Journal of Material Science and Mechanical Engineering (JMSME)
p-ISSN: 2393-9095; e-ISSN: 2393-9109; Volume 10, Issue 2; April-June, 2023, pp. 82-87

http://www.krishisanskriti.org/Publication.html

Application and Durability of Coir Geotextile in Subgrade Soil

Jayant[1] and Dr. Praveen Aggarwal[2]

[1]PG Student, N.I.T. Kurukshetra
[2]Faculty, N.I.T. Kurukshetra
E-mail: [1]jayant_32112404@nitkkr.ac.in, [2]praveen_agg@hotmail.com

Abstract—*Over a few decades, the use of geotextile in ground improvement has received more attention. In this context, ecofriendly and biodegradable geotextiles made of natural fibers are a good alternative to synthetic geotextiles. Coir fiber is a natural fiber which is obtained from coconut husk. Coir geotextile made of coconut fibers has proved its worth by working as a separation layer, improving drainage and filtration, providing reinforcement, reducing soil erosion and reducing settlement etc. Coir geotextile has higher lignin content which makes it stronger and slows degradation as compared to other natural geotextiles. But in some soils, it degrades fast. Hence, the coir geotextile used in this study has been buried in two distinctive type of soil samples with different chemical compositions and compressibility properties to find it's degradation rate. The soil samples were procured from two different places. The study was carried out in laboratory. The rate of degradation was evaluated by conducting California bearing ratio and wide width tensile strength test after seasoning of coir geotextile in both soils for 0-135 days. The surface morphological analysis of coir fibers before and after seasoning for different days and chemical analysis of both the soils were conducted.*

1. INTRODUCTION

India is the 2nd largest road network in the world. The traffic load is ultimately taken by subgrade soil. Hence, the characteristics of subgrade soil has a remarkable impact on road performance. At locations where India is covered with expansive soils having unfavorable engineering properties like low bearing capacity, prolonged water retention capacity, poor load transfer mechanisms, high compressibility and unexpected large volumetric changes hence ground improvement is required. Commonly adopted techniques include mechanical stabilization; deep compaction, replacement of the weak material, chemical stabilization; lime and cement stabilization, and polymer stabilization etc. But cost of some of the techniques are high or are rising, availability of materials like lime and cement decreasing and at the same time some of these cause environmental issues. Hence, we are in a need of some alternate materials. Since a few decades, the use of geotextile has gained more attention in ground improvement techniques. These materials can be synthetic or natural. Synthetic products are more long-lasting and durable than natural ones, but because they can't decompose, they could eventually cause environmental issues. In this context, eco-friendly and environmentally sustainable alternatives like geotextiles made of natural fibers have gained recognition. Natural geotextile like jute, sisal, hemp, abaca, kenaf and coir has been used as geotextile. Coir geotextile has proved its worth in past few years by working as a separation layer, improving filtration and drainage, providing reinforcement, reducing settlement and reducing soil erosion etc. According to a previous field research on rural roads with the same subgrade soil, roads reinforced with it didn't need an extra overlay even after a long span. It is obtained from coconut husk and contains lignin, cellulose, hemicelluloses and pectin. It is stronger and having high durability than other natural geotextile because of its higher lignin content. Hence it degrades slowly in comparison to other natural geotextiles. Although coir geotextiles work good in engineering applications and decay at slow rate but previous researches shows that the degradation rate in distinct soils varies based on the chemical components found in the soil and cannot be ignored. This analysis will be helpful in determining how untreated coir geotextiles behave in various subgrade soil.

2. LITERATURE REVIEW

Sayida et al. embedded coir geotextile in 5 distinctive types of soils with different characteristics. Laboratory studies were conducted from 0 to 135 days to find the rate of degradation using "wide width tensile strength test" and "CBR test" before and after soil burial. Also, morphological analysis of raw and degraded coir fibre samples i.e., SEM and chemical analysis of soils was done. CBR value also decrease as time increases. Degrading rate increases quickly after 30 days. Soil rich in P, N and Ca with less saline shows higher rate of degradation[1].

Sumi et al. carried surface modifications of coir geotextiles by using cashew nut shell liquid (CNSL) to enhance performance. The geotextiles were subjected to alkaline, acidic and neutral pH conditions, alternate wetting drying cycles, saline condition and thermal cycles to find the durability. Also, soil burial studies of geotextiles in soil at various depths were carried out to know it's biodegradable behaviour. Chemical degradation: The unmodified samples a maximum degradation in alkaline medium. Most of the microorganisms that degrade coir survive in a pH range of 4-9. Top layer embedded geotextile degrades more. Degradation is less in more saline medium. Morphology shows highest increase in roughness, irregularities and pore for alkaline medium[2].

Arora et al. Carried out study using two woven, two non-woven untreated, treated coir geotextile i.e., two woven W1, W2 650 gsm and 900 gsm respectively and two nonwoven NW1, NW2 700 gsm and 900 gsm respectively. Tensile strength test for durability and monotonic load test was carried out by placing coir geotextile between sand and silty sand layer. Geotextile was treated with potassium permanganate and sodium hydroxide. Sand and silty sand were locally available from Kurukshetra, Haryana. Tensile strength (TS) of treated W1, W2 were less than untreated. For non-woven treated one had high tensile strength than untreated. In every case tensile strength had an order $KMnO_4$ and NaOH treated>$KMnO_4$ treated>NaOH treated. Same results came out for monotonic load test. The reduction in the tensile strength in the X-machine direction after six months was higher than in machine direction[3].

Marques et al. used untreated and lime treated coir geotextile to know the impacts of the weather on the mechanical properties like tensile strength and structural properties like Fourier transforms infrared spectroscopy (FTIR), thermogravimetry (TGA) of geotextile. Geotextiles used was manufactured by Deflor Bioengenharia was placed at interface of commercially available soil of P_H=7 overlying a layer of sand. After 12 months of degradation untreated samples shows retention of 23% while treated one shows 20% retention of tensile strength but for first three months tensile strength of treated samples were higher than untreated samples. These can be justified with FTIR and TGA revealed that the initial retention of o of cellulose was improved by lime lasts for first 3 months of exposure then there was a gradual decrease in cellulose content[4].

Miller et al. used coir geotextile for stream bank stabilization i.e., to design bioengineered stream bank treatment that would rely on the balance between degradation rate of geotextile and vegetative establishment. Tensile strength test was performed on woven coir geotextile of 700 and 900 gsm manufactured in Belton Industries, Bon Terra America, and Ro Lanka International on 20 sites ranged from California to Georgia to find it’s degradation rate., It showed a large amount of loss in tensile strength during the first 1 to 3 years. After 1 year it shows degradation in tensile strength of 38 to 54% and after 3 year 77 to 90%[5].

Harinder et al. carried out investigation using coir fibre and two types of coir mats on flexible pavement system subgrade and sub-base layer. Black cotton soil classified in CH group used as subgrade and sandy gravel as sub-base layer. CBR test for both unsoaked and soaked condition with varies amount of coir fibre like 0.25%-1.25% and Wheel tracking test (WTT) with coir mats at different levels over the subgrade soil. 1% coir fibre shows maximum increase in CBR value from 0.5 to 1.8% and from 5.51 to 8.12% for soaked and unsoaked condition respectively. Coir mats shows good results for all levels of embedment, also coir composite shows better performance in all levels[6].

Vivek et al. carried out investigation using two woven, two non-woven untreated, treated coir geotextile in both unsoaked and soaked condition. Monotonic load test was carried out by placing coir geotextile between sand layer overlying clay layer. River sand which is locally available in Sunder Nagar, Himachal Pradesh, India classified as poorly graded and clay was collected from Ludhiana, Punjab classified as high plasticity clay. Geotextile was treated with p-aminophenol, sodium periodate and sodium hydroxide. Tensile strength of woven coir geotextile decreased with chemical treatment. Bearing capacity improvement was observed after a certain deformation. Results shows that treated or untreated woven or non-woven geotextiles can be helpful in improving the bearing capacity of unpaved roads, particularly in conditions where the rut depth is high because the enhancement in bearing capacity was noticed up to greater deformation. Type A shows best results[7].

Sumi et al. investigates the resistance of coir geotextiles modified using cashew nut shell liquid (CNSL) at 20% (C20) and 40% (C40) amount towards microbial degradation by using a mixed

suspension composed of four fungal stains, Curvularia lunata, Chaetomium indicum, Penicillium rubrum and Aspergillus fumigatus; Subterranean Termite and Soil burial test for 240 days on the basis of moisture absorption, weight loss, surface morphology and tensile strength. CNSL was collected from Vijayalakshmi Cashew Company, India and geotextiles were collected from Charan Gattu coir manufacturing Co. (P) Ltd., India. The test soil was created by combining garden soil, cow dung, and sand. An increase in pull out resistance 45% and 43% was observed for C40 and C20 respectively. For untreated sample high loss of 26% in weight was observed while modified samples shows high resistance towards mixed culture at 60 days. Tensile strength got increased by 22% with both the percentage of CNSL. At the end of 240 days Untreated sample losses, it’s strength to 19% while treated sample retained upto 76% strength in case of soil burial. In case of termite untreated samples were completely degraded after120 days, weight loss of 19% was observed for treated samples and about 20% strength loss was recorded for treated samples, SEM verifies all the results[8].

Shirazi et al. used two patterns- plain and incline of untreated and treated woven kenaf with two different opening sizes 2 × 2 and 0 × 0 mm to carry the wide-width tensile strength test with geotextile buried for one year period in natural ground in dry and wet conditions. The chemical treatment was done with 6% NaOH solution. Treated plain pattern with 0 × 0 mm shows maximum improvement in the tensile strength to 51% and 45.5% for dry and wet conditions respectively. After one year treated samples shows loss in strength of 71.9% and 53.3% than those treated with unburied samples for dry and wet conditions respectively. Here, treated samples shows more degradation than untreated one but still having higher strength and elongation and break than the untreated samples[9].

Saha et al. carried out study using untreated and two treated jute geotextiles by performing chemical, biological and physical degradation for different days; water affinity and leachate tests. Geotextile was transesterified with plant tannin, sodium hydroxide, cashew nut shell liquid, neem oil, resorcinol, and formaldehyde in certain proportion by weight. Geotextiles that are woven from treated jute fibres designated as JG1 and the one which was treated at the fabric level designated as JG2. Geotextile was buried in a medium that was made by combining cow dung, sand, and organic black garden soil in a 1:1:2 by weight for biological degradation. In all degradation conditions untreated sample shows high degradation than treated samples. Complete degradation of untreated sample was reported for 90 days in soil burial study. Water absorption for JG1, JG2 and JGU was 90%, 120% and 270% respectively shows highest for untreated sample. In case of physical degradation JGU, JG1 and JG2 had retained 33%, 80%,75% respectively. Treated sample didn't show any chemical or toxicity risks[10].

3. OBJECTIVE

In this study, coir geotextile is embedded in two locally available soils from two different sites to find degradation rate.

1. To study the effect of coir geotextile embedded in both the soils by performing tensile strength and CBR test for 0, 15, 30, 90 and 135 days.
2. To conduct the morphological analysis of coir geotextile for 0 and 135 days, and chemical analysis of both the soils.

4. MATERIALS USED

4.1 Soil

Locally available soil samples are procured from Karnal and Kurukshetra districts of Haryana, India. The properties of soils are determined according to IS code specifications. The characteristics of both the soils are shown in Table 1.

4.2 Coir geotextile

Woven coir geotextile is collected from Rabitha exports in punnapra, Alappuzha, Kerala, India. The properties of soils are determined according to IS code specifications as shown in Table 2.

dung, sand, and organic black garden soil in 1:1:2 by weight for biological degradation. In all degradation conditions untreated sample shows high degradation than treated samples. Complete degradation of untreated sample was reported for 90 days in soil burial study. Water absorption for JG1, JG2 and JGU was 90%, 120% and 270% respectively shows highest for untreated sample. In case of physical degradation

Figure 1: Karnal and Kurukshetra soil samples

Table 1: Properties of soil samples

Properties	Specification	Karnal soil	Kurukshetra soil
Liquid limit (%)	[11]	28.75	20.76
Plastic limit (%)	[11]	20.63	16.52
Plasticity index (%)		8.12	4.24
Maximum dry density (g/cm^3)	[12]	1.88	2.06
Optimum moisture content (%)		14.9	9.3
California bearing ratio (%)	[13]	4.09	7.08
Classification	[14]	CL	CL-ML

Table 2: Properties of coir geotextile

Properties	Values
Width of roll (m)	1
Length of roll (m)	50
Thickness at 2kPa (mm)	7
Weight/Unit area (g/m^2)	640
Mesh size (mm)	6.35x6.35
Wide-width tensile strength (KN/m) (machine direction)	11.22
Strain at failure (%)	20.107

5. EXPERIMENTAL PROCEDURE

5.1 California bearing ratio test (CBR)

CBR mould was used as a container for seasoning of coir geotextile for 0, 15, 30, 90 and 135 days. Static CBR was performed, for this coir geotextile was cut to a size same as the diameter of CBR mould i.e., 15cm and placed at the top of spacer disc then soil was filled and compacted in such a way that when we invert CBR mould the geotextile comes at the top surface of the soil. The coir geotextile was then extracted from the mould after the above-mentioned days so as to perform soaked CBR test by making the sample in the same way.

5.2 Wide width tensile strength test

It was performed as per IS: 13162(Part-5)[15]. A mould of size 20.8x20.8x6.3cm^3 was made for the seasoning of coir geotextile of size 20x20cm^2 for 0, 15, 30, 90 and 135 days in it. Quantity of soil that was taken for this purpose is in accordance with 2163cm^2 (20.8x20.8x5) volume. Soil samples used were divided into a ratio of 2/3 and 1/3, the coir geotextile is embedded between these amounts of soil. After that the coir geotextile is extracted carefully at above mentioned days then tested for Wide-width tensile strength.

(a)

(b)

Figure 2: Seasoning of coir geotextile for (a) CBR test and (b) wide width tensile strength test

5.3 Chemical analysis

Chemical composition of the soils procured from two distinct locations are done by performing Energy-dispersive X-ray spectroscopy (EDS) test to find the chemical components such as potassium (K), nitrogen (N), manganese (Mn), phosphorus (P), ferrous (Fe), calcium (Ca) and copper (Cu) etc.

5.4 Morphological analysis

Morphological properties of coir fiber plucked from coir geotextile is studied by Scanning Electron Microscope. The morphological analysis of raw coir geotextile at 0th day as well as degraded coir fiber at 135th day was carried out by cutting them into small pieces of about 1cm.

6. RESULTS AND DISCUSSION

6.1 Tensile strength

Table 3 shows the values of tensile strength of coir geotextile before and after extracted from both subgrade soil at various days. It can be observed that the tensile strength of coir geotextile decreases as time increases. This reduction increases rapidly after 30days.

Table 3: Wide-width tensile strength of coir geotextile before and after extracted from soil samples

Soil samples	Wide-width tensile strength of raw coir geotextile (KN/m)	Wide-width tensile strength with coir geotextile extracted at different days (KN/m)			
		15	30	90	135
Karnal soil	11.22	10.5	9.6	6.8	4.2
Kurukshetra soil		10.4	9.2	6.2	3.8

6.2 CBR

CBR test also shows decreasing trend as the time of embedment increases as shown in Table 4 Reduction was found to be more in Kurukshetra soil which is of lower compressibility than Karnal soil. Decrease in tensile strength may cause the decrease in CBR values.

Table 4: Soaked CBR values of soils reinforced with coir geotextile

Soil samples	CBR values with raw coir geotextile	CBR values with coir geotextile extracted at different days			
		15	30	90	135
Karnal soil	7.74	6.9	6.4	5.6	5.4
Kurukshetra soil	12.92	11	10.6	9.3	8.8

6.3 Chemical analysis

Table 5 shows that Kurukshetra soil contains more nitrogen (N), calcium (Ca) and phosphorus (P) which promotes the bacteria growth. Presence of lime in soil makes the lignocellulose present in geotextile weak causing rapid decomposition. Also, as the alkalinity increases decomposition rate increases because [it removes waxy and oily and coating from the surface of coir fiber hence expose it to moisture intake.

Table 5.Chemical composition of soil samples

Soil sample	Elements weight (%)					
	N	P	K	Ca	Mn	Fe
Karnal soil	69.8	2.95	7.76	1.58	0.55	13.64
Kurukshetra soil	76.63	3.65	4.39	1.61	0.41	11.93

6.4 Morphological analysis

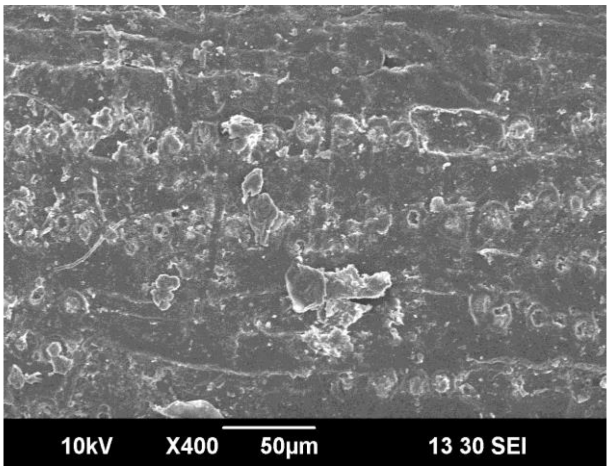

Figure 3: SEM image of raw coir fiber

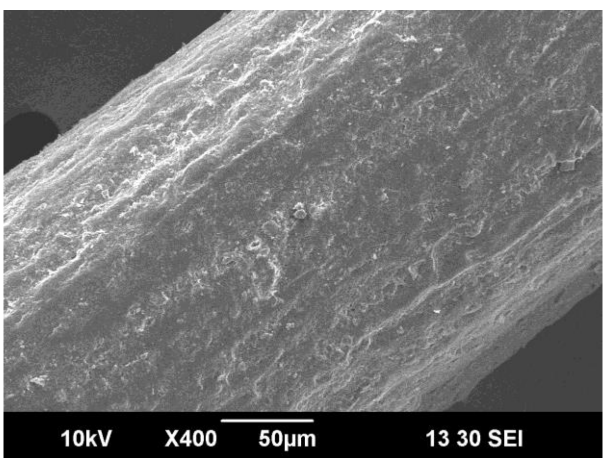

Figure 4: SEM image of coir fiber extracted from Kurukshetra soil after 135 days

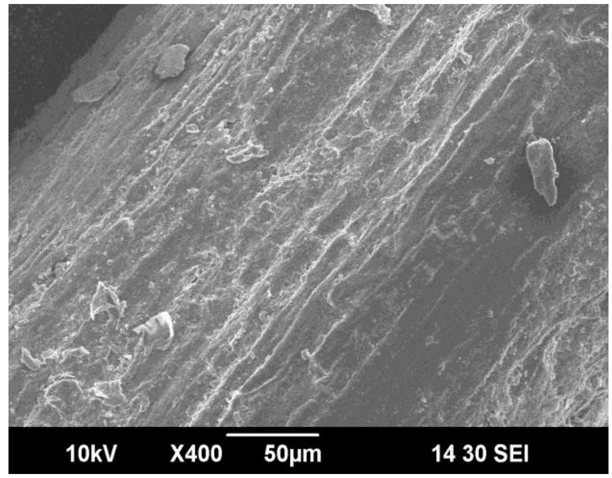

Figure 5: SEM image of coir fiber extracted from Karnal soil after 135 days

Figure 3Figure 4 Figure 5 clearly shows the degradation of coir fiber. It can be observed that at the end of 135 days the coir fiber surface gets rougher and more damaged than the raw fiber. This may be due to the environmental factors and microbial attack which may grow due to the presence of nutrients in the soil like P, K, Ca and N in the soil. Also, the degradation is more in Kurukshetra soil as the roughness and pore size is high in this soil.

7. CONCLUSION

Tensile strength and CBR values decrease as the time of embedment increases. The decomposition rate increases after 1 month. By analyzing the degradation rate in both the soils it can be seen that Degradation rate was higher in Kurukshetra soil which is low compressible then Karnal soil. This may be due to the presence of higher Ca, N, P and K in it which are the nutrients for bacteria increase their growth. SEM images also shows the same results. Also, the coir geotextile was found to be more disintegrate after extraction from Kurukshetra soil.

The laboratory studies underestimate the capabilities of coconut geotextile. This can be because of circumstances in the field and the lab differ from each other like that of sample size, depth of embedment, good drainage across resists accumulation of water. Hence, rate of degradation in laboratory studies are faster than actual one.

8. ACKNOWLEDGEMENT

This work was supported by N.I.T. Kurukshetra.

REFERENCE

[1] M. K. Sayida, S. Evangeline, A. Vijayan, and M. S. Girish, "Durability Study of Coir Geotextile Embedded in Different Types of Subgrade Soil," *J. Nat. Fibers*, vol. 19, no. 6, pp. 2288–2298, 2022, doi: 10.1080/15440478.2020.1808146.

[2] S. Sumi, N. Unnikrishnan, and L. Mathew, "Durability studies of surface-modified coir geotextiles," *Geotext. Geomembranes*, vol. 46, no. 6, pp. 699–706, 2018, doi: 10.1016/j.geotexmem.2018.07.007.

[3] M. Arora, R. K. Dutta, and A. Jain, "Characterization, Durability, and Application of Treated Coir Geotextiles in Low Volume Roads," *J. Nat. Fibers*, vol. 19, no. 12, pp. 4509–4529, 2022, doi: 10.1080/15440478.2020.1863297.

[4] A. R. Marques, P. Santiago de Oliveira Patrício, F. Soares dos Santos, M. L. Monteiro, D. de Carvalho Urashima, and C. de Souza Rodrigues, "Effects of the climatic conditions of the southeastern Brazil on degradation the fibers of coir-geotextile: Evaluation of mechanical and structural properties," *Geotext. Geomembranes*, vol. 42, no. 1, pp. 76–82, 2014, doi: 10.1016/j.geotexmem.2013.07.004.

[5] D. E. Miller, T. R. Hoitsma, and D. J. White, "Degradation rates of woven coir fabric under field conditions," *Eng. Approaches to Ecosyst. Restor.*, pp. 266–271, 1998, doi: 10.1061/40382(1998)46.

[6] D. Harinder, P. Yugendar, and S. Shankar, "Experimental assessment of coir geotextile to improve the strength of weak subgrade at different load conditions," *Mater. Today Proc.*, vol. 62, pp. 1785–1789, 2022, doi: 10.1016/j.matpr.2021.12.351.

[7] Vivek, R. K. Dutta, and R. Parti, "Application Potential of Treated Coir Geotextiles in Unpaved Roads," *J. Nat. Fibers*, vol. 17, no. 10, pp. 1454–1467, 2020, doi: 10.1080/15440478.2019.1578718.

[8] S. Sumi, N. Unnikrishnan, and L. Mathew, "Experimental Investigations on Biological Resistance of Surface Modified Coir Geotextiles," *Int. J. Geosynth. Gr. Eng.*, vol. 2, no. 4, pp. 1–9, 2016, doi: 10.1007/s40891-016-0073-3.

[9] M. G. Shirazi, A. S. A Rashid, R. Bin Nazir, A. H. Abdul Rashid, A. Kassim, and S. Horpibulsuk, "Investigation of tensile strength on alkaline treated and untreated kenaf geotextile under dry and wet conditions," *Geotext. Geomembranes*, vol. 47, no. 4, pp. 522–529, 2019, doi: 10.1016/j.geotexmem.2019.01.016.

[10] P. Saha, D. Roy, S. Manna, B. Adhikari, R. Sen, and S. Roy, "Geotextiles and Geomembranes Durability of transesteri fi ed jute geotextiles," vol. 35, 2012, doi: 10.1016/j.geotexmem.2012.07.003.

[11] IS: 2720(Part-5)-1985, "'Indian Standard Methods of Test for Soil: Determination of Liquid Limit and Plastic Limit', BIS-New Delhi.," 1985.

[12] IS:2720(Part-8)-1983, "Indian Standard Methods of Test for Soils-Determination of water content-dry density relation using heavy compaction, BIS-New Delhi" 1983.

[13] IS:2720(Part-16)-1987, "Indian Standard Methods of Test for Soils- Determination of CBR, BIS- New Delhi" 1987.

[14] IS: 1498-1970, "Indian Standard Methods of Test for Soils-Classification and identification of soils for general engineering purposes, BIS-New Delhi" 1970.

[15] IS:13162(Part-5)-1992, "Indian standard geotextile-method of test-Determination of tensile properties using a wide width strip, BIS-New Delhi" 1992.