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Testing and application of coir based geotextiles

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ABSTRACT: This paper presents some of the recent developments made in developing coir based geotextiles along with their physical characteristics and tensile strength behavior for their application in rural roads. Both monotonic and cyclic load tests carried out in this connection are very encouraging. The paper highlights the significant behavioral changes obtained by using the coir products.

1.0 INTRODUCTION

India is well endowed with natural fibers like jute and coir available in a processed form, inexpensively. It is the first largest country (66% of world production), producing coir fiber from the husk of coconut fruit. The coir fibers (50 to 150 mm long and 0.2 to 0.6 mm diameter) till recently were being spun into coir yarn and then woven to obtain woven nettings. The fibers are also now a days being air laid, needle punched or adhesive bonded to obtain non-woven products or blankets. Like their polymeric counterparts geotextiles can be synthesized for specific applications in civil engineering like erosion control, ground improvement etc. Most of the present day products are being developed with an eye on erosion control applications (for vegetative growth), particularly, because among naturals they have much longer life. Their biodegradability has not encountered users for more permanent applications. In fact they are yet to be standardized , for their tensile behaviour and their biodegradability characteristics. Studies in this direction were initiated at Indian Institute of technology, Delhi (Venkatappa Rao and Balan (1994), Balan (1995) and Venkatappa Rao (1997)). These studies have broadly indicated that their biodegradability can be used to advantage and the coir based geotextiles have potential of being used for many geotechnical applications. Keeping this in view , over the years many varieties of woven and non-woven products have been developed in India and are now commercially available.

The paper presents a brief review of the earlier work carried out on characterizing the tensile strength behaviour and biodegradability of coir geotextiles. It then presents tensile strength characteristics of four woven products and four non-woven products. Results of monotonic and cyclic load tests carried in a model test tank simulating unpaved roads with geotextiles are presented. The results are encouraging, for use in developing countries (like India) in rural roads (village roads) that are yet to be developed to connect as many as 0.2 million villages (with a population less than 1,000). Most of these roads happen to be on soft soils.

2.0 PREVIOUS WORK

2.1 *Evaluation of natural fiber geotextile*

Extensive testing has been carried out at IIT Delhi (Balan (1995) and Venkatappa Rao (1997)) on jute and coir geotextiles in order to arrive at a rational procedure for evaluating the physical and strength characteristics as well as their biodegradability. Based on these studies, it was recommended that the thickness of natural geotextiles can be taken corresponding to a normal pressure of 2 kPa after one minute of application of pressure. The tensile strength of natural geotextiles can be taken as that corresponding to a wide width specimen (200 mm wide * 100 mm long) at a deformation rate of 10 mm/min determined in a constant rate of extension machine, and the overall life of jute and coir can have a life of more than one and two/three years respectively. It is also pertinent to point out that the tensile strength testing has been conducted on specimens of varying length of 25 mm to 200 mm keeping the width as 200 mm and also by varying the width from 25 mm to 200 mm and keeping a length of 100 mm constant. The deformation rate used varied from 2 to 300 mm/min. Five different varieties of jute and coir have been used in this study.

Hence the above parameters have been used in the present study for the evaluation of the different products.

3.0 EXPERIMENTAL WORK

3.1 *Coir geotextiles used*

3.1.1 *Physical properties*

Four different varieties of non-woven coir geotextiles designated as A, B, C, D and four woven coir geotextiles designated as E,F,G,H were used in the present study.

The non-woven coir geotextile Type A is 100% de-curled coir fiber web of 650 g/m^2 encased over top and bottom with stable woven heavy jute netting. The matrix is stitched together on 5 cm centres with 2-ply jute yarn. The mass per unit area of top and bottom jute netting is 100 g/m^2 each.

The Type B is composed of 100% de-curled coir fiber web of 400 g/m^2 encased over top and bottom with brown PP netting. The matrix is stitched together on 5 cm centres with white PP thread dipped in black natural glue. The mass per unit area of top and bottom netting is 7.1 g/m^2 and 4.8 g/m^2. Type C is similar to Type B except that the coir fiber web is 750 g/m^2

The Type D is 100% de-curled coir web with 390 g/m^2 encased over top heavy duty woven coir netting of 700 g/m^2 and bottom brown UV stabilized PP netting of 4.8 g/m2. The matrix is stitch bonded together on 5.0 cm centres with heavy 2 ply jute thread.

The woven geotextiles Type E, F, G and H are netting composed of 100% coir fiber spun into yarn 240 m/kg (warp and weft) and woven in conventional flat bed looms in widths of 1,2 or 4m.

3.1.2 *Tensile strength*

The tensile strength testing has been carried out as per Balan (1995) and Venkatappa Rao (1997). The physical and mechanical properties are presented in Tables 1 and 2 for all varieties of non-woven and woven products respectively.

3.1.3 *Model testing*

Model tests were carried out in a tank made of 10 mm thick perspex side plates fitted inside a rigid aluminum frame. The internal dimensions as shown in Figure 1 are 350 mm * 350 mm in plan and 420 mm in depth. A typical test model consisted of saturated
soft subgrade (270 mm thick) overlain by 75 mm thick sand layer representing a granular course. At the outset, a thin sheet of polythene was fixed with cello tape over the internal surfaces of the tank in an attempt to minimize the friction. At the bottom of the tank a thin layer of grease was applied.

Table 1 Physical and mechanical properties of non-woven coir geotextiles

Property	Non-woven coir geotextiles			
	A	B	C	D
Roll width (m)	2.2	2.2	2.2	2.0
Roll length (m)	25	25	42	25
Roll weight (kg)	33	22	69	50
Thickness (mm)	12	8.9	9	13.6
Mass per unit area (g/m^2)	865	420	750	1175
Tensile strength m/c (kN/m)	7.6	1.7	2.3	15.4
% Elongation m/c	11.3	35	27.5	27
Tensile strength x-m/c (kN/m)	3	0.8	0.7	8.3
% Elongation x-m/c	9.7	15.8	19.2	24
Initial tangent Modulus at 5 mm deformation (kN/m)	68	10	13.8	49

Table 2 Physical and mechanical properties of woven coir geotextiles

Property	Coir geotextile			
	E	F	G	H
Roll width (m)	1.2	1,2,4	1,2,4	1.2
Roll length(m)	25	50	50	24
Roll weight (kg)	10	1/20,2/40 ,4/80	1/35,2/70,4/ 140	42
Runnage of yarn		240	240	
Aperture size (mm*mm)	45*30	25*25	6.25*6.25	7*4
Thickness (mm)	7.3	6.7	8	9.5
Mass per unit area (g/m^2)	335	360	610	1335
Tensile strength m/c (kN/m)	3.86	6.34	10.63	31.50
% Elongation m/c	20	19.17	31.67	42
Tensile strength x-m/c (kN/m)	2.50	4.38	7.50	12.73
% Elongation x-m/c	27.5	31.67	26.25	18
Initial tangent Modulus at 5 mm deformation (kN/m)	30	48	46	100

Nextly, kaolinite clay ot a moisture content 36 % is placed into the tank by hand kneading. The resulting dry density obtained is 12.35 kN/m^3. After the preparation of subgrade, a sand layer of 75 mm thickness was placed over this in two layers 40 mm and 35 mm each at a density 14.95 kN/m^3. Where required, a geotextile could be conveniently placed over the clay before placing the sand layer. The model thus prepared was placed on the Hounsfield Universal Testing Machine. The models were tested under monotonic and cyclic loading through a square steel plate of 75 mm * 75 mm at a deformation rate of 4 mm/min and 75 mm/min respectively.

4.0 TEST RESULTS AND DISCUSSION

4.1 *Tensile strength of coir geotextiles*

The tensile strength of Type B and G geotextiles ranged from 1.50 kN/m to 1.87 kN/m and 5.2 kN/m to 13.75 kN/m in m/c direction with a mean of 1.70 kN/m and 10.63 kN/m and variance of 0.02 and 9.91 for five specimens tested. The corresponding failure strain were found to be 35 % and 31.67 % respectively. Similarly the tensile strength in x-m/c direction for Type B and Type G ranged between 0.66 kN/m to 0.99 kN/m and 5.83 kN/m to 8.92 kN/m with a mean of0.84 kN/m and 7.5 kN/m and a variance of 0.02 and 0.91 respectively. The corresponding failure strain were found to be 15.83 % and 26.25 % respectively. Despite the variation that could be expected in a natural material, there is a fair level of uniformity in the specimens tested. The average tensile strength curves for geotextile Type B and G both in m/c and x-m/c directions are depicted in Figure 2&3 respectively.

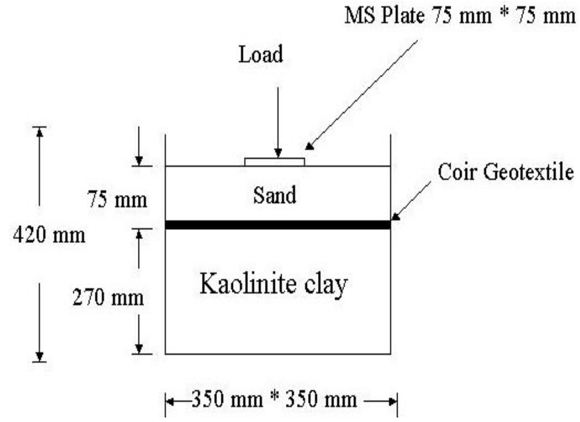

Figure 1 Model test tank.

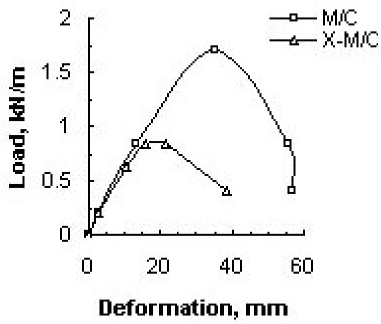

Figure 2 Load versus elongation curves for non-woven coir geotextile Type B in m/c and x-m/c direction

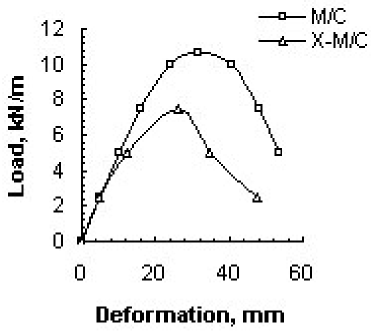

Figure 3 Load versus elongation curves for woven coir geotextiles Type G in m/c and x-m/c direction

4.2 *Monotonic load tests*

4.2.1 *Woven coir geotextiles*

The woven coir geotextiles Type E, F, G, H were used at the interface of base course and sub grade.The bearing pressure versus deformation plots are shown in Figure 4. It can be seen from this figure that there is an improvement in the bearing pressure of the reinforced models over the unreinforced model. It is observed that Type H reinforced model shows an overall better performance than the other geotextiles. The bearing pressures of model reinforced with Type E, F, G, H geotextiles and unreinforced models are around 57 kPa, 60.04 kPa, 62.69 kPa, 75.81 kPa and 54.03 kPa corresponding to a deformation of 20 mm. The Type E, F, G, H reinforced models show 1.05, 1.11, 1.16, 1.40 times higher bearing pressure than the unreinforced model. It is thus evident that Type H reinforced model behaves better than Type G, F and Type E reinforced model which could be attributed to difference in their tensile strength, initial tangent modulus and aperture size.

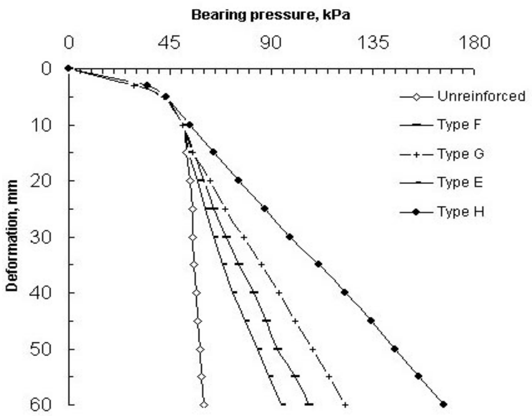

Figure 4 Static load versus deformation behaviour of models reinforced with different types of woven geotextiles

4.2.1.1 *Effect of aperture size*

Herein, the influence of the aperture size of the woven geotextiles on the behaviour of the model pavement is studied. From Figure 4 it can be inferred that as the aperture size decreases, the reinforced model can bear more bearing pressure. But with the increase in aperture size, the trend is reverse. However, the reinforced model still behaves better than the unreinforced model. This behaviour of the reinforced model is due to better friction mobilization and more number of yarns per unit area in lower aperture size coir geotextile.

4.2.2 *Non-woven coir geotextiles*

The bearing pressure versus deformation plots obtained in the model tests with the non-woven geotextiles Type A, B, C, D are shown in Figure 5. It may be noted D_f represents the case where the woven coir scrim is in touch with the subgrade and D_b is the reverse case. It is evident that there is an improvement in the bearing pressure of the reinforced models over the unreinforced model.

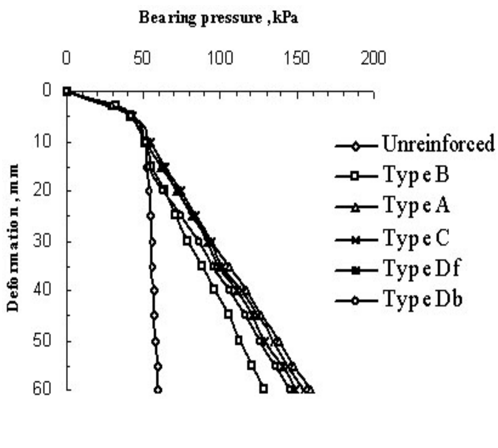

Figure 5 Static load versus deformation behaviour of models reinforced with different types of non-woven geotextiles

The non-woven geotextile Type A reinforced model shows an overall better performance than the other non-wovens. The bearing pressures of model reinforced with Type A, B, C, D_f, D_b and unreinforced models are 72.58 kPa, 63.71 kPa, 74.01 kPa, 71.84 kPa, 63.13 kPa and 54.03 kPa corresponding to a deformation of 20 mm. The Type A, B, C, D_f and D_b reinforced models show 1.34, 1.18, 1.37, 1.33 and 1.17 times higher bearing pressure than the unreinforced model. Comparing the results of Type B and Type C it is clear that model with Type C behaves better than with Type B, as expected, keeping in view that Type C has higher mass per unit area, tensile strength and initial tangent modulus compared to Type B. Further models reinforced with Type A, D_f and D_b are performing better than the model reinforced with Type B. This is attributed to higher tensile strength and higher initial tangent modulus of these products. Also Type A reinforced model behaves better than Type D_f and D_b reinforced model. It may be attributed to its higher initial tangent modulus.

4.2.3 *Comparison*

A comparison of the behaviour of models reinforced with non-woven and woven geotextiles are shown in Figure 6. It is observed that model reinforced with Type H show an overall better performance than all others. This is attributed to high modulus and high tensile strength of this product. Further it is also observed that models reinforced with non-wovens show better performance than models reinforced with Type G, F and Type E. This could be be attributed to better surface friction of these products. The variation in bearing capacity ratios of these models with respect to deformations are shown in Figure 7. It may be seen that BCR values for model using non-wovens and wovens have an increasing trend upto 60 mm deformation.

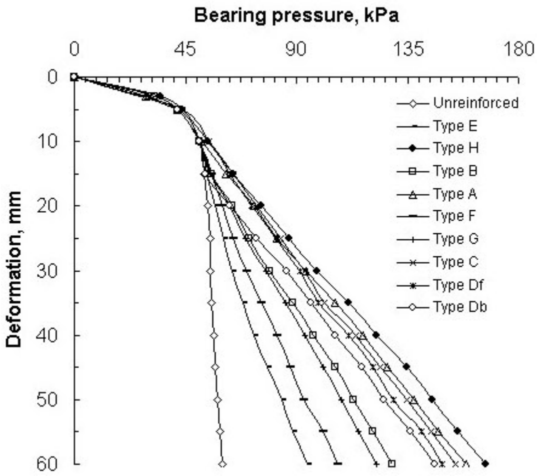

Figure 6 Static load versus deformation behaviour of models reinforced with different Non-woven and woven coir geotextiles.

5.0 CYCLIC LOAD TESTS

The behaviour of model pavements having sand as base course and kaolinite as subgrade have been studied under the repeated loading of 17.94 kPa, 35.88 kPa and 71.76 kPa. Out of the six tests which were repeated twice, three were conducted at repeated load of 35.88 kPa for comparison purposes. The geotextiles used at the interface were of the Type G and B. The variation in permanent vertical deformation with number of load repetitions of unreinforced and reinforced models is shown in Figure 8. Under a repeated load of 35.88 kPa the permanent deformation increases upto 27.46 mm at 200 number of repetitions in the unreinforced model while in the model reinforced with Type B and G, a significant improvement in the behaviour of the models by restricting its permanent deformation upto 11.30 mm and 12.17 mm.

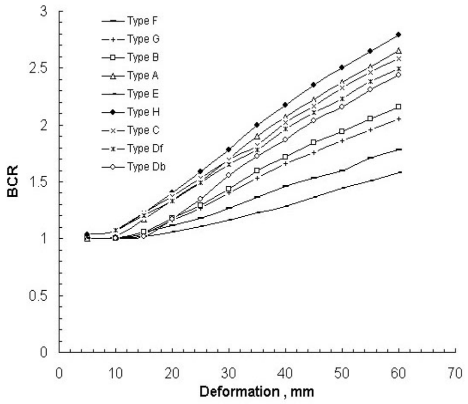

Figure 7 Bearing capacity ratio versus deformation behaviour of models reinforced with non-woven and woven coir geotextiles.

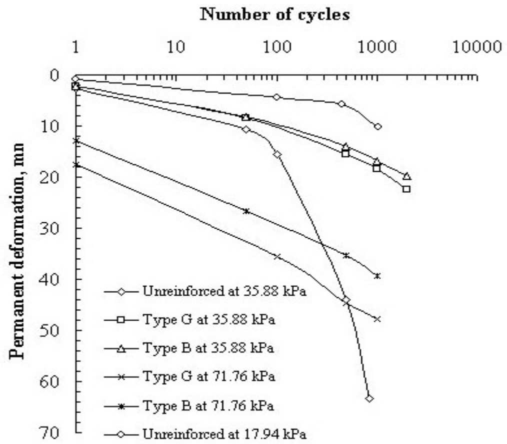

Figure 8 Permanent vertical deformation versus number of load repetitions

Similarly at 700 number of repetitions, the permanent vertical deformation for the unreinforced model is 63.39 mm whereas it is 14.78 mm and 16.09 mm for the model reinforced with Type B and G geotextiles. Thus the effect of geotextile inclusion can be very well noted. It can also be seen from Figure 8 that at 50 number of cycles the behaviour shown by both the types is similar with more or less improvement in permanent deformation. But after 50 number of cycles Type B is behaving better than the Type G. This may be due to better friction offered by the Type B than Type G though the mass per unit area of Type B is less than Type G. From a comparison curve, it is observed that the reinforced model consistently performed better than the unreinforced model. In models reinforced with Type B and Type G the permanent deformation continue to increase upto 1000 cycles to a value of 16.30 mm and 18.04 mm. The failure in reinforced models tend to be general shear type, while in the unreinforced model punching shear failure occurs. All models were tested upto 1000 number of repetitions.

The percentage reduction in the permanent deformation for models reinforced with Type B and Type G are presented in Table 3. The ranges of percentage reduction for geotextile Type and Type G reinforced models are 21.19 to 76.68% and 21.19 to 7.62%. From permanent deformation versus number of repetition plot, it is evident that Type B reinforced model performs better than Type G reinforced model. Further when the repeated load was doubled, the reinforced model was still behaving better than the unreinforced model. But the better behaviour of reinforced model was observed at greater permanent deformation.

Table 3 Percentage reduction in permanent deformation

Number of cycles	Percentage reduction in permanent deformation	
	Geotextile Type	
	B	G
10	21.19	21.19
200	58.85	55.68
700	76.68	74.62

5.1 *Apparent resilient modulus*

The variation of apparent resilient modulus of different test with the number of load repetitions are shown in Figure 9.This figure shows that for the Type B and Type G reinforced models, there is a distinct decrease in the apparent resilient modulus with the number of load repetitions. For the unreinforced models, under a repeated load of 35.88 kPa, the apparent resilient modulus decreases from 25 kPa/mm at N = 2 to 12.3 kPa/mm at N = 100 at which unreinforced sample failed. Similarly for the model reinforced with Type B, the apparent resilient modulus decreased from 23 kPa/mm at N = 2 to 18 kPa/mm at N = 100. Whereas, the variation in apparent resilient modulus for the model reinforced with Type G is some what similar and it varies from 19.65 kPa/mm at N = 2 to 15.1 kPa/mm at N = 100. It can also be seen from Figure 9 that as the intensity of repeated loading is doubled, the apparent resilient modulus is marginally increasing.

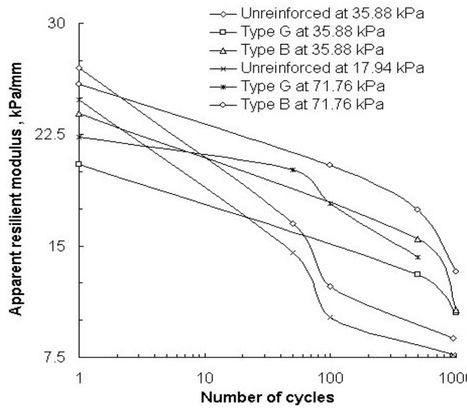

Figure 9 Apparent resilient modulus versus number of load repetitions.

6.0 CONCLUSION

On the basis of results and discussion presented in this paper the following conclusions can be drawn.

1. Use of coir geotextiles in road appears to be of great potential in rural road application particularly on soft soils. The optimum product selection is possible by further detailed analysis.
2. As the coir geotextiles have life at least upto 5 years in submerged/saturated condition, there is a possibility that the subgrade soil will improve in course of time as it serves as a drainage and filteration layer apart from being separator.

7.0 REFERENCES

1. Balan, K 1995. Studies on engineering behavior and uses of geotextiles with natural fibers, Ph.D Thesis submitted to Indian Institute of Technology Delhi (India).
2. Venkatappa Rao, G & Balan, K 1994. Design and development of a natural fiber strip drain, *Proc. Int. Symp. on Biocomposites and Blends Based on Jute and Allied Fibers*, pp. 87 – 95.
3. Venkatappa Rao, G. 1997. Geosynthetic testing – recent developments, *Proc. Geosynthetics Asia'97*, 26-29 Nov, Bangalore, India, Vol. II., pp. A137 – A168.