural), twisting and spinning. The yarn is then converted into mats in handlooms, semi automatic looms or power looms. Scorage of yarn differs among different types of geotextiles.

There are two types of coir mats (geotextiles) available: non-woven mats and woven mats. Non-woven mats are made from loose fibres, which are interlocked by needle punching or rubberizing. Woven mats are available in different mesh opening ranging from 3 to 25mm. A higher density means a tighter mesh and less open area. Over the years many varieties have been developed in India and are now commercially available in different mesh matting with international trade names. Coir has the highest tensile strength of any natural fibre and retains much of its tensile strength when wet. It is also very long lasting, with infield service life of 4 to 20 years. The reason for the greater strength of coir is its high lignin content. The degradation of coir is found to retain 80% of its tensile strength after 6 months of embedment in clay (Rao and Balan, 2000). Models reinforced with coir geotexiles improve the bearing capacity of kaolinite (Rao and Dutta, 2006).

The benefits of using reinforcements in flexible pavements depend largely on the quality and thickness of the granular base and location of the geosynthetics within the pavement structure along with other factors such as mechanical properties of reinforcement material, subgrade strength, nature of interaction between soil and geosynthetics and applied load magnitude (Al-Qadi et. al, 2007). Benefits of reducing base course thickness are realized if the cost of the geosynthetics is less than the cost of the reduced base course material. It is reported increased bearing capacity when woven and non-woven coir geotextiles were used at the interface of silty clay subgrade and granular base course of 150mm thickness. It has been found that the membrane effect of reinforcement diminishes with an increase in the thickness of the road aggregate layer (Babu et. al, 2008). The aggregate thickness can be considerably reduced by using geotextile and the percentage reduction depends on the quality of geotextiles, property of soil and the placement depth of the reinforcement. The maximum improvement ratio obtained from the tests is 1.52 for red soil and 3.5 for clayey silt when the reinforcement was placed at a depth of H/4 from the top (Chauhan et. al, 2008). Coir geotextile develops good interface friction with granular fill which can induce tensile stress in the reinforcement when embedded within the fill material. Such minor changes in horizontal stress distribution can cause significant changes in system performance. Hence, when used as reinforcement in unpaved roads, laying of coir Geotextile must be carried out so as to take full advantage of this biodegradable material during the early period of construction when much of the working of membrane action cannot be expected (Subaida et. al, 2008).

The studies shows that the inclusion of coir geotextile as reinforcement in soil improves the California Bearing Ratio of lateritic soil (Vinod and Minu, 2009; Senthil and Pandiammal, 2011). The presence of the reinforcement in unpaved road can also markedly improve the performance when built on weaker subgrade (Palmeira and Antunes 2010)

III. CONSTRUCTION OF COIR GEOTEXTILES REINFORCED ROAD

Three roads reinforced with coir geotextiles were selected for field performance study. They are (i) Attukal-Pampadi road (Trivandrum District) (ii) Karikuzhi-Chekidampara road (Trivandrum District) and (iii) Kumbaravila-Kollantemukku (Kollam District) are designated as road-1, road-2 and road-3 respectively. Coir geotextiles were placed at the interface of Granular sub grade and sub base layer as shown in fig.-1. Lengths of roads are presented in table-1 and the construction photographs are shown in fig. 2 and 3. The properties of coir geotexties are presented in table 2. Coir geotextiles was laid having poor soil condition in roads having CBR value less than 10.

Fig.1. *Typical Road cross section*

TABLE 1. NAME AND LENGTH OF THE TEST ROADS

Road Designation No	**Name of Road**	**Total length of road**	**Length of road reinforced with Coir Geotextiles**
Road-1	Attukal Pampadi (Trivandrum Dist)	1.86 km	150m
Road-2	Karikuzhi Chekidampara (Trivandrum Dist)	2.535km	470m
Road-3	Kumbarivilla Kollantemukku (Kollam Dist.)	1.218km	1.168km

Fixing of Coir Geotextiles to the Road Embakment

Fig.2. *Laying of Coir Geotextiles*

Laying of coir geotextiles in Attukal Pambadi road on 23-09-2011

Fig.3. *Laying of Coir Geotextiles in Attukal-Pampadi road*

TABLE 2. PROPERTIES OF COIR MAT SAMPLE USED IN THE ROAD

Properties	**Values**
Specific gravity	1.402
Mass/Unit area	681 g/m^2
Thickness at 2 kPa	7.2mm
Tensile Strength M.D	10.6Kn/m
Tensile strength X.D	7.5kN/m

Soil samples from three locations were collected and tested in the laboratory. The properties of soil are presented in table 3

TABLE 3. PROPERTIES OF SOIL

Properties	**Road-1**	**Road-2**	**Road-3**
Liquid Limit	41.70%	25.20%	31.20%
Plastic Limit	25.25%	18.03%	22.19%
OMC	13.15%	17.62%	16.22%
Max. dry density	1.94 g/cc	1.75 g/cc	1.84 g/cc
CBR (unsoaked without geotextile)	3.34%	5.85%	3.47%

IV. STRUCTURAL PERFORMANCE

Structural performances were determined using Benkelman Beam. Benkelman beam is a device which can be conveniently used to measure the rebound deflection of a pavement due to a dual wheel load assembly or the design wheel load. The equipment consists of a slender beam of length 3.66m which is pivoted to a datum frame at a distance of 2.44m from the probe end. The datum frame rests on a pair of front levelling legs and a rear leg with adjustable height. The probe end of the beam is inserted between the dual rear wheels of truck and rests on the pavement surface at the centre of the loaded area of the dual wheel load assembly. A dial gauge is fixed on the datum frame with its spindle in contact with the other end of the beam in such a way that the distance between the probe end and the fulcrum of the beam is twice the distance between the fulcrum and the dial gauge spindle. Thus the rebound deflection reading measured at the dial gauge is to be multiplied by two to get the actual movement of the probe end due to the rebound deflection of the pavement surface when the dual wheel load is moved forward.

Truck loaded with 12 tonne such that the rear axle load is 8170 kg equally distributed over the two sets of dual wheels; the spacing between the tyre walls should be 30-40 mm; the tyres is 10x20 ply inflated to a pressure of 5.60 kg/sq. cm. Schematic sketch of

Benkelman beam is shown in fig.4. Photographs taken during measurements are shown in fig. 5.

The rebound deflection value D at any point is given by D = 2(Do-Df) + 2K (Di-Df) . Where Do is the Initial Dial gauge reading under and in between the gap of the back dual wheel of Truck normally it is adjusted to zero. Di = Intermediate Dial gauge reading at a distance 2.7m after running of Truck. Df = Final Dial gauge reading at a distance 9m after running of Truck. Moisture correction, Temperature correction and Leg correction are to be made to the deflection.

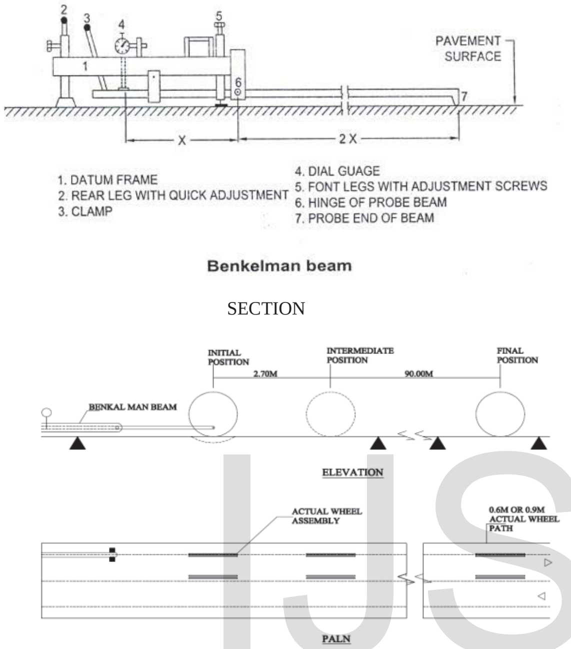

Fig. 4. *Schematic diagram of Benkelman beam*

The allowable limit of deflection having no need of any improvement works in the pavement as per IRC 81 – 1997 is 0.45mm. There is no need of any upgradation when the deflection is below 0.45mm as per overlay thickness design curve from million standard axial loads (msa) of 100. Allowable limit of deflection without any improvement works for different cumulative numbers of standard axial load is presented in table 4

Table 4. Allowable limit of deflection without any improvement works for different cumulative numbers of standard axial loads

Deflection in mm	3	2	1.65	1.4	1.05	1	0.8	0.45
msa	0.1	0.5	1	2	5	10	20	100

V. RESULTS AND DISCUSSION

The pavements were constructed during 2011 and the Benkelman deflections obtained in coir geotextile reinforced as well as unreinforced roads found are presented in table 5. It can be seen that the deflections are comparatively lesser in coir geotextile reinforced roads. To have a better comparison the results of road -1 and all the roads are presented in fig 5 and 6 respectively in graphical form. The variation in deflection is less with time for coir reinforced roads. The defection result shows that considerable values of deflection is reduced due to the coir reinforcement which reflect the rigidity and increasing load bearing capacity of pavement. Variation in deflection is comparatively more when the CBR value is less.

Fig.5. *Benkelman beam test in progress*

TABLE 5. BENKELMAN BEAM DEFLECTION (BBD) OF REINFORCED AND UNREINFORCED ROADS

Name of road	Without Coir (BBD) deflection in mm		With coir (BBD) deflection in mm	
	Date of taking measurement			
	18.10.2012	*11.8.2013*	*18.10.2012*	*11.8.2013*
Road-1	1.03	0.86	0.72	0.71
Road-2	0.98	0.76	0.736	0.73
Road-3	1.4	0.80	0.728	0.63

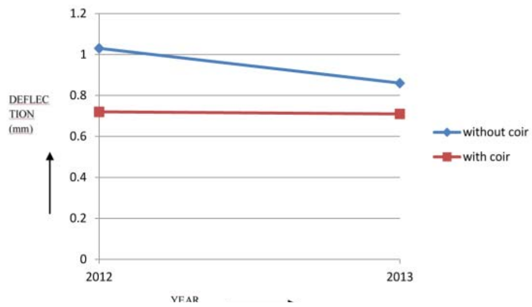

Fig. 6. *Variation of deflection of road 1 with year CBR 3.34%*

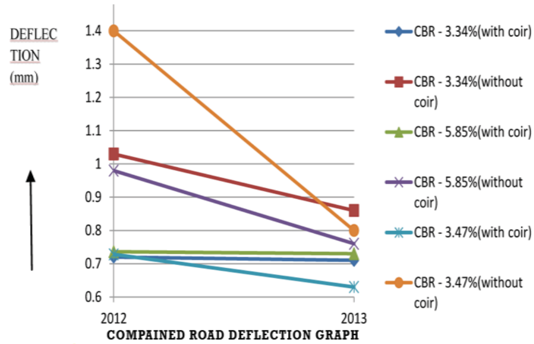

Fig 7. *Variation of deflection with year*

VI. CONCLUSION

From the study on the structural performance of coir geotextile reinforced roads it can be concluded that the variation in deflections of reinforced roads with time are less compared to unreinforced roads.

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