Performance studies on Coir Geotextiles in Pavements having Soft Soil Subgrade

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CONTENT

CHAPTER 1

INTRODUCTION

India has one of the largest road networks in the world, aggregating to about 33 lakh km at present. However many of the existing roads are becoming structurally inadequate because of the rapid growth in traffic volume and axle loading. At locations with adequate subgrade bearing capacity/CBR value, a layer of suitable granular material can improve the bearing capacity to carry the expected traffic load. But at sites with CBR less than 2% problems of shear failure and excessive rutting are often encountered. The ground improvement alternatives such as excavation and replacement of unsuitable material, deep compaction, chemical stabilization, pre loading and polymeric geosynthetics etc are often used at such sites. The cost of these processes as well as virgin material involved is usually high and as such they are yet to be commonly used in developing nations like India. In this context natural fiber products hold promise for rural road construction over soft clay.

India is the first largest country, producing coir fiber from the husk of coconut fruit. The coir fiber (50 to 150 mm long and 0.2 to 0.6 mm diameter) till recently were spun into coir yarn and then woven to obtain woven nettings. The fibers are now a days being needle punched or adhesive bonded to obtain non woven products or blankets. Geotextiles are proving to be cost effective alternative to traditional road construction method. Studies have indicated that the biodegradability of coir can be used to advantage and the coir based geotextile have the potential of being used for rural road construction over soft clay. In paved and unpaved road construction, geosynthetic reinforcement has been applied to improve their overall strength and service life. The stabilization of pavements on soft ground with geotextiles is primarily attributed to the basic functions of separation of base course layer from subgrade soil, reinforcement of composite system etc. But these synthetic products are biodegradable and cause environment problems, whereas natural geotextile like coir is biodegradable.

In paved and unpaved road construction, geosynthetic reinforcement has been applied to improve their overall strength and service life. The stabilization of pavements on soft ground with geotextiles or geogrid is primarily attributed to basic functions of separation of base course layer from subgrade soil, reinforcement of composite system etc.

The report presents the results of CBR and plate load test carried in a model test tank simulating rural roads with coir geotextiles. The results of the test in the laboratory and the construction of road stretches at 3 locations, with each 100m length are encouraging for use in developing countries (like India) in rural roads that are yet to be developed to connect as many as 0.2 million villages as most of these roads happen to be on soft clay. The coir board has sanctioned the project titled **"Performance study on Coir Geotextiles in pavements having soft soil subgrade"** to the department of Civil Engineering, College of Engineering Trivandrum. The main objective of the project is to construct 100m stretches of Coir geotextile reinforced road and evaluate the performance. These details of the test stretches and the results of tests conducted in the laboratory are described in this report.

The details of project are as follows.

Project title**: "Performance study on Coir Geotextiles in pavements having soft soil subgrade"**

Name of Investigators:

Principal Investigator of the project : - Dr. Mariamma Joseph,
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OBJECTIVES OF PROJECT

The main objective of the project is to reduce maintenance cost and increase pavement longevity of roads in rural roads using Coir Geotextiles. The precise objectives are the following.

- To review the literature on coir geotextile reinforced rural roads.
- To study the load settlement behaviour of Coir Geotextile reinforced and unreinforced subgrade in the laboratory.
- To construct 300 m road at 3 location of each 100 m length, rural roads reinforced with coir geotextiles and study its performances.

Project Sanction date: 15/11/2007
Coir Board order no CCRI/Res/C.Proj/2007

STUDY AREA

Three roads were selected for the study. The 3 roads are selected such that the subgrade CBR is very low. They are

1. Chirakkad- Kumbakkad Road in Varkala Block [Trivandrum Dist]
2. Mangala Bharathi- SN Kadavu Road in Harippad Block [Alleppy Dist]
3. Kozhimada -Murukkampuzha Road in Kazhakoottom Block [Trivandrum Dist]

All the three roads selected come under PMGSY Scheme.

CHAPTER 2

LITERATURE REVIEW

2.1 GEOSYNTHETICS

Geosynthetics are Synthesized Polymeric or natural materials used to solve Coir Engineering problem. The problem of rural roads on soft soil can be solved to some extent using Geosynthetics. Polymeric materials are polypropylene, polyethylene, nylon, polyester etc. Natural geosynthetics are produced from natural materials like coir, jute, sisal etc. The manufacturing process of geotextiles defines two key terms, the machine direction (MD) and the cross-machine direction (XD). The MD is parallel to the longitudinal (unrolled roll length) direction, likewise XD corresponds to the shorter length and transverse direction.

A geotextile is similar to a fabric. It is manufactured by interweaving together numerous yarns in a close-knit pattern. The pattern is tight enough to filter sand/aggregate particles, thus an apparent opening size (AOS) typically characterizes the openings of a geotextile

A geosynthetic is affected by its surroundings or Environment. Environmental factors that contribute to the degradation of geosynthetics include UV radiation (sunlight), mechanical/physical wear, long duration loads, and temperature. For instance a polypropylene textile or grid, will creep when exposed to tensile loads. Creep is also enhanced by an increase in temperature and additionally, UV radiation in sunlight can cause serious degradation and weakening of polymer bonds.

2.2 HIGHWAY APPLICATIONS

There are many applications of geosynthetics. Even within the highway application of geosynthetics, further division is necessary for clarity. Geosynthetic highway applications can be split into two areas, which are unpaved and paved roads. It is important to distinguish between the two, since different theories, physical mechanisms, design methodologies and failure criteria are utilized for each.

2.2.1 Unpaved Road

An unpaved road haul loads across undeveloped terrain. Typically, such grades are crossed with a minimum amount of preparation that allows for an efficient movement of relatively few, but heavy, load repetitions. Rutting in the wheel paths is allowed but typically desired to be four inches or less in depth. Regrading or leveling of the ruts can be performed but is not typically, considered for an initial design of a layer of select granular material, which is placed upon the subgrade as a surface course. The purpose of this surface course is to transfer the surface load to the subgrade while spreading out the load to the subgrade, which effectively reduces the intensity of pressure on the subgrade (Steward et al. 1977).

A geosynthetic placed properly does improve an unpaved road. The most effective location of the geosynthetic is below the select granular material and on the subgrade surface (Das et al. 1998). In this location the geosynthetic provides separation, lateral restraint of the upper granular course and a tensioned membrane effect when strained extensively. A geotextile separates a granular course from a fine-grained subgrade, due to its relatively small apertures or apparent opening size (AOS). However, a geogrid also provides separation due to its less than 100 percent open area and better lateral restraint of upper granular particles. Due to interface friction and interlock with many individual ribs, a geogrid provides superior lateral restraint of the upper granular course, whereas the geotextile relies exclusively on interface friction for lateral restraint (Steward et al. 1977). The tensioned membrane effect requires that the geosynthetic be extensively strained (i.e., deeply rutted) for this mechanism to contribute a significant benefit.

2.2.2 Paved Road

The other application is the paved road. This application also encompasses the unpaved application since during construction of a paved road relatively few repetitions of trucks heavily loaded with construction materials traverse the partially completed (unpaved) highway grade. This often leads the road to critical stage. Then, construction is completed with placement of an asphalt surface course, thus the highway is paved and open to the public. The opened highway is exposed to many repetitions from loaded truck traffic; however the intensity of subgrade load is considerably less due to the greater stiffness of the surface course. Benefits of an underlying geosynthetic during construction are apparent, but as time and greater numbers of load cycles pass, the benefits are not as clear for the paved road (Barksdale et al. 1989).

Geogrids and geotextiles are the two types of geosynthetics most widely used in pavement systems at aggregate subgrade interface to reinforce or stabilize pavements. Field evidences suggest that both geogrid and geotextile could improve the performance of pavement sections constructed on weak soil.

Several investigators have reported significant effects of pavement stabilization using geotextile reinforcement to improve the bearing capacity of subgrade soil.

Steve et al. (2005) conducted a field demonstration to study how the performance of highway pavements is improved with geotextiles. In his research a field demonstration was conducted using a 21-m section along a Wisconsin highway (USH 45) near Antigo, Wisconsin, that incorporated three test sub-sections. Three different geosynthetics including a woven geotextile and two different types of geogrids had been used for stabilization. Observations made during and after construction indicate that all sections provided adequate support for the construction equipment and that no distress seems to be evident in any part of the highway. Large-scale experiments conducted on working platforms of crushed rock (breaker run stone or Grade 2 gravel) overlying a simulated soft subgrade. The tests were intended to simulate conditions during highway construction on soft subgrades where the working platform is used to limit total deflections due to repetitive loads applied by construction traffic. Tests were conducted with and without geosynthetic reinforcement to evaluate how the required thickness of the working platform is affected by the presence of reinforcement. Working platforms reinforced by geosynthetics accumulated deformation at a slower rate than unreinforced working platforms, and in most cases deformation of the geosynthetic reinforced working platforms nearly ceased after 200 loading cycles. As a result, total deflections were always smaller (about a factor of two) for reinforced working platforms relative to unreinforced working platforms.

Hans and Andrew (2001) investigated the reinforcement function of geosynthetics for a typical Minnesota low volume roadways. From the study it was observed that the addition of a geosynthetic does provide reinforcement to the roadway as long as the geosynthetic is stiffer than the subgrade material. The service life of a roadway may also be increased with the addition of geosynthetic reinforcement. It was also observed that the deflection response of roadway is governed by the Young's modulus of the geosynthetic used. Since the deflections were controlled by the Young's modulus of the geosynthetic; the largest modulus geosynthetic produced the largest increase in service life.

Schriver at al. (2002) conducted experimental study on geogrid reinforced lightweight aggregate beds to determine their subgrade modulus and increase in the bearing capacity ratio. From study it was observed that the geogrid reinforcement placed at sub base/aggregate interface effectively increases the service life of paved roads. Geogrid reinforcement provides a more uniform load distribution and a deduction in maximum settlement more at the asphalt-aggregate and aggregate-subgrade interface.

Ranadive (2003) investigated the performance of geotextiles reinforcement in soil other than sand. In this study, model strip footing load tests are conducted on soil with and without single and multi-layers of geotextile at different depths below the footing. Testing was carried out on Universal Testing Machine. From the study it was observed that bearing capacity improved considerably for reinforced soil over unreinforced soil. It was observed that for a single layer system, BCR (Bearing Capacity Ratio) for depth of layer below footing equal to 0.25B is maximum where B is the width of the footing and BCR decreases as the depth of layer increases and for multilayer system, BCR for a constant d/B ratio and S/B ratio, (where d is the depth of single reinforcing layer below footing and S is spacing between subsequent geotextile reinforcing layers when depth of top layer below footing was kept constant equal to 0.25B). The BCR is maximum for N=4 but the percentage increase in BCR for N=4 over BCR for N=3 is very low. Thus N=3 is recommended as optimum value.

Gitty and Ajitha (2008) conducted plate load test to study the variation of load carrying capacity for both reinforced and unreinforced pavements. It was observed that the bearing capacity improved by providing coir geotextiles as reinforcement. She reported an increase in bearing capacity by 1.83 times for reinforced pavement compared to unreinforced pavement.

Venkatappa and Dutta (2005) conducted monotonic and cyclic load test on Kaolinite with geotextile placed at the interface of the two soils. It was found bearing pressure of the soil improved by about 33% when reinforced with coir geotextiles.

Indian Roads Congress also suggest in its Rural Road Manual (IRC: SP: 59-2002) the use of coir geotextile but no design methodology, construction guidelines and product specifications are mentioned.

COIR GEOTEXTILES

2.3 PERFORMANCE EVALUATION

Performance evaluation of pavement can be classified as functional Performance and Structural performance.

2.3.1 Functional Performance

Functional Performance can be evaluated by Visual examination, Merlin test and bump indicator.

Visual examination is done for Alligator Cracking, Block Cracking, Transverse Cracking, Joint Reflection Cracking, Patching, Potholes, Corrugation and Shoving, Depression, Rutting/ Permanent deformation, Stripping, Raveling and raveling. The details of visual examination are explained in table 2.1

VISUAL EVALUATION

TABLE 2.1: VISUAL EVALUATION

Sl. No.	Distress Type	Identification and Problems
1.	Alligator Cracking	Series of interconnected cracks caused by fatigue failure of the surface under repeated traffic loading. Indicator of structural failure, cracks allow moisture infiltration, roughness, may further deteriorate to a pothole.
2.	Block Cracking	Interconnected rectangular cracks. Larger blocks are generally classified as longitudinal and transverse cracking. Block cracking normally occurs over a large portion of pavement area but sometimes will occur only in non-traffic areas.
3.	Transverse Cracking	Cracks occur in perpendicular to the pavement's centerline or lay down direction. It allows moisture infiltration.
4.	Joint Reflection Cracking	Cracks in a flexible overlay of a rigid pavement. Allows moisture infiltration.
5.	Patching	An area of pavement that has been replaced with new material to repair the existing pavement.
6.	Potholes	Small, bowl shaped depressions in the pavement surface. It causes serious vehicular damage and moisture infiltration
7.	Corrugation and Shoving	A form of plastic movement typified by ripples or an abrupt wave across the pavement surface.
8.	Depression	Depressions are small localized areas. Noticeable after a rain. It cause vehicle hydroplaning.

9.	Rutting/ Permanent deformation	Surface depression along the wheel path. Ruts filled with water can cause vehicle hydroplaning, can be hazardous because ruts tend to pull a vehicle towards the rut path as it is steered across the rut.
10.	Stripping	The loss of bond between aggregates & asphalt binder. It causes decrease in structural support, rutting, shoving/corrugations raveling or cracking.
11.	Raveling	The progressive disintegration of an layer from the surface downward as a result of the dislodgement of aggregate particles. It causes loose debris on the pavement, roughness, water collecting in the raveled locations resulting in vehicle hydroplaning, loss of skid resistance.

Merlin Test for Roughness Measurement

Road surface roughness is an important measure of road condition. The Merlin road roughness measurement machine was developed by the Transport Research Laboratory for use in developing countries. Schematic sketch and photograph of Merlin are shown in figures 2.1 and 2.2

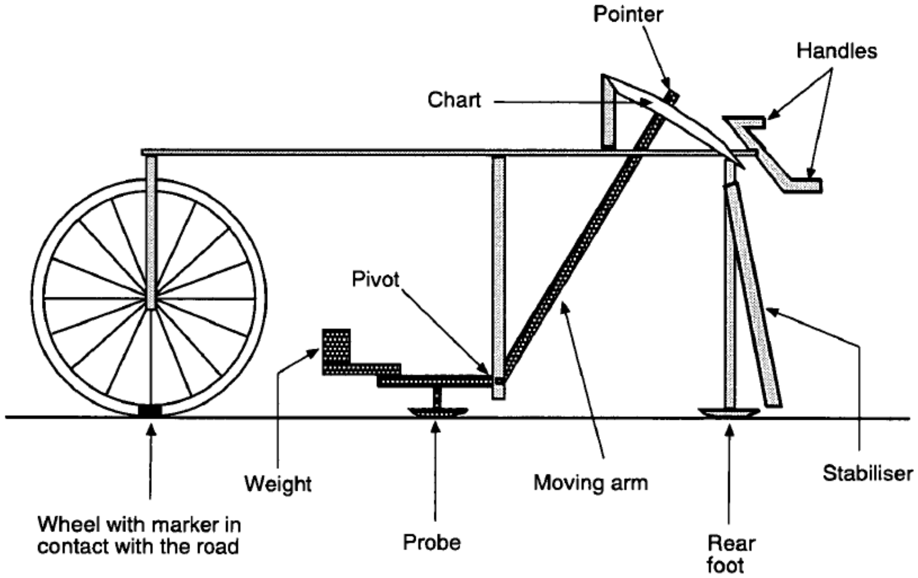

Fig.2.1 Schematic sketch of Merlin test apparatus

Fig.2.2 Photograph of Merlin test apparatus

The Merlin consists of a metal frame with a wheel at front and handles and a foot at the rear. The distance between the rear foot and the bottom of the wheel is 1.8 m. Attached to the frame is a pivoted moveable arm which has a probe at one end which rests on the road surface half way between the wheel and the rear foot. At the other end of the arm is a pointer which moves over a prepared chart. The arm is pivoted close to the probe so that a vertical displacement of the probe of 1 mm will produce a displacement of the pointer of 1 cm.

The Merlin is used to measure the roughness of a stretch of road by taking repeated measurements at the intervals along the road. For each measurement the machine is made to rest on the road with the wheel, the rear foot and probe in contact with the road surface. The position of the pointer on the chart is recorded with a cross. Each new measurement is taken by moving the Merlin forward to a new position on the road and recording the corresponding new position of the pointer on the chart so that a histogram distribution of crosses is gradually built up. Once two hundred measurements have been made the position between the tenth and eleventh crosses, counting in from one end of the distribution, is marked. The procedure is repeated for the other end of the distribution and the spacing between the two marks, D is measured in millimeters.

For most road surface the road roughness can be determined using the equation,

$$IRI = 0.593 + 0.0471D$$

$$(2.4 < IRI < 15.9)$$

Where IRI is the roughness in terms of the International Roughness Index (in m/km) and D is measured from the Merlin chart (in mm).

Allowable IRI values for different types of pavements as per Sayers et al., 1986 are

Presented in Fig. 2.3

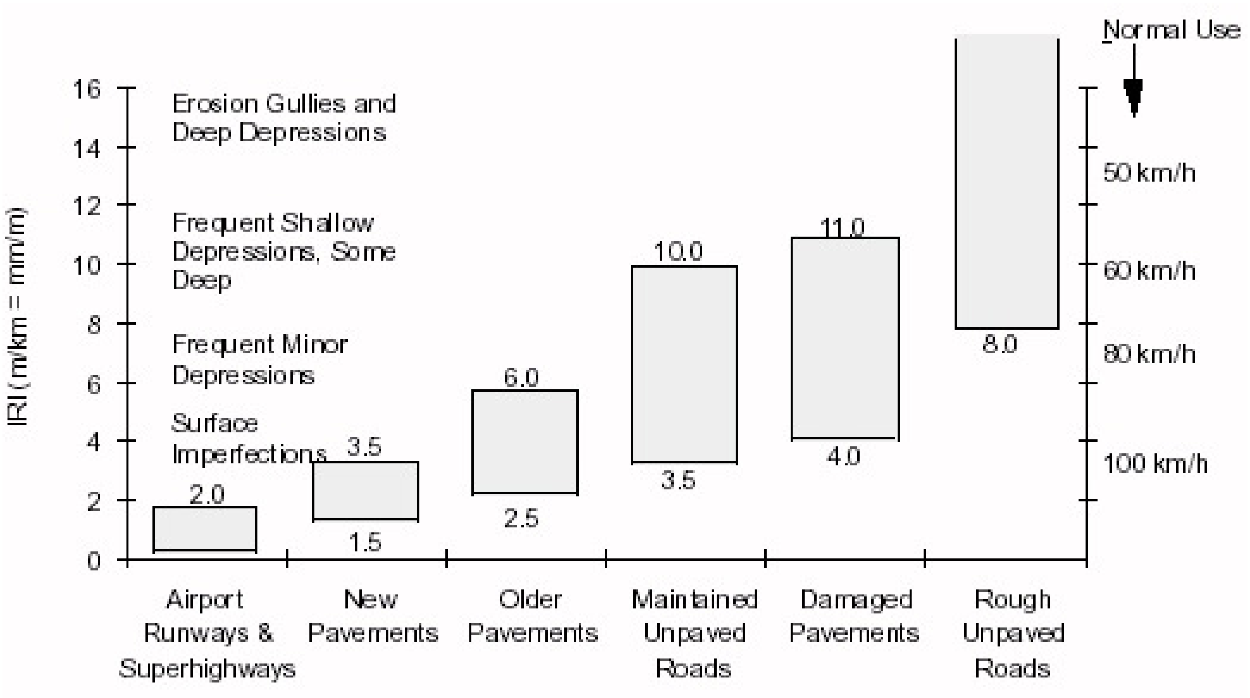

Fig. 2.3 Allowable IRI Values for different types of pavements

Skid Resistance

Skid resistance is the frictional force developed at the tyre pavement interface when a tyres on being prevented from rotating skid along the pavement surface. Adequate skidding resistance is essential for safe operation of vehicles from the point of acceleration, deceleration, cornering and abrupt stoppings. Functional performance/quality of any pavement is affected in two ways. Reduction in surface evenness (roughness), Reduction in skid resistance of the pavement with the passage of time and traffic (dependent on climatic and environmental factors)

Skid resistance found out using British Portable Skid Resistance Tester (Portable Pendulum Tester is shown in Fig. 2.4). This apparatus gives the frictional resistance between a rubber slider (mounted on the end of a pendulum arm) and the road surface.

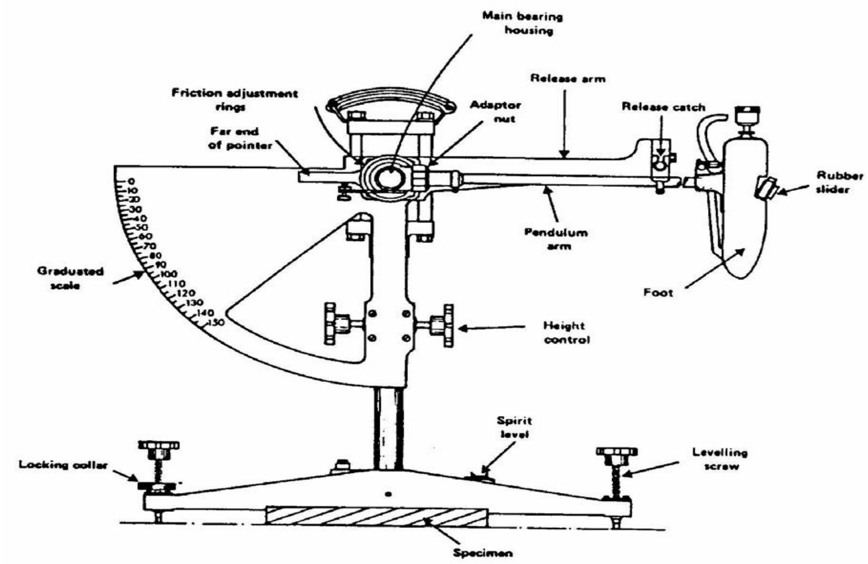

Fig 2.4 The British Pendulam Tester

Allowable Skid Resistance values of different conditions as per (IRC:SP:83–2008) are 1. Values between 45 to 55 indicates satisfactory surface in only favorable weather and vehicle condition. 2.Value of 55 or greater indicates generally acceptable skid resistance in all conditions. 3Value of 65 and above indicates good to excellent skid resistance in all conditions.

2.3.2 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. Schematic sketch of Benkelman Beam is shown in Fig. 2.5

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. 2.4.

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.

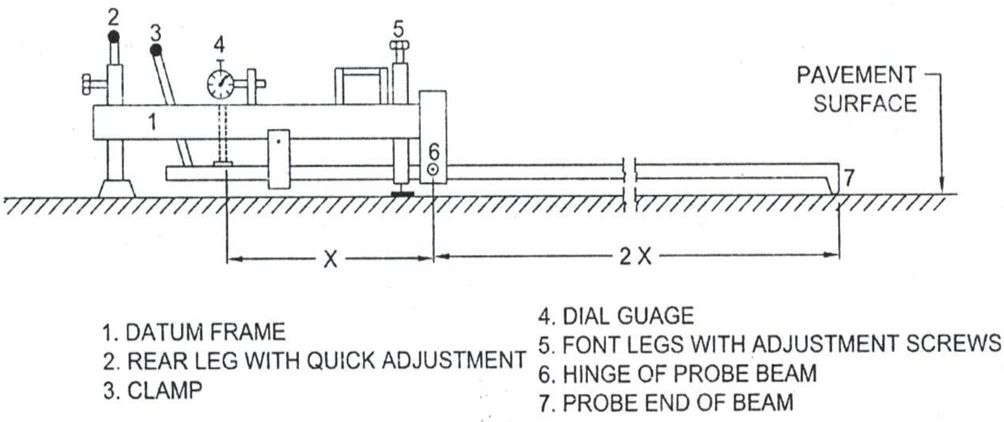

Fig. 2.5 Benkelman Beam

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. Allowable limit of deflection without any improvement works for different cumulative numbers of standard axial loads is presented table 2.2.

Table 2.2 Allowable limit of deflection without any improvement works for different cumulative numbers of standard axial loads is presented

Deflection in mm	3	2	1.65	1.4	1.05	1	0.8	0.45
Million standard axial load	0.1	0.5	1	2	5	10	20	100

CHAPTER 3

LABORATORY EXPERIMENTAL STUDY

3.1 MATERIALS USED

The materials used for the study are soil and geotextile. The soils were collected from the three different locations selected for field study. They are Haripad, Varkala and Kozhinada. Local as well as fill soil were collected and tested in the laboratory. The geotextiles used for the study were H_2M_6, H_2M_8 and non woven geotextiles.

3.1.1 Soil

Two different varieties of soil collected from three different constructions site were collected and tested. The locations are Harippad, Varkala and Murukkampuzha (Kozhinada, Trivandrum) areas in Kerala and the soil properties are given in Table 1.The soil are referred to as Varkala local soil, Varkala fill soil, Kozhinada local soil and Kozhinada fill soil. Harippad fill soil and Harippad Local soil.

Table 1. Properties of soil

Properties	Varkala Local	Varkala Fill	Kozhinada Local	Kozhinada Fill	Harippad Local	Harippad Fill
OMC (%)	12	9	14	12	11	10
Maximum dry density (g/cc)	2.02	2.07	2.14	2.02	2.2	2.04
Liquid limit (%)	42	24	49	20	47	23
Plastic limit (%)	17.8	23.1	30	15.6	18.2	23.8
Plasticity Index	6.2	18.9	4.4	19	4.8	23.2
% of clay and silt	32	51	30	55	33	53

3.1.2 Geotextile

Three different type of coir geotextiles were used for the study, viz, H_2M_6, H_2M_8 and non woven geotextiles. Soil collected from Varkala was reinforced with H_2M_6 type geotextile and that collected from Kozhinada is reinforced with non woven geotextiles and that collected from Harippad was reinforced with H_2M_8 geotextiles. The properties of Coir geotextiles are shown in table 2 and 3

Coir is a natural fibre and is an organic polymer. The composition of the coir fibre is given in Table 2.

Table 2. Composition of coir fiber

Lignin	45.84%
Cellulose	43.44%
Hemi-cellulose	0.25%
Water soluble components	7.74%
Pectin's etc (soluble in boiling water)	3.00%

3.1.6 The properties of geotextile are given in Table 3.

Table 3. Material properties of Geotextile

Properties		**H_2M_6**	**H_2M_8**	**Non woven geotextile**
Opening size		2.5 cm x2.5 cm	0.5 cm x0.5 cm	0.2mm(O_{95})
Strength(kg/m)	M/C direction	325	800	Very low
	CM/C direction	350	1000	Very low
Thickness in 2kPa(mm)		8.1	8.3	8.1
Weight (g/m^2)		425	700	400

3.2 LABORATORY STUDY

a) CBR Tests

CBR test were conducted to find out the variation in load carrying capacity for both reinforced and unreinforced pavements. The tests were carried out on plain soil and also by placing the geotextile at various positions of the sample in the mould as shown in Fig.3.1. The tests were conducted immediately after compaction as well as after soaking it in water for 4 days.

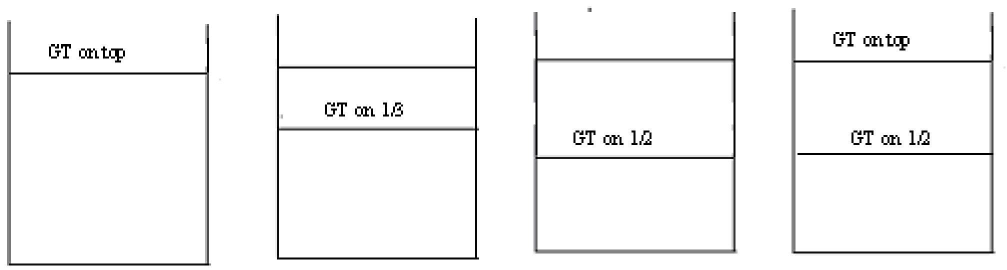

Fig.3.1. Position of geotextile for CBR tests

The tests were also conducted on samples with coir geotextile anchored. Anchorage was done by means of bamboo pins of 2.5 cm long and a maximum of four pins were placed around the coir geotextile as shown in Fig .3.2.

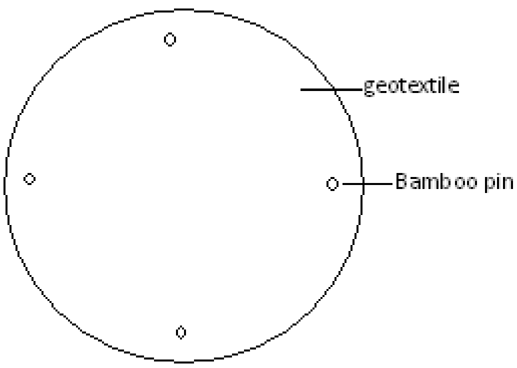

Fig.3.2. Position of bamboo pins as anchorage

b) Plate load tests

Mini plate load tests were conducted on a tank of size 600mm x 600mm. The coir geotextile was placed on the surface of the soil. The tests were conducted with anchors and without anchors. Eight pins were placed at the four edges of the coir geotextile to properly anchor them as shown in Fig.3.3.

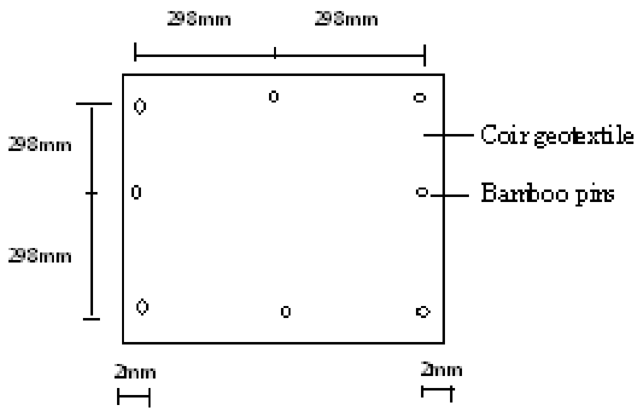

Fig.3.3. Position of pins on coir geotextile and test plate

CBR and plate load test were conducted to find out the variation in load carrying capacity for both reinforced and unreinforced pavements. The plate load tests are performed in Mild steel rectangular box of 600 x 600 mm cross- section. The box is well stiffened by welding Mild steel angles as stiffeners. The size of the test plate is 150 x 150 mm and 8mm thick. The tests were also carried out on plain soil as well as by placing the geotextile on top, 10cm from top and 15 cm from top of the soil surface as done in the field. Load is applied using hydraulic jack. For accurate measurements of load, it was applied through a proving ring of capacity 50kN. Settlements were recorded with the dial gauge of least count of 0.01 mm.

3.3 RESULTS AND DISCUSSION

Results of tests done in the laboratory are discussed below.

3.3.1 VARKALA LOCAL SOIL

3.3.1 CBR test Results

3.3.1.1 No anchorage provided to the geotextiles.

The results of CBR test conducted on Varkala local soil by placing geotextile at various depths are shown in Fig 3.4. No anchorage was provided.

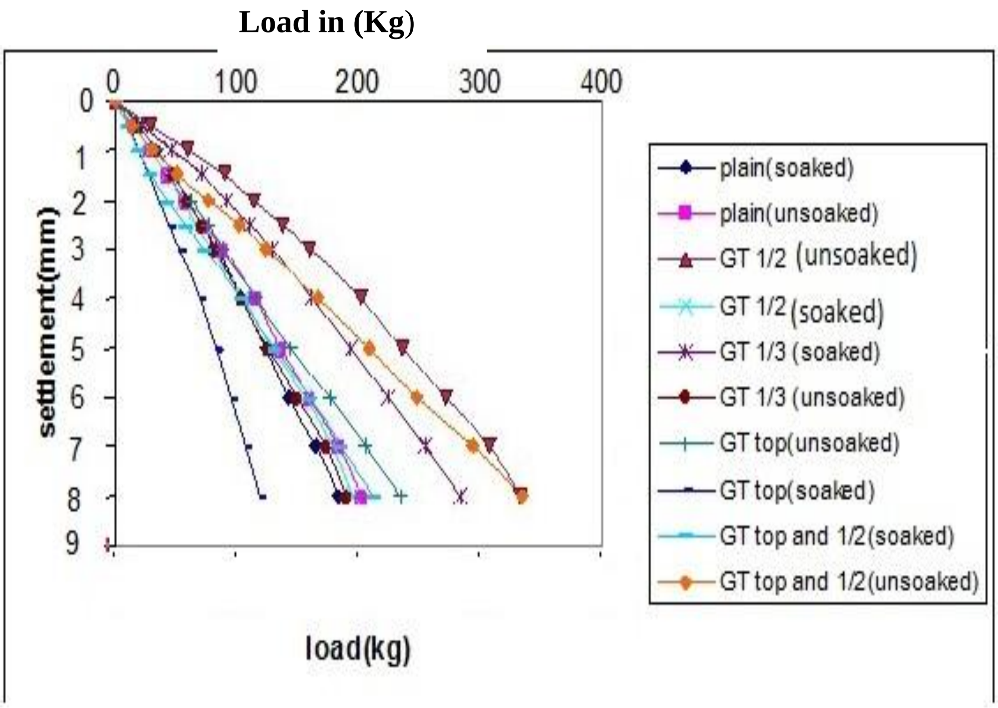

Fig.3.4.CBR test results of Varkala local soil

Table 4. Summary of CBR values for Varkala local soil

Soil		Plain	GT top	GT 1/2	GT 1/3	GT top and 1/2
Varkala local	Unsoaked	5.4	10	6	8.5	10.3
	% change		+85	+11	+57.4	+91
	Soaked	3.2	6	3.4	2.8	4
	% change		+12.5	+7	-12.5	+25

From Table 4 it can be observed that the CBR values for soil reinforced with geotextiles shows a lower CBR value than that obtained for reinforced case in case of soaked soil. This decrease may be attributed to the slippage of the geotextile that takes place between the soil layers. In the field layer slippage doesn't happen. Hence anchors were provided and the CBR test was repeated.

3.3.1.2 Anchorage provided to the geotextiles.

A series of same test were conducted after proper anchorage of geotextiles in soil layers using bamboo nails of 2.5 cm long. Fig.3.5. Shows the results of CBR tests conducted after providing proper anchorage to the geotextiles.

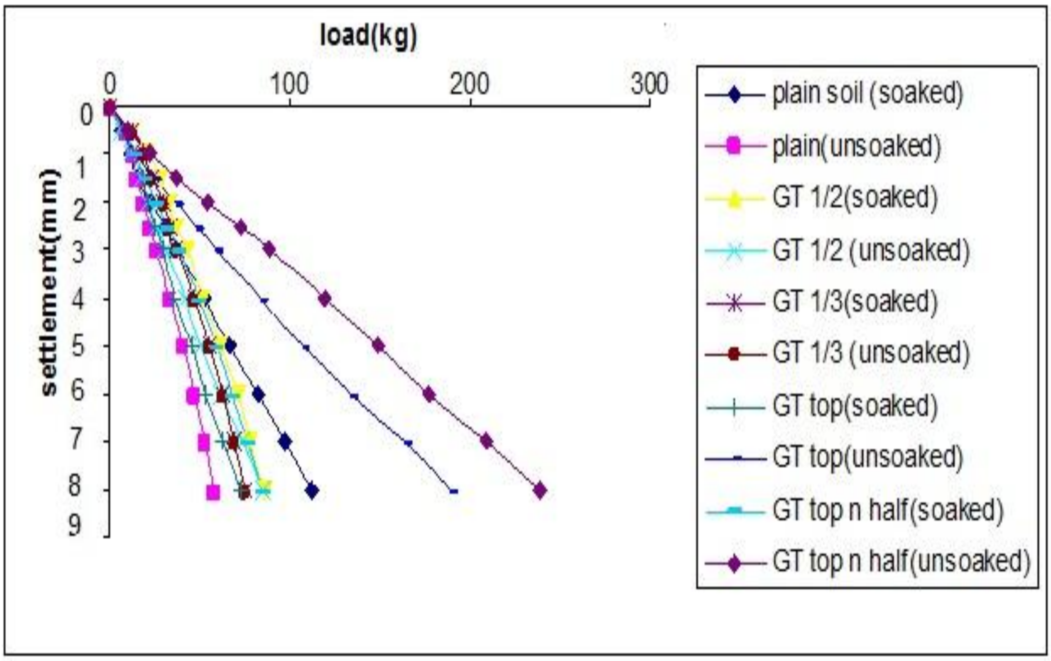

Fig.3.5. CBR Test results on Varkala local after anchorage was provided.

Table 5. Summary of CBR values for Varkala local soil after properly anchoring the geotextiles

Soil		**Plain**	**GT top**	**GT 1/2**	**GT 1/3**	**GT top and ½**
Varkala local	Unsoaked	5.4	11	7	9.1	12
	% change		+103	+30	+69	+122
	Soaked	3.2	5.2	4.1	3.8	6
	% change		+62.5	+28	+19	+87.5

From Table 5 it was observed that a percentage increase of 122% was seen when two layers of geotextiles was placed at top and half the depth from top of the subgrade.

3.3.2 Plate Load Test Results

The results of plate load test conducted on Varkala local soil by placing geotextile at various depths are shown in Fig.3.6.

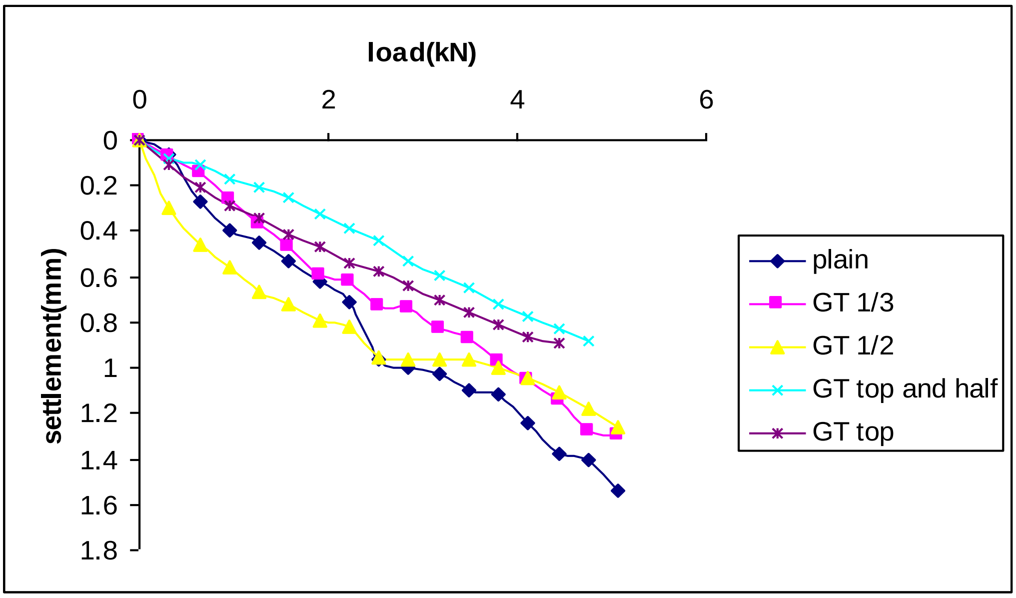

Fig.3.6. Plate load test results of Varkala local soil

From the graph it can be observed that the bearing capacity of soil improves when the geotextiles is placed at top and 2 layers of reinforcement are provided at top and at 15cm from top

3.4 VARKALA FILL SOIL

3.4.1 CBR Results

3.4.1.1 No Anchorage provided to the geotextiles.

The results of CBR test conducted on Varkala Fill soil by placing geotextile at various depths are shown in Fig 3.7.

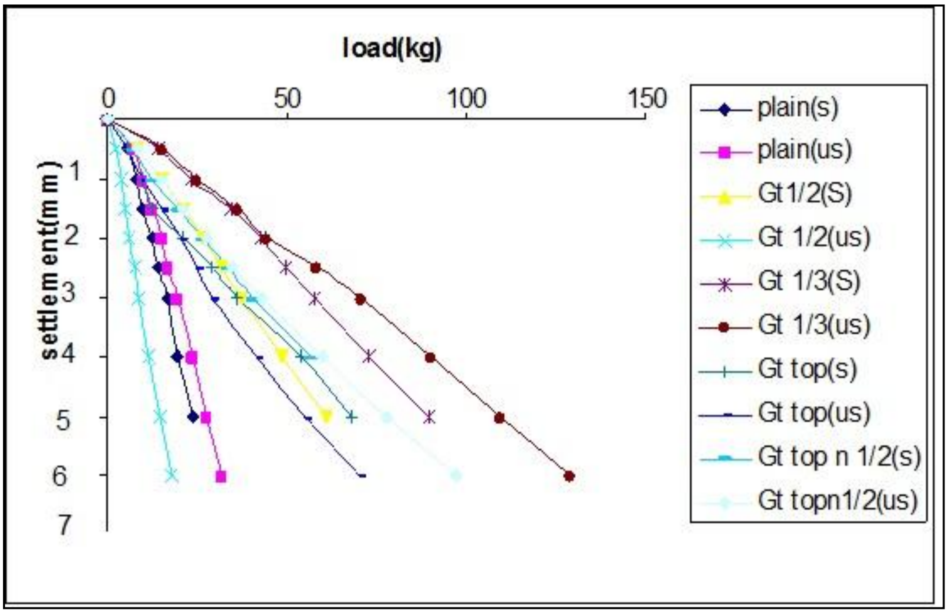

Fig 3.7. CBR test results of Varkala Fill soil

From Table 6 it can be observed that the CBR values for soil reinforced with geotextiles shows a lower CBR value than that obtained for reinforced case. This decrease may be attributed to the slippage of the geotextile that takes place between the soil layers.

Table 6. Summary of CBR values for Varkala Fill soil

Soil		**Plain**	**GT top**	**GT 1/2**	**GT 1/3**	**GT top and ½**
Varkala Fill	Unsoaked	1.9	2.8	2.4	4.2	3.2
	% change		+41	+26.3	+121	+68.4
	Soaked	1.8	2.2	1.2	1	2.9
	% change		-22	-33	-44.4	+61.1

3.4.1.2 Anchorage provided to geotextiles

A series of same test were conducted after proper anchorage of geotextiles in soil layers using bamboo nails of 2.5 cm long. Fig.3.8 shows the results of CBR tests conducted after providing proper anchorage to the geotextiles.

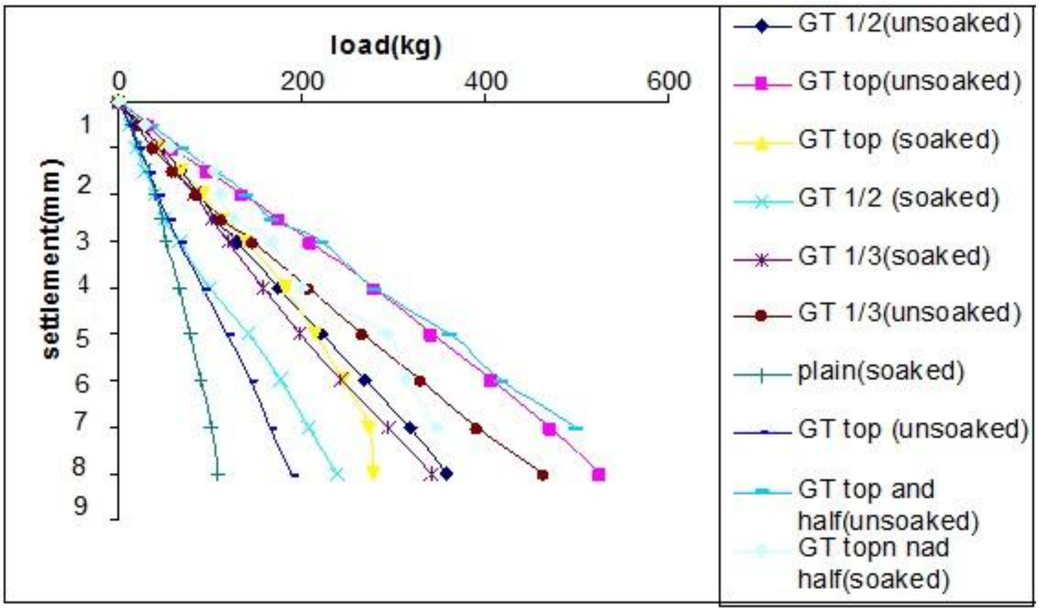

Fig.3.8. CBR Test results on Varkala Fill after anchorage was provided

Table 7.Summary of CBR values for Varkala Fill soil after properly anchoring the geotextiles

Soil		**Plain**	**GT top**	**GT 1/2**	**GT 1/3**	**GT top and ½**
Varkala Fill	Unsoaked	1.9	4.8	2.4	4.2	5.2
	% change		+152	+26.3	+121	+173
	soaked	1.8	2.75	2.1	2.2	3.2
	% change		+52.7	+16.7	+22.2	+77.7

From table 7 it was observed that a percentage increase of 173% was seen when two layers of geotextiles was placed at top and half the depth from top of the subgrade.

3.4.2 Plate Load Test results

The results of plate load test conducted on Varkala Fill soil by placing geotextile at various depths are shown in Fig.3.9

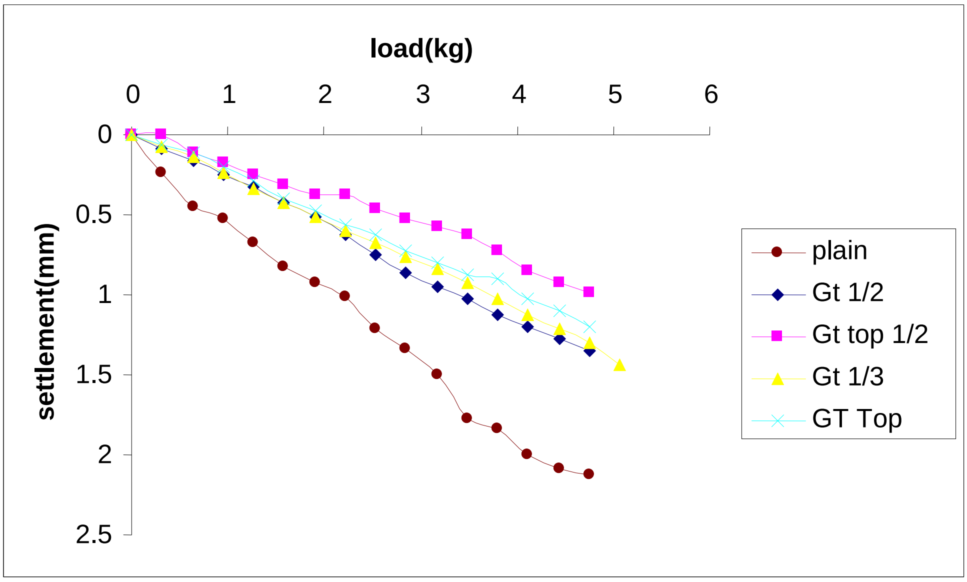

Fig.3.9. Plate load test results of Varkala Fill soil

From the graph it can be observed that the bearing capacity of soil improves when the geotextiles is placed at top and at 10 cm from top of the subgrade.

3.5 KOZHINADA LOCAL SOIL

3.5.1 CBR Results

3.5.1.1. No Anchorage provided to the geotextiles.

The results of CBR test conducted on Kozhinada Local soil by placing geotextile at various depths are shown in Fig 3.10.

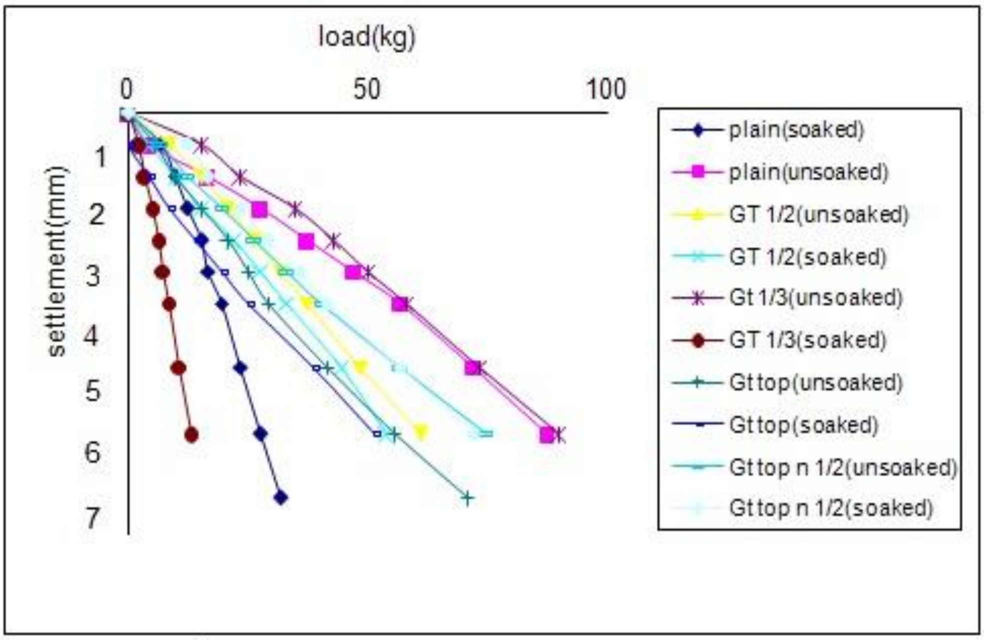

Fig.3.10. CBR Test results on Kozhinada Local soil.

A series of same test were conducted after proper anchorage of geotextiles in soil layers using bamboo nails of 2.5 cm long. Fig .3.11 shows the results of CBR test conducted after proving proper anchorage to the geotextiles.

Table 8. Summary of CBR values.for Kozhinada Local soil

Soil		**Plain**	**GT top**	**GT 1/2**	**GT 1/3**	**GT top and ½**
Kozhinada Local	Unsoaked	1.3	3.6	3	4.3	3.6
	% change		+177	+130	+230	+177
	soaked	1	1.2	1.6	0.8	2.2
	% change		+20	+60	-20	+120

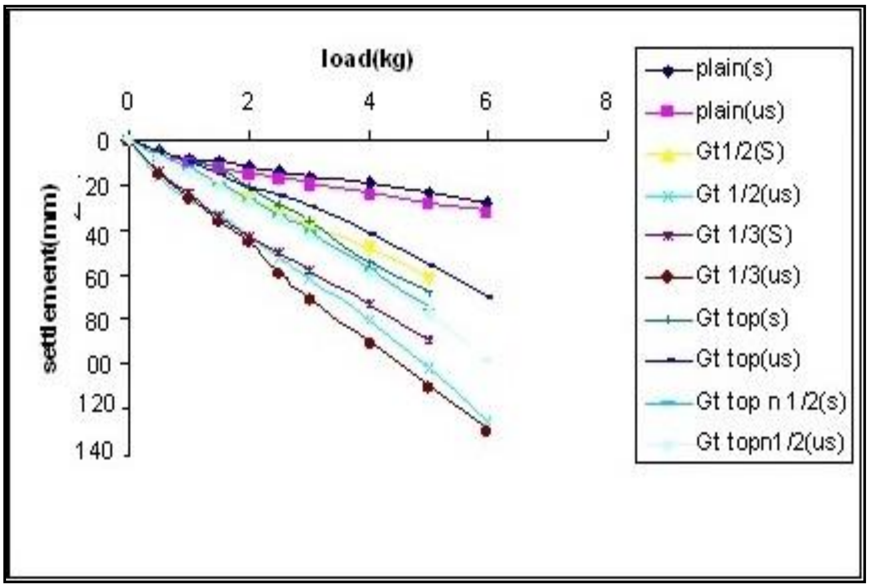

Fig.3.11. CBR Test results on Kozhinada Local after anchorage was provided

From Table 8 it was observed that an increase of 307% was seen when the geotextiles was placed at top and half the depth from the top of the subgrade.

Table 9 : Summary of CBR values for Kozhinada Local soil after properly anchoring the geotextiles

Soil		**Plain**	**GT 1/2**	**GT 1/3**	**GT top**	**GT top and ½**
Kozhinada Local	Unsoaked	1.3	2.3	3.7	5	5.3
	% change		+77	+184	+284	+307
	soaked	1	2	3.6	3	4.3
	% change		+100	+330	+200	+330

3.5.2 Plate Load Test results

The results of plate load test conducted on Kozhinada Local soil by placing geotextile at various depths are shown in Fig.3.12.

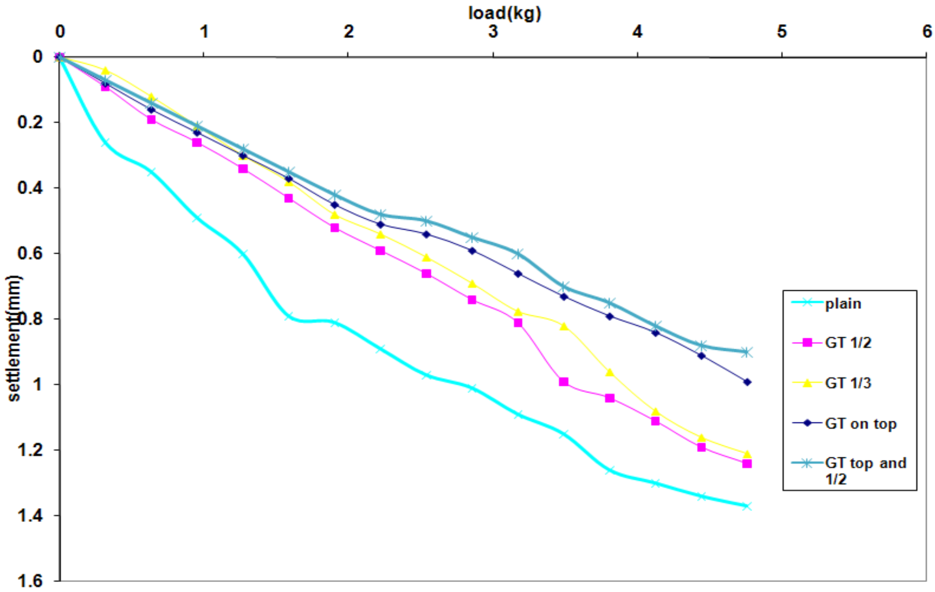

Fig.3.12. Plate load test results of Kozhinada Local soil.

From the graph it can be observed that the bearing capacity of soil improves when the geotextiles was placed at top and half the depth from the top of the subgrade.

3.6 KOZHINADA FILL SOIL

3.6.1 CBR Results

3.6.1.1 No Anchorage provided to the geotextiles.

The results of CBR test conducted on Kozhinada Fill soil by placing geotextile at various depths are shown in Fig.3.13.

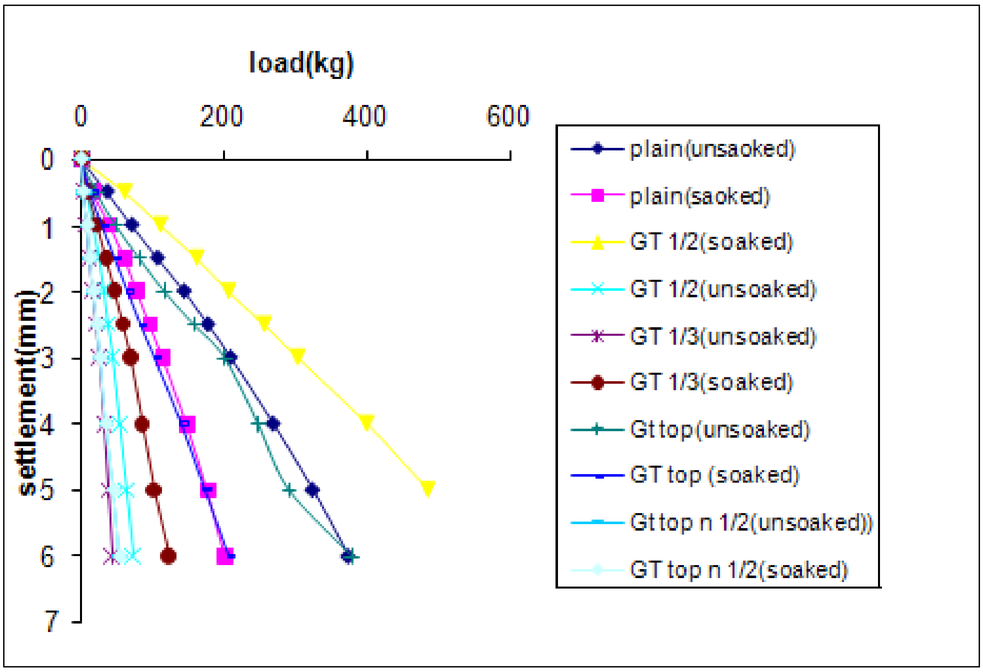

Fig.3.13. CBR Test results on Kozhinada Fill soil

From Table 10 it can be observed that the CBR values for soil reinforced with geotextiles shows a lower CBR value than that obtained for reinforced case. This decrease may be attributed to the slippage of the geotextile that takes place between the soil layers.

Table 10. Summary of CBR values for KF soil

Soil		**Plain**	**GT top**	**GT ½**	**GT 1/3**	**GT top and ½**
Kozhinada Fill	Unsoaked	15.8	14.8	18	12.8	14.72
	% change		-6.3	+12.2	-19	-6.9
	soaked	7	6.2	8.3	9.5	5.4
	% change		-11.4	+18.5	+36	-23

3.6.1.2 Anchorage provided to geotextiles

A series of same test were conducted after proper anchorage of geotextiles in soil layers using bamboo nails of 2.5 cm long Fig.3.14. Shows the results of CBR tests conducted after proving proper anchorage to the geotextiles.

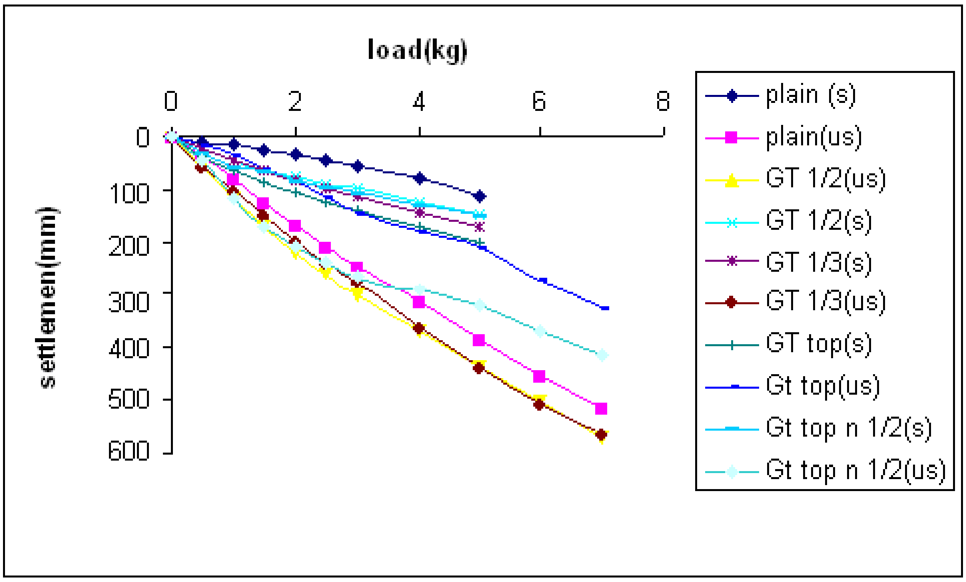

Fig.3.14. CBR Test results on Kozhinada Fill after anchorage was provided

Table 11. Summary of CBR values for Kozhinada Fill soil after properly anchoring the geotextiles

Soil		Plain	GT top	GT 1/2	GT 1/3	GT top and ½
Kozhinada Fill	Unsoaked	15.8	21.5	21.2	21.3	22
	% change		+36	+34	+34	+39
	Soaked	7	10	8.3	9.5	12
	% change		+43	+18.5	+35.7	+71.4

From Table 11 it was seen that an increase of around 35% was seen when the soil was reinforced with geotextiles and an increase of 39% was seen when two layers of geotextle was placed at top and half the depth from top of the subgrade.

3.6.2 Plate Load Test results

The results of plate load test conducted on Kozhinada Fill soil by placing geotextile at various depths are shown in Fig.3.15.

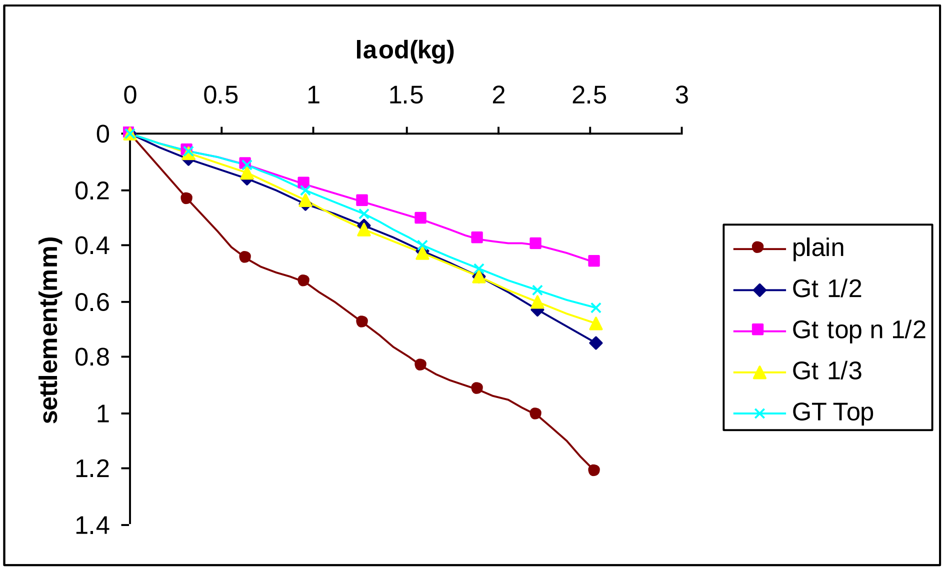

Fig.3.15. Plate load test results of Kozhinada Fill soil

From the graph it can be observed that the bearing capacity of soil improves when reinforced with geotextiles and better improvement is seen when two layers of geotextiles are provided at top and half the depth from top of the subgrade.

CHAPTER 4

FIELD APPLICATIONS

Three locations each of 100m stretch for laying coir geotextiles in the field were chosen, one in Alleppy district and two in Trivandrum district. The site chosen in Trivandrum has almost similar soil characteristics of soil in Alleppy district. The locations in Trivandrum district are Varkala block and Kazhakoottom Block. The road chosen in Varkala block is Chirakkad- Kumbakkad road and in Kazhakoottom Block is Kozhinada Road to Murukkampuzha. In Alleppy district, the road is Mangalabharathy - SN Kadavu road in Harippad Block. The Geotextiles are laid in Mangalabharathy - SN Kadavu Road, during the period October 2008 and Chirakkad-Kumbakkad road during the period January 2009 and surfacing of pavements was done immediately. At present, the above mentioned road is in good traffic condition. Kozhinada-Murukkampuzha road was done during the May 2011 and surfacing is not yet done due to local problems. Details of the test road are shown in table 4.1.

Table 4.1. Details of the test road

Name of Road	Length (m)	Chainage (m)	Position of coir geotextile (Distance from top of subgrade in cm)	Type of coir geotextile
Chirakkad-Kumbakkad road(Haripad)	25	1080 – 1105	0	H_2M_6
	25	1105 – 1130	10	
	25	1130 – 1150	15	
	25	1150 – 1180	2 layers- 0 and 15	
SN Kadavu road (Varkala)	25	800 – 825	0	H_2M_8
	25	825 – 850	10	
	25	850 – 875	15	
	25	875 – 900	30	
Kozhinada road	25	1810- 1835	0	Non- woven
	25	1835-1860	10	
	25	1860-1885	15	
	25	1885-1910	2 layers- 0 and 15	

3 roads are designed as Road 1, 2 and 3. The details are given below

Test road 1

Location Details

Name of Block: Haripad

Name of Road: Mangala Bharathi – SN Kadavu

The stretches for the 800m to 900m is chosen as the test stretch

Design of Section H1

Chainage from 800m to 825m

Coir geotextiles are to be placed between subgrade and subbase as shown in Fig.4.1.

Type of geotextiles: Woven Coir Geotextile H2M8

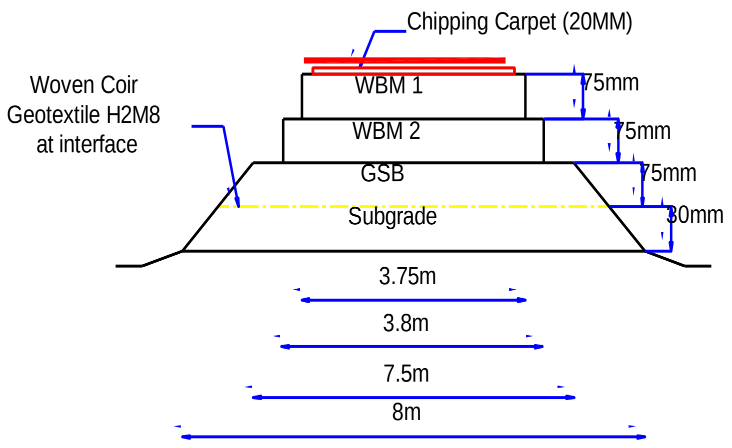

Fig.4.1. Cross Section H1

Design of Section H2

Chainage from 825m to 850m

Thickness of subgrade 300m

Coir reinforcement are placed at a depth of h/3 from top of subgrade. h/3 = 300/3 = 100m as shown in Fig.4.2.

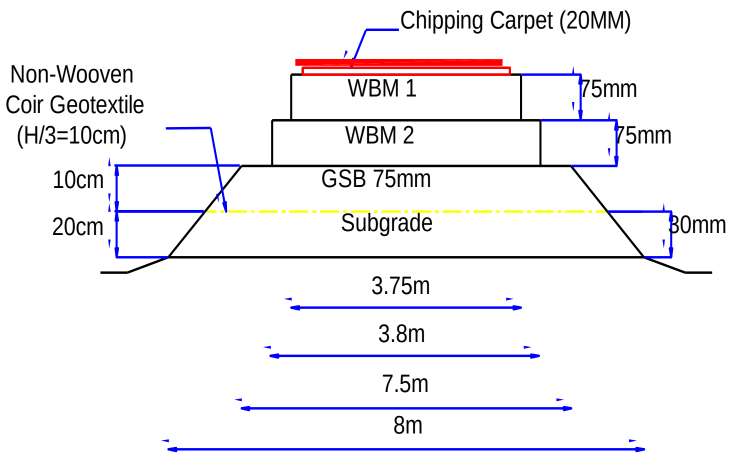

Fig.4.2. Cross Section H2

Design of Section H3

Chainage from 825m to 850m

Thickness of subgrade 300m

Coir reinforcement are placed at a depth of h/3 from top of subgrade. h/2 = 300/2 = 150m as shown in Fig.4.3.

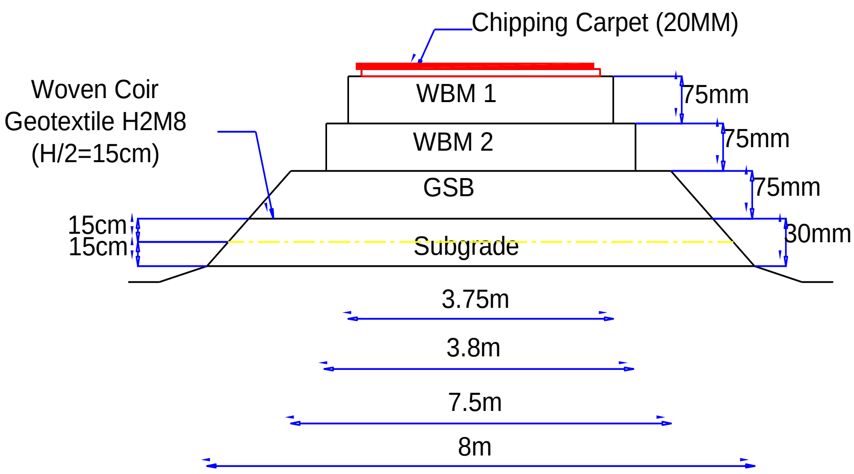

Fig .4.3. Cross section H3

Design of Section H4

Chainage from 1460m to 1480m

Thickness of subgrade 300mm

Top 30cm depth of the sub grade is locally available clay

Coir reinforcement are providing at the top and 15cm from the top of locally available clay material as shown in Fig.4.4.

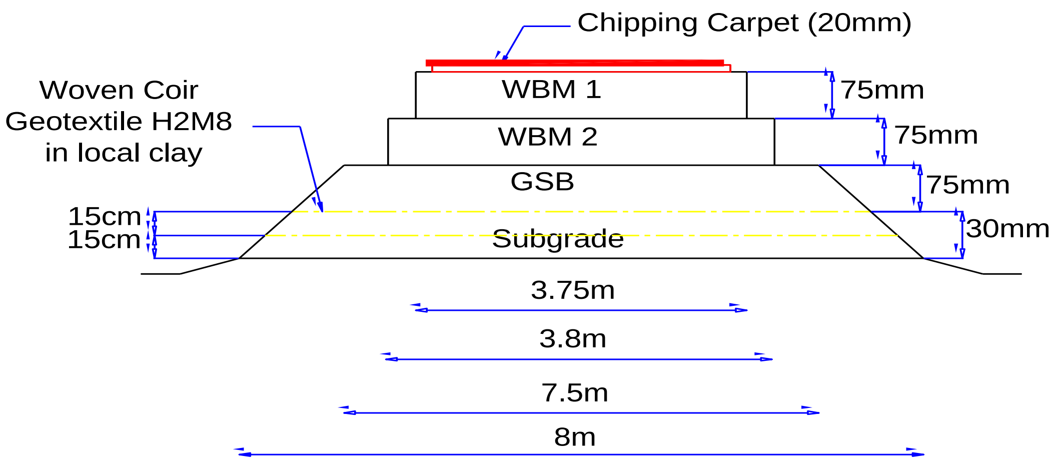

Fig .4.4. Cross Section H4

Test Road 2

Name of Block: Varkala Block

Name of Road: Chirakkad – Kumbakad road

The stretches for the 1080m to 1180m is chosen as the test stretch.

Design of SectionV1

Chainage from 1080m to 1180m.

Thickness of subgrade 300mm

Coir reinforcements are placed between sub grade and sub base as shown in Fig.4.5.

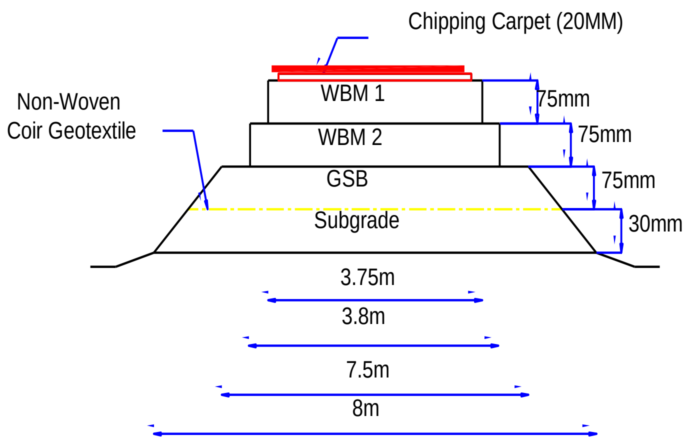

Fig.4.5. Cross Section V1

Design of Section V2

Chainage from 1105 m to 1160m

Thickness of subgrade 300mm

Coir reinforcements are placed at a deoth of h/3 from top of subgrade. H/3 = 300/3 = 100mm as shown in Fig.4.6.

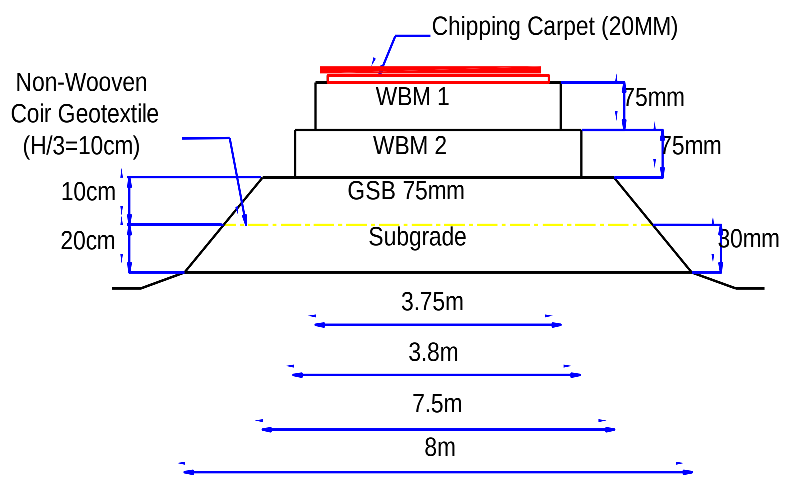

Fig.4.6. Cross Section V2

Design of Section V3

Chainage from 1130m to 1155m.

Thickness of subgrade 300mm

Coir reinforcements are placed at a depth of h/3 from top of subgrade. h/3 = 300/2 = 150mmas shown in Fig.4.7.

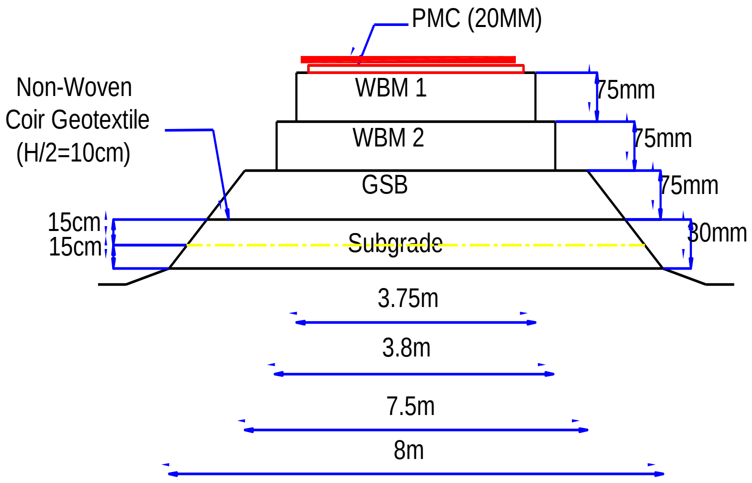

Fig .4.7. Cross Section V3

Design of Section V4

Chainage from 1155m to 1180m.

Thickness of sub grade 300mm

Top 30cm depth of the sub grade is locally available clay

Coir reinforcement are providing at the top and 15cm from the top of locally available clay material as shown in Fig.4.8.

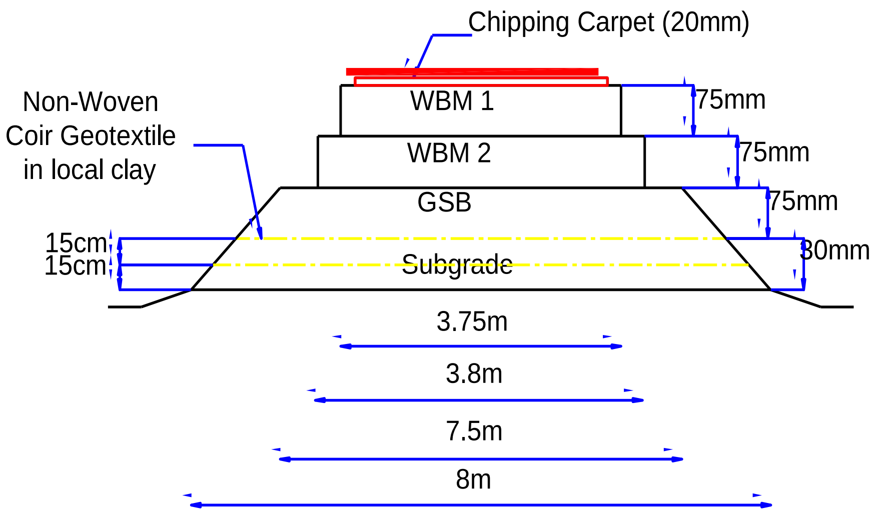

Fig.4.8. Cross Section V4

Test Road 3

Name of Block: Kazhakoottom

Name of Road: Kozhinada –Murukkampuzha road

The stretches for the 1080m to 1180m is chosen as the test stretch.

Design of Section K1

Chainage from 1810m to 1835m.

Thickness of subgrade 300mm

Coir reinforcements are placed between sub grade and sub base as shown in Fig.4.9.

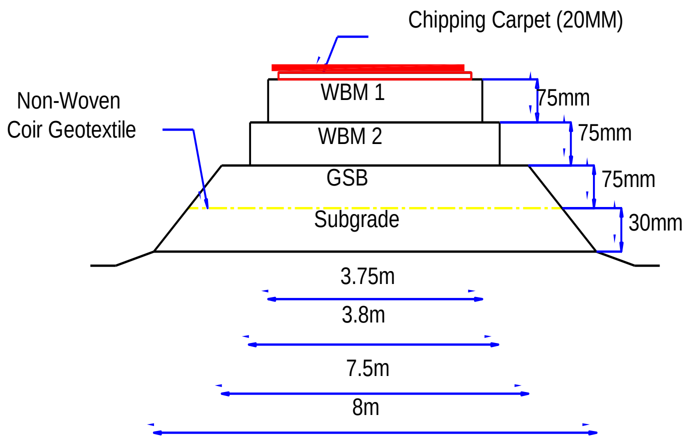

Fig.4.9. Cross Section K1

Design of Section K2

Chainage from 1835m to 1860

Thickness of subgrade 300mm

Coir reinforcements are placed at a depth of h/3 from top of subgrade. H/3 = 300/3 = 100mm as shown in Fig.4.10.

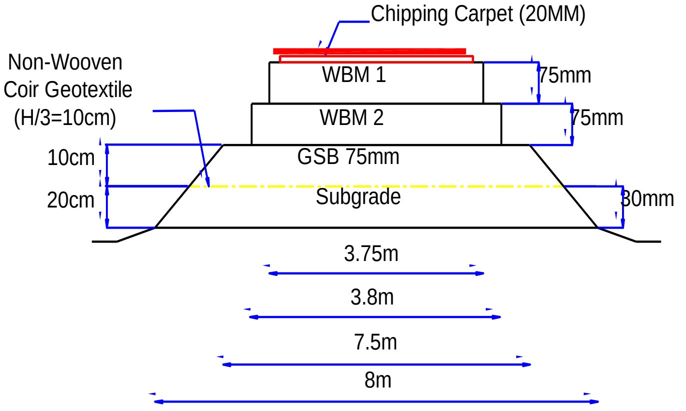

Fig.4.10. Cross Section K2

Design of Section K3

Chainage from 1860m to 1885m.

Thickness of subgrade 300mm

Coir reinforcements are placed at a depth of h/3 from top of subgrade. h/3 = 300/2 = 150mmas shown in Fig.4.11.

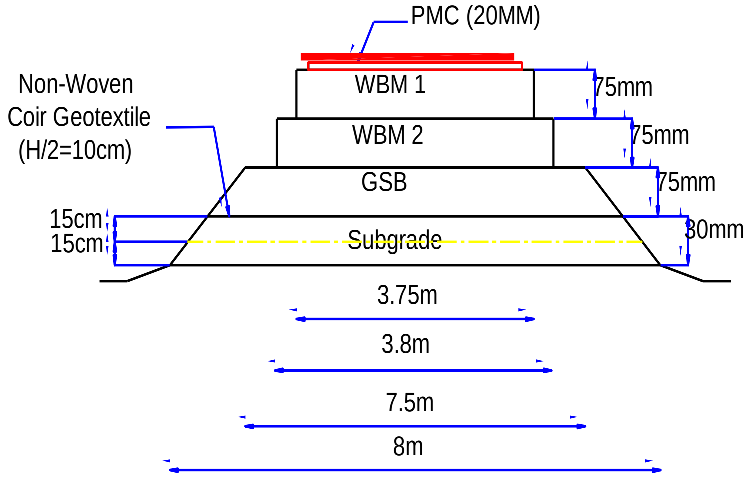

Fig .4.11. Cross Section K3

Design of Section K4

Chainage from 1885m to 1910m.

Thickness of sub grade 300mm

Top 30cm depth of the sub grade is locally available clay

Coir reinforcement are providing at the top and 15cm from the top of locally available clay material as shown in Fig.4.12.

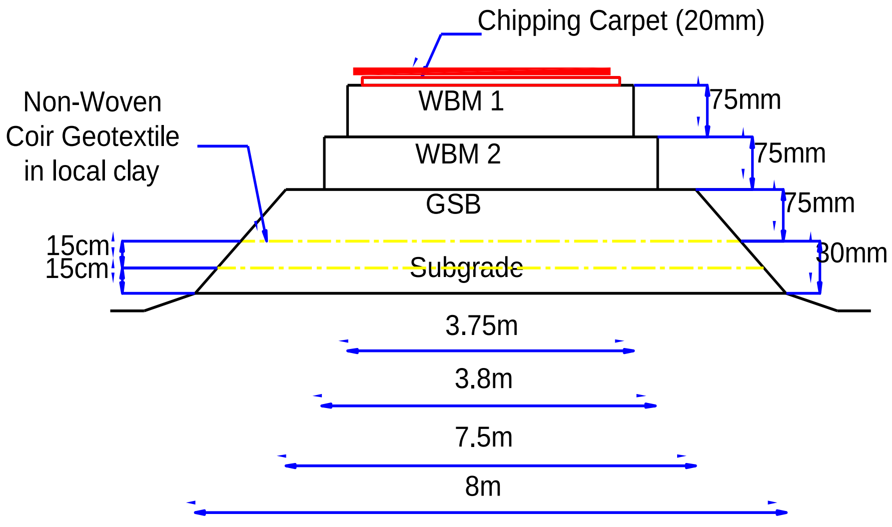

Fig.4.12. Cross Section K4

Coir Geotextiles reinforced pavements were constructed as per the figure 4.1 to 4.12. The photographs of roads during constructions are shown in Annexture.

CHAPTER 5

PERFORMANCE EVALUATION

Performance study was carried out by visual examination, deflection measurement by Benkelman Beam, International Roughness index using Merlin test and Skid resistance using bump indicator.

5.1 Visual Examination

The defect in the Coir Geotextile reinforced roads are Comparatively less than unreinforced roads.

The details of each road are presented below

Sl. No.	Without coir Geotextile			With coir Geotextile	
	Distress type	Road 1	Road 2	Road1	Road2
1	Alligator cracking	X	X	X	X
2	Block cracking	√	√	X	X
3	Transverse cracking	√	√	X	X
4	Joint Reflection Cracking	X	X	X	X
5	Patching	X	X	X	X
6	Potholes	X	√	X	X

X - represents without distress road and √ - represents with distress road

Test road 3

Surfacing of road 3 is not done still now due to local problems. The road seen to be with less pot holes compared unreinforced road. At one place surface soil was removed to find the Geotextiles. There seen to be no change for Coir Geotextiles even after 4 years. The photographs of the unpaved road and the exhumed Coir Geotextiles are also shown Annexure.

5.2 Merlin Test Results

IRI value found out using Merline test apparatus on three roads reinforced with geotextile are presented in table. IRI values of the two roads are presented in Table 5.2.

Table 5.2 IRI value of Road 1 and 2

Name of road	IRI Value and date of measurement		
	2012	2013	2014
Road 1	6.88	6.70	5.29
Road 2	5.90	5.75	5.10

Skid Resistance values for different roads

Name of road	Skid resistance Value	
	Without coir geotextile	With coir geotextile
Road 1	65.5	68.0
Road 2	100.6	107.82

5.4 Structural performance

The pavements were constructed during 2008 and the Benkelman deflections obtained in coir geotextile reinforced as well as unreinforced roads found are presented in table 4

Table 4. Benkelman Beam deflection (BBD) of reinforced and unreinforced roads.
Deflection measured with Benkelman Beam test are presented table 5.3

Benkelman Beam Deflection in mm						
Year		**2009**	**2010**	**2011**	**2012**	**2013**
With Coir Road. 1	With Coir	1.50	1.32	1.23	1.10	0.70
	Without Coir	3.01	2.82	2.80	2.79	0.82
Without Coir Road. 2	With Coir	1.20	0.72	0.64	0.52	0.40
	Without Coir	2.20	2.03	1.80	1.5	1.10

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.

Chapter 6
Conclusions

The following are the conclusions drawn from the study

Laboratory Study

1. The CBR value of soil is found to increase with the inclusion of geotextiles.
2. The CBR value for reinforced soil under soaked condition is found to be lower than the unreinforced soil for very soft soil.
3. There is considerable increase in the CBR value when the geotextile is anchored to the soil. There is an increase of more than 100% for geotextile placed at the surface and more than 25% increase when the geotextile is placed at the mid height of the subgrade to that of unreinforced soil.
4. The CBR value of soil with anchored geotextile is observed to vary from 17% to 100% for unsoaked condition and 4% to 75% for soaked condition with respect to that without anchorage.

Field Study

1. By visual examination the Coir Geotextile reinforced roads are better in performance compared to unreinforced roads.
2. Potholes as well as cracking seem to be more in unreinforced road sections.
3. IRI values as well as skid resistance seem to reduce with time but they are all with in the allowable limits.
4. Benkelman deflection of reinforced roads are less compared to unreinforced roads.
5. Initially the variation in Benkelman Beam deflection between reinforced and unreinforced road is high and with time the variation reduces in both the roads.

Hence it can be concluded that Coir Geotextle reinforced roads are structurally strong compared to unreinforced roads it remains stable.

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Paper Published

Greeshma P G, Mariamma Joseph and Sheela Evangeline Y, 2010:- "Effect of Anchorage on Coir Geotextile Reinforcement" Proceedings of International Conference on Technological Trends (ICTT 2010), CET, TVM

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ANNEXURE

Test Road 3

Kozhinada Road Construction

Fig.1 Before laying coir geotextiles Kozhinada

Fig. 2 Leveled subgrade before laying coir geotextiles

Fig. 3 Laying of coir geotextile in Kozhinada

Fig. 4Placing of soil above geotextile in Kozhinada

Test Road 2

Fig. 1 Placing of coir geotextile – Mangalabharathy SN Kadavu road in Haripad

Fig. 2 Placing of coir geotextile - Mangalabharathy SN Kadavu road in Haripad


Fig. 3 Placing of coir geotextile Mangalabharathy SN Kadavu road in Haripad


Fig. 4 Surfacing of road Mangalabharathy SN Kadavu road in Haripad

Test Road 1
Chirakkad- Kumbakkad road (Varkala)

Fig. 1 Laying of coir geotextile in Chirakkad- Kumbakkad road (Varkala)

Fig. 2 Laying of coir geotextile Chirakkad- Kumbakkad road (Varkala)

Fig. 3 Surfacing of road Chirakkad- Kumbakkad road (Varkala)

Benkelman Beam test in progress


Merlin test in progress

Non woven coir geotextiles taken from Kozhinada road after 4 years

Non woven coir geotextiles taken from Kozhinada road after 4 years

Kozhinada road after 4 years

Kozhinada road after 4 years