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Study of Application of Coir Geotextile used in Rural Road Construction

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ABSTRACT: Total productive maintenance is one of the most valuable strategies to follow for those who want to be competitive over the coming "world class competition" decades. Total productive maintenance (TPM) is a maintenance program, which involves a newly defined concept for maintaining plants and equipment's. The goal of the TPM program is to markedly increase production while, at the same time, increasing employee morale and job satisfaction. After carrying out several visits and direct observations of machines on the production shop floor and analyzing previous machine utilization records at Kasturi Metals Pvt. Ltd., it was found that machines were not operating up to its full production capacity due to problems associated with it. A Case Study conducted on machines of the production shop floor is used to illustrate need for implementation of TPM. Thus by the application of TPM it was found that the stepwise implementation of TPM in the company marked improvements in availability, performance efficiency and quality rate and thereby leading to increase in OEE of model machine and which will further lay down foundation for companywide implementation of TPM.

I. INTRODUCTION

As we know, most of the unpaved roads are built in weak subgrade even through the traffic intensity is low in rural roads. This can be considered as one of the major problems of rural roads. Several experiments are going for the stabilization of soil using different materials. One of them is geosynthetics. Geosynthetics 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 functions as reinforcement, separation and drainage. To avoid all such inherent problem of rural roads, it can be reinforced by laying geosynthetics in between subgrade and subbase/base course.

1.1 Problem Definition

Soil properties vary a great deal and construction of structures depends a lot on the bearing capacity of the soil, hence, we need to stabilize the soil to improve the load bearing capacity. The gradation of the soil is also a very important property to keep in mind while working with soils. The soils may be well-graded which is desirable as it has less number of voids or uniformly graded which though sounds stable but has more voids. If roads are built on poor subgrade soils, deformations can occur, thus which increase maintenance cost and lead to interruption of traffic service.

1.2 Objectives of the Study

a) To study the effect of the soil strength after the application of geotextile materials. This study was primarily concerned with the use of coir geotextile materials to strengthen the soil.
b) To study the outcome of analysis of the rut behaviour of coir geotextile reinforced under static as well as repetitive wheel loads.
c) Evaluation of the strength and compressibility characteristics of coir fibre reinforced soil.
d) To study the improvement in the engineering characteristics of reinforced coir geotextile in BC soil for road construction and to explore the possibility of usage of coir as geotextile in rural road construction on large scale basis.
e) To study the performance of coir geotextile in rural road construction where Black Cotton soil is expansive in nature, having low shear strength and swelling/shrinkage.

II. RESEARCH METHODOLOGY

2.1 Materials used for study

2.1.1 Black Cotton soil

Black soils are formed by lava basaltic rocks. Hence they are very dark in color. They develop cracks during dry period and swell if got moisture, hence they are self-tilling in nature, that's why they are fertile and can hold water for long time. This capacity is used for Cotton cultivation, hence they also called Regular Black Cotton Soil.

Expansive soils, popularly known as black cotton soils in India are, amongst the most problematic soils from Civil Engineering construction point of view. Of the various factors that affect the swelling behaviour of these soils, the basic mineralogical composition is very important. Most expansive soils are rich in mineral montmorillonite and a few in illite.Black soils are formed by lava basaltic rocks. Hence they are very dark in color. They develop cracks during dry period and swell if got moisture, hence they are self-tilling in nature, that's why they are fertile and can hold water for long time. This capacity is used for Cotton cultivation, hence they also called Regular Black Cotton Soil.

2.1.2 Properties of black cotton soil

a) Black soil has a texture like clayey and is highly fertile.
b) Black soil structure is cloddish or sometimes friable.
c) Black soil when dry gets a contract and develops deep wide cracks.
d) Black soil expands when they are wet and they are hard to plow.
e) Black soil contains almost 50% of clay and can hold water for a long time.

2.1.3 Characteristics of Black cotton soil

Table 2.1: Physical properties of BC Soil

Property	Value
Dry density (γd)	1300- 1800 Kg/m³
Liquid Limit (L.L.)	40 - 120%
Plastic Limit (P.L.)	20 - 60%
Activity	0.8- 18%
Specific Gravity(G)	2.60 - 2.75
Proctor Density	1350- 1600 Kg/m³
OMC (Max dry density)	20- 35%
Free Swell Index	40- 180%
Swelling pressure	50- 800 KN/m²
C.B.R. (soaked)	1.2- 4.0
Compression Index	0.2- 0.5
Fines(<75m)	70- 100%
2 µ Fraction	20 - 60%
Soil Classification	CH or MH

2.1.3 Coir Geotextile

Testing and evaluation of coir geotextiles is a key issue, which can answer the question of successful performance in the field. Most of the properties of coir geotextiles are obtained in the same way as that of polymeric geotextiles. No separate testing procedures have evolved so far. Again, though coir geotextiles are classified based on the type of yarn and other parameters, standardization of coir geotextiles is yet to be evolved.

Table 2.2: Engineering properties of coir fibre

Property	Value
Length (mm)	15 - 280
Density (g/ cc)	1.15 – 1.4
Tenacity (gltex)	10
Breaking elongation (%)	30
Diameter (mm)	0.1 -1.5
Rigidity modulus (dynes/cm^2)	1.8924
Swelling in water (diameter)-(%)	5
Moisture at 65% RH (%)	10.5
Specific gravity	1.15
Young's modulus (GN/m^2)	4.5
Specific heat	0.27

2.2 TESTS CONDUCTED

2.2.1 Proctors Compaction Test

Proctors compaction test is used to find the optimum moisture content of the soil sample in California Bearing Ratio Test.

2.2.2 California Bearing Ratio Test

The object of the experiment is to determine the California Bearing Ratio (C.B.R) of a soil compacted soil sample in the laboratory, both in soaked as well as unsoaked state. The method also covers the determination of CBR of undisturbed soil sample obtained from the field.

2.2.3 Direct Shear Test

This is the most common test used to determine the shear strength of the soil on predetermined failure surfaces. It can be defined by Mohr-Coulomb theory depicted by the equation goes as follows:

$\tau = c + \sigma * \tan(\varphi)$

This test is performed to determine the consolidated-drained shear strength of a sandy to silty soil. The shear strength is one of the most important engineering properties of a soil, because it is required whenever a structure is dependent on the soil' s shearing resistance. The shear strength is needed for engineering situations such as determining the stability of slopes or cuts, finding the bearing capacity for foundations, and calculating the pressure exerted by a soil on a retaining wall.

2.2.4 Rut Behaviour Test

A road continuously deteriorates under the combined action of traffic loading and the environment. The most common indicators of pavement performance, the ability of roads to satisfy the demands of traffic and environment over its design life, are surface rutting, fatigue cracking, riding quality and skid resistance. Geotextiles increase the stability and improve the performance of weak subgrade soils primarily by separating the sub base from the subgrade. Placing geotextile at subgrade-sub base or sub base-base interface, subgrade restraint can be enhanced which will facilitate the mobilization of heavy construction machinery at site. The mechanisms attributing to this are increased bearing capacity in addition to lateral restraint and tension membrane effect. Substantial life cycle cost saving is possible with geosynthetic reinforced aggregate base course in pavements.

III. IMPLEMENTATION

3.1 Compaction Test

The Modified Proctor's Test have been conducted for the determination of the Optimum Moisture Content(w) and Maximum Dry Density($\Upsilon d(max)$) of the plain (Table-3.1) as well as coir geotextile reinforced soil (Table-3.2) by compacting the soil samples manually.

Fiber-reinforced soil samples were prepared by mixing BC soil and different percentage of coir fibers on dry weight basis using maximum dry density and water content corresponding to OMC obtained from compaction test. Fibers were mixed with wet soil randomly, place in the mould and compacted to get 97% of the desired density.

Different percentage of coir fibers were added to BC soil and tested in tri-axial compression testing machine. Parameters such as percentage of reinforcement and length of coir-

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fibers were considered for investigation. Samples were prepared by adding coir fibers at different percentage and with different length viz., 10mm and 20mm. Undrained tri-axial tests were conducted in a standard tri-axial apparatus, with and without coir fibers, to study the improvement in the shear strength parameters of black cotton soil. Size of soil specimen used was 38 mm diameter and 76 mm high. Sufficient care was taken so that coir fiber distribution was uniform thought the mixed soil.

Tests were conducted for fiber contents of 0.5%, 1.0%, and 1.5% by dry weight of soil, The specimens were subjected to three levels of confining pressures (100kPa, 200kPa, and 300kPa). The tests were repeated by mixing BC soil with fiber lengths 10mm and 20mm. Deviator stress was applied up to 15% axial strain level or up to the failure of specimen which ever occurred earlier. The peak deviator stress increases with increase in fiber content only up to a specified percentage of fiber content, for all length of fibers used.

Table 3.1: Data for OMC-MDD of Plain Soil Samples

Sample No.	**Dry Density (g/cc)**	**Moisture Content (%)**
1	1.67	7.56
2	1.76	6.83
3	1.98	6.5
4	1.72	10.11

Table 3.2: Data of OMC – MDD for the Soil Reinforced with Coir fibre of 10mm & 20mm size

Percentage of coir with soil (%)	**Length of Coir fibre**	**Dry Density (g/cc)**	**Moisture Content (%)**
0	10mm	1.98	6.5
0.5		1.86	12
1		1.77	16
1.5		1.72	19
0	20mm	1.98	6.5
0.5		2.12	15
1		2.6	19
1.5		2.3	18

Unreinforced Black Cotton soil showed optimum moisture content of 19% and a maximum dry density of 2.60g/cm3. It was observed that addition of coir fibre increased the maximum dry density, with the optimum value being at 1% Coir Fibre. Optimum moisture content was observed to be decreasing with increasing percentages of Coir fibre with the optimum value being at 1%.

3.2 Direct Shear Strength Test

Shear parameters were determined from modified failure envelope. It is found that modified failure envelopes of soil with different fiber contents are parallel to each other. Using the modified failure envelopes the shear parameters such as cohesion (c) and angle of internal friction (F) were calculated.

Fig. 5.4 shows the variation of cohesion with fiber content for different length of fiber for BC soil admixed with coir fiber. It can be seen that, increase in length of the fiber increases ERT cohesion. However, when length of the fiber becomes large ERT than 1.0mm, there is marginal decrease in cohesion. This is attributed to the fact that, increase in length beyond 20mm of coir fiber induces difficulty in uniform mixing with the formation of soil lumps.

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Table 3.3: Value of Cohesion Parameters of the coir fibres of different length

S. No.	Fibre content (%)	Cohesion in kPa	
		10mm size	20mm size
1	0	115	115
2	0.5	140	160
3	1	152	230
4	1.5	100	195

Table 3.3 shows variation of angle of internal friction (ø) obtained for different fiber content and fiber length. Increase in fiber content increases ø for BC soil. It can be seen that increase in length increases ø up to 1% of 10mm & 20mm. Beyond 1%, the ø value decrease marginally.

3.3 California Bearing Ratio (CBR) Test

The soil samples of unreinforced and reinforced soil for CBR test were prepared as per standard procedure. The desired amount of oven dried (100-1050C) soil was taken and mixed thoroughly with water corresponding to its optimum moisture content (OMC) in the CBR mould having 150 mm diameter and 175 mm high with detachable perforated base plate (IS:2720-XVI). The soil was then compacted to its maximum dry density obtained by laboratory standard Proctor test. For the preparation of soil samples of reinforced soil the desired amount of Polypropylene and Polyethylene fibers was mixed in dry state before the addition of water and then compacted to same Proctor density as per IS: 2720, Part VII- (1974). The top surface of the specimen in the CBR mould was made level and a filter paper and a perforated metallic disc were placed over the specimen. The CBR mould along with compacted soil and surcharge load of 5 kg was then transferred to a tank containing water for soaking of the sample as shown.

After 4 days (i.e. 96 hours) of soaking, the mould assembly was taken out from water and the top surface of sample was left exposed to air for half an hour. The CBR mould along with soaked soil sample was brought to a motorized loading frame for testing. The CBR values of the test samples of unreinforced and reinforced soil were determined corresponding to plunger penetrations of 2.5mm and 5.0mm as per the standard procedure laid down in IS: 2720, Part XVI (1965). The results are shown in Table 3.4 and Table 3.5.

Table 3.4: California Bearing Ratio Test Results for BC soil reinforced with Coir fibre 10mm length

Description	CBR value for Penetration of	
	2.5mm	5.0mm
Soil Alone - Unsoaked	4	3.99
Soil + 0.5% Coir – Unsoaked	5.8	5.6
Soil + 1% Coir – Unsoaked	6.5	6.4
Soil + 1.5% Coir – Unsoaked	6.4	6.2
Soil Alone - Soaked	2.8	2.7
Soil + 0.5% Coir – Soaked	4.7	4.4
Soil + 1% Coir – Soaked	5.1	5
Soil + 1.5% Coir – Soaked	4.9	4.75

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Table 3.5: California Bearing Ratio Test Results for BC soil reinforced with Coir fibre 20mm length

Description	**CBR value for Penetration of**	
	2.5mm	**5.0mm**
Soil Alone - Unsoaked	4	3.99
Soil + 0.5% Coir – Unsoaked	6.2	6.1
Soil + 1% Coir – Unsoaked	8.6	7.9
Soil + 1.5% Coir – Unsoaked	7.6	6.5
Soil Alone - Soaked	2.8	2.7
Soil + 0.5% Coir – Soaked	5.8	5.7
Soil + 1% Coir – Soaked	8.1	7.9
Soil + 1.5% Coir – Soaked	7.5	6.3

From above data, it is observed that the CBR value in soaked and unsoaked condition for soil with coir fibre is increased than that of virgin soil respectively. There is about increase in CBR value upon addition of 1% fibers of 10mm length. The similar trend of increase in CBR value upon coir fiber of 20mm length is noted.

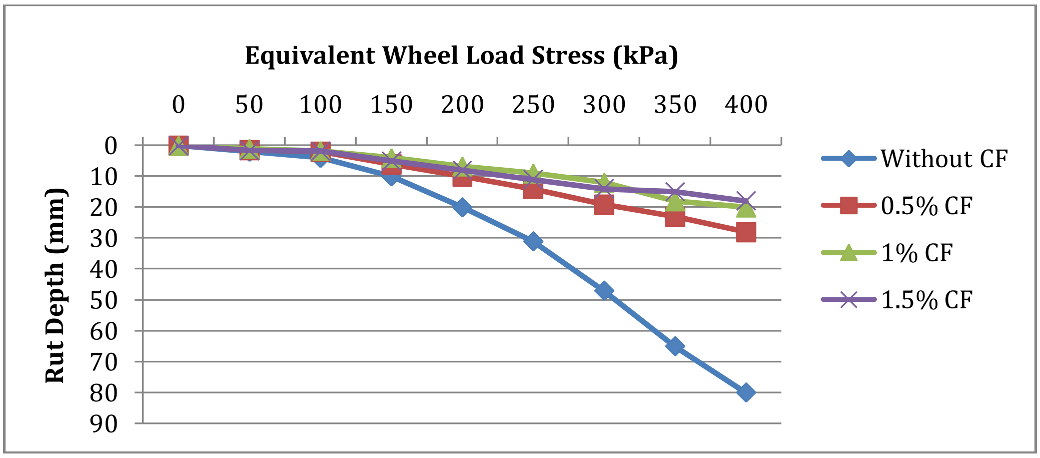
3.4 Rut Behaviour Test

3.4.1 Under Static Wheel Loads

Plate bearing tests were performed to investigate the behaviour of coir geotextile reinforced unpaved roads under static loads. The test section consisted of 600mm thick subgrade overlain by water bound macadam (WBM) 150 mm thick. The tests were done as per the current Indian Standard test procedure for plate load tests. The load was applied through the thick square mild steel plate. Rut measurements were taken by LVDT placed one each at four corners of the plate.

Load was applied at regular intervals and corresponding settlements were noted. Each load was kept constant until the rate of settlement reduces to less than 0.025mm/minute. Fresh soil samples, aggregates and coir geotextiles were used for each testing.

It could be observed from the test results that, in the case of without Coir geotextiles for a rut depth of 20mm the carrying capacity was 200kN/m2. With 0.5%, 1% and 1.5% coir fibre reinforcement the carrying capacity is increased to 300kN/m2, 350kN/m2 and 400kN/m2 respectively. So, the effect on carrying capacity due to the added percentage of coir fibre is found.



Graph 3.1: Effect of layer of coir geotextile (10mm)

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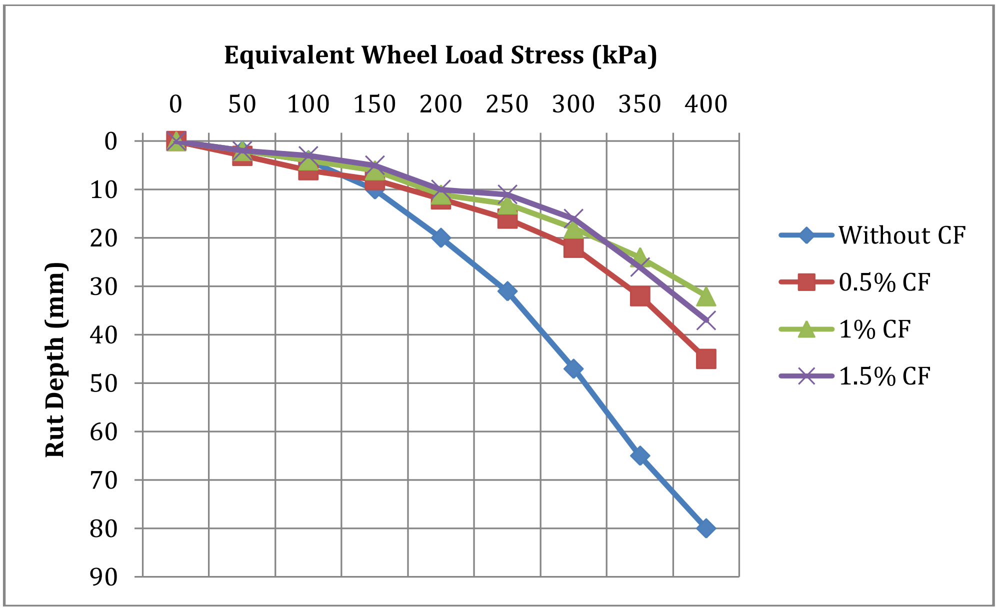

Graph 3.2: Effect of layer of coir geotextile (20mm)

3.4.2 Rut Behaviour Under Repetitive Loads

In order to study the benefits of applying coir geotextile reinforcement in improving rutting resistance of unpaved roads, laboratory wheel tracking tests were performed. The details of the study are explained in the following sections.

From the experimental results it was observed that Coir geotextiles reinforcement can substantially reduce the rut depth due to static as well as repetitive wheel loads. In both cases, it was noticed that 1% added coir geotextiles (10mm & 20mm) produced almost identical results.

IV. RESULTS AND DISCUSSION

From the experiments conducted, following results are obtained

4.1 BC Soil Reinforced With 10mm Coir Fibre (CF)

1. Maximum dry density of the soil sample increased with increasing percentages of coir fibre, optimum value being that at 1% CF.
2. The Optimum moisture content decreased with increasing percentages of CF. The optimum value was obtained at 0.5% CF. At 1% CF, the water content obtained was about triple as that of unreinforced soil.
3. The variation of cohesion with fiber content for different length of fiber for BC soil admixed with coir fiber. It can be seen that, increase in length of the fiber increases ERT cohesion. However, when length of the fiber becomes large ERT than 1.0%, there is marginal decrease in cohesion. This is attributed to the fact that, increase in length beyond 1% of coir fiber induces difficulty in uniform mixing with the formation of soil lumps.
4. Variation of angle of internal friction (ø) obtained for different percent of fiber content and fiber length. Increase in fiber content increases ø for BC soil. It can be seen that increase in length increases ø up to 1% of 10mm. Beyond 1%, the ø value decrease marginally.
5. In unsoaked condition, the C.B.R. value at 2.5mm penetration increases in the range of 4.0 to 6.5 for addition up 1% of CF fibers and decreases afterwards. In case of 5mm penetration, C.B.R. value increases in the range of 3.99 to 6.4 for addition up to 1% of CF and decreases afterwards. Therefore, addition of 1% fibers can be considered as an optimum mix.
6. In soaked condition, the C.B.R. value at 2.5mm penetration increases in the range of 2.8 to 5.1 for addition up 1% of CF fibers and decreases afterwards. In case of 5mm penetration, C.B.R. value increases in the range of 2.7 to 5.0 for addition up to 1% of CF and decreases afterwards. Therefore, addition of 1% fibers can be considered as an optimum mix.
7. It could be observed from the rut behavior test under static loads, the results shows that, in the case of without Coir geotextiles for a rut depth of 20mm the carrying capacity was 200kN/m2. With 0.5%, 1% and 1.5% coir fibre reinforcement the carrying capacity is increased to 300kN/m2, 400kN/m2 and 350kN/m2 respectively. So, the effect on carrying capacity

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due to the added percentage of coir fibre is found.

8. From the experimental results of rut behavior test under repetitive loads, it was observed that Coir geotextiles reinforcement can substantially reduce the rut depth due to static as well as repetitive wheel loads. In both cases, it was noticed that 1% added coir geotextiles (10mm) produced almost identical results.

4.2 BC Soil Reinforced With 20mm Coir Fibre (CF)

1. Maximum dry density of the soil sample increased with increasing percentages of coir fibre, optimum value being that at 1% CF.
2. The Optimum moisture content decreased with increasing percentages of CF. The optimum value was obtained at 1% CF. At 1% CF, the water content obtained was about triple as that of unreinforced soil.
3. The variation of cohesion with fiber content for different length of fiber for BC soil admixed with coir fiber. It can be seen that, increase in length of the fiber increases ERT cohesion. However, when length of the fiber becomes large ERT than 1.0%, there is marginal decrease in cohesion. This is attributed to the fact that, increase in length beyond 1% of coir fiber induces difficulty in uniform mixing with the formation of soil lumps.
4. Variation of angle of internal friction (ø) obtained for different percent of fiber content and fiber length. Increase in fiber content increases ø for BC soil. It can be seen that increase in length increases ø up to 1% of 20mm. Beyond 1%, the ø value decrease marginally.
5. In unsoaked condition, the C.B.R. value at 2.5mm penetration increases in the range of 4.0 to 8.6 for addition up 1% of CF fibers and decreases afterwards. In case of 5mm penetration, C.B.R. value increases in the range of 3.99 to 7.9 for addition up to 1% of CF and decreases afterwards. Therefore, addition of 1% fibers can be considered as an optimum mix.
6. In soaked condition, the C.B.R. value at 2.5mm penetration increases in the range of 2.8 to 8.1 for addition up 1% of CF fibers and decreases afterwards. In case of 5mm penetration, C.B.R. value increases in the range of 2.7 to 7.9 for addition up to 1% of CF and decreases afterwards. Therefore, addition of 1% fibers can be considered as an optimum mix.
7. It could be observed from the rut behavior test under static loads, the results shows that, in the case of without Coir geotextiles for a rut depth of 20mm the carrying capacity was 200kN/m2. With 0.5%, 1% and 1.5% coir fibre reinforcement the carrying capacity is increased to 300kN/m2, 350kN/m2 and 400kN/m2 respectively. So, the effect on carrying capacity due to the added percentage of coir fibre is found.
8. From the experimental results of rut behavior test under repetitive loads, it was observed that Coir geotextiles reinforcement can substantially reduce the rut depth due to static as well as repetitive wheel loads. In both cases, it was noticed that 1.5% added coir geotextiles (20mm) produced almost identical results.

V. CONCLUSION

In poor soils the soil sub-grade strength and other desirable properties can be achieved by various means. The conventional method such as lime, cement, fly ash stabilization can be used as per their availability/practicality. The geosynthentic offers wide variety of products to solve may geotechnical problems being non-biodegrable and costly. Their use should be restricted the natural materials like coir geotextile can be an option to improve the poor sub-grade soil.

- This research is the outcome of the extensive research work carried out to explore the possibility of utilising coir geotextiles, a natural eco friendly material, for the construction of rural roads.
- Experiments were done to study the applications of coir geotextiles. This was accomplished by performing elaborate laboratory investigations in different aspects.
- The main focus in the present investigation was to conduct systematic research work on the use of coir geotextiles, so that new methods of application can be evolved which will pave way for the growth of traditional coir industry.
- On the basis of present experimental investigation, the conclusion can be drawn that coir geotextile can play a vital role in the construction of rural roads.

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