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Design and Engineering of an Innovative Bituminized Jute Paving Fabric for Potential Application in Road Construction

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Abstract

Geotextiles are mainly made of man-made fibresbut since the last two decades natural fibre made geotextilelike jute geotextile have been found to be effective in improving geotechnical characteristics of soil and are being extensively used for various technical end-uses like erosion control, management of slopes, strengthening of roads, stabilization of embankments, protection of river banks, consolidation of soft soil, etc. The backdrop of growing global concern for environment concomitant with the alarming danger of carbon foot-print generation amalgamated with non-biodegradability and higher toxicity generation from the use of synthetic fibres have created an urge to come back to natural fibres, thereby opening new market opportunities.Jute Geotextiles (JGT), apart from its advantages of being eco-compatible and techno-economically viable, have proven to be among the most versatile and cost effective ground modification materials which play a significant part in modern pavement design and maintenance techniques.Several varieties of Jute Geotextiles (JGT) both woven and nonwoven have since been developed for a number of geotechnical end uses e.g. improving pavement performance, soil erosion, embankment, drainage system. But, the use of JGT has been restricted mainly as underlay in road construction for strengthening the pavement structure by increasing the soil California Bearing Ratio (CBR) value apart from the other end uses. Some fabrics are also being used as interlayer for the prevention of the reflective cracking in the road. But the use of JGT as overlay in the road construction has not yet been tried so far. Jute Paving Fabric which is a combination of woven and nonwoven jute fabric impregnated with suitable type andgrade of bitumen followed by its laboratory simulation testing carried out at the premiere Central Road Research Institute (CRRI), New Delhi has great potential to be used as overlay fabric for strengthening the pavement structure as well as partial substitute of bitumen mastic commonly used in road construction. The focus of this paper is the designing and engineering of Bituminized Jute Paving Fabric (BJPF)and commercial application of the same on the roads of different traffic volumes with assessment of its performance based on design consideration, selection criteria and overall enactment.

Keywords: geotextile, jute geotextile, eco-compatible, overlay, bituminized jute paving fabric

Introduction

Geotextiles are textiles applied in soil to help its engineering performance(***Martin, Sarsby, Robert, Anand, 2000***). Geotextiles may be either man-made or natural. Man-made geotextiles are made of artificial fibres like polypropylene, polyethylene and some other petrochemical derivatives(***Horrocks, 1992***). Natural geotextiles, on the other hand, are made out of natural fibres like jute, coir, sisal and the like(***Maiti, 1979)***. Jute Geotextile (JGT) is a natural technical textile.Jute Geotextiles (JGT) provides indigenous, available technologies, which have got enough potential in offering eco- friendly sustainable, cost effective geotechnical solution to many ground engineering problems(***Kusumgar, 1988***). Although several varieties of Jute Geotextiles both woven and nonwoven are being used for a number of geotechnical end uses, it is a fact that there is an urgent need to design and develop precise fabric as overlay in the existing pavements and other emerging civil engineering applications if it has to stay technically and economically competitive in the global market(***Jha and Mandal, 1988***).To make effective use as an overlay fabric on existing pavements, paving fabric has to be water-proof and abrasion resistant(***Zanten, 1986***).It has been reported that nonwoven Jute Geotextile

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is an extremely good receptor of hot bitumen, besides having thermal compatibility with bitumen in the range of 190^{0}c(***Ghosh and Datta, 2006***). Woven Jute Geotextiles ensure durability against abrasion and shear(***Ranganathan, 1994***). Hence Grey jute Paving Fabric (GJPF) which is a combination of woven and nonwoven jute fabric, smeared with suitable type and grade of bitumen can be used as overlay fabric for strengthening of the pavements as well as partial substitute of commonly used bitumen mastic in road construction.Extensive research works are going on to make a durable and cost effective smooth road transport system. The research works are mainly based on construction of roads by using suitable geotextiles.Very recently, one such exhaustive research and developmental work entitled "Engineering suitable overlay fabric to serve as a cheaper substitute of bitumen mastic"had been carried out by the Department of Jute and Fibre Technology, University of Calcutta, India in collaboration with Central Road Research Institute (CRRI), New Delhi, India under the valued supervision of National Jute Board (NJB), Ministry of Textile, Government of India. The prime objective of this research work was to develop suitable grey jute paving fabric with the combination of woven and nonwoven fabric, followed by its bituminization by a suitable type and grade of bitumen. After bituminization the developed product had been subjected to several field trials at different high traffic volume roads across the heart of the major cities.Continuous monitoring of all those ear-marked roads are going on at regular intervals, following the Indian Roads Congress (IRC) guidelines and the results obtained so far prolifically speaks aboutthe satisfactory performance and techno-economic viability of the developed bituminized jute paving fabric.

Material and Methods

The entire experimental operations for preparation of different types of Grey Jute Paving Fabric (GJPF) samples starting from selection of raw Jute fibres and fibre-mixing (batch composition) to the production of Bituminized Jute Paving fabrics (BJPF) has been carried out under four stages - (a) the choice of raw Jute fibre-mixing, i.e. batch composition, (b) the preparation of woven fabric sample (c) the preparation of single layered combined woven and nonwoven fabric sample (d) the preparation of paving fabric samples (e) bituminization of the grey jute paving fabric.

The Choice of Raw Jute Fibre for Mixing (Batch Composition)

Based on experience and economic considerations and as well as depending upon common fibre quality criteria / attributes of Jute fibres, different fibre-mixing (batch composition) have been used, for preparation of all the paving fabric samples. Keeping in view the factor of techno-economic viability of this new product, 10% – 15% Jute caddies/waste has been judiciously used during manufacturing of Grey Jute Paving Fabric.

Preparation of Woven Fabric Sample

Ten plain weave fabric samples of different gsm (120 – 210 gsm) were prepared in the conventional Jute Loom. After testing all of the developed woven fabric samples related to the different geotechnical property parameters, the specifications of the optimized standard woven fabric sample selected as the woven component for the production of the grey jute paving fabric are shown in Table 1.

Table 1 – Test Results of Woven Jute Fabric prepared in conventional Jute Loom

Testing Parameters	Values
1. Mass per unit area (gsm)	205.00
2.(a) Warp Grist (lbs/spyndle)	6.90
(b) Weft Grist (lbs/spyndle)	9.50
3. Thickness (mm)	1.10
4.(a) Ends/dm	38.00
(b) Picks/dm	33.00
5.(a) Wide – Width Tensile Strength (kN/m), (MD X CD)	10.5 X 11.5
(b) Elongation- at- break (%) (MD X CD)	5.00 X 5.00

Preparation of Single Layered Combined Woven and Nonwoven Fabric Sample

Ten cross-laid nonwoven batts of different gsm (120-250 gsm) were combined with the selected woven fabric sample in the Needle Punching Loomfor production of single layered combined fabric. After testing and analysis of all the single layered combined fabrics, the single layered combined fabric of the selected woven fabric sample and the nonwoven batt of 210 gsm was selected for production of the paving fabric.

Photo 1: Feeding of the carded slivers

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for Nonwoven Fabric preparation

Photo2: Combination of Cross lapped batt and Single layer woven fabric

Photo 3: Combined layer of Woven and Nonwoven Fabrics

Preparation of Grey Jute Paving Fabric Samples

Initially, ten numbers of Grey Jute Paving Fabrics (GJPF) were produced by suitable combination of single layered combined fabrics and woven fabric samples (as shown in Photos- 1 to 5) with the help of needle punching machinein a commercial Jute Mill. These produced fabric specimens have been tested in the Jute Geotextile Laboratory, Department of Jute and Fibre Technology, India as per National and International Standards listed in Table 2, for assessing their geotechnical property parameters as per the end-use requirements.

Photo 4: Combination of the combined layers of fabric with woven fabric layer

Photo 5: Inspection of Finished Roll of GJPF

Table 2- Physical tests along with the standard test methods of GJPF carried out at Geotextile Laboratory, Department of Jute and Fibre Technology, India.

Sl. No.	Test Parameters	ASTM Test No.
1.	Mass per unit area	D5261-92(2009)
2.	Fabric Thickness	D5199-01(2006)
3.	Tensile Properties of Geotextiles by Wide Width Strip Method	D4595-09
4.	CBR Puncture Resistance	D6241-04(2009)
5.	Bursting Strength – Ball	D3787-07
7.	Permittivity	D4491-99(2009)
8.	Apparent Opening Size (AOS)	D4751-04

Bituminization of Grey Jute Paving Fabric

Selected grey jute paving fabric samples, physical properties of which had been furnished in table -3(annexure-1) have been sent to Central Road Research Institute (CRRI), New Delhi, India for selection of the right grade of bitumen such as Bitumen30/40, 60/70, 80/100, Polymer Modified Bitumen like PMB 40, PMB 70, PMB 120, Crumb Rubber Modified Bitumen CRMB 50, CRMB 55, CRMB 60 and Cationic Bitumen Emulsion MS, SS_1, SS_2.SPRAMUL (SS_1ASTM and CQS1H). After the laboratory testing as well as laboratory simulation testing of the bituminized samples it was observed by the CRRI scientists that the overall tensile properties of the developed GJPFs treated with emulsified Bitumen and specially emulsified Bitumen had deteriorated. This could be due to the presence of acidic base in the emulsion, which degrades the Jute fibre while the other grades of Bitumen cause stiffening of the Jute fabric. Moreover the tests carried out by CRRI scientists revealed that excepting the polymer modified bitumen (PMB) grades, coating GJPF with other types of bitumen did not have properinter- phasingresulting in peeling off of bitumen in some portions.

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Impact Factor: 1.852

Results and Discussions

Materials used in the study

The materials used in the study for preparation of samples included aggregates, bitumen alongwith grey jute paving fabric. It was necessary to conduct the physical testing of the materials used to check their suitability for use in the bituminous layers(***Adhikari and Zhanping, 2010***).

Physical Tests on Aggregates

Aggregate forms the major part of the pavement structure(***MoRT&H, 2001***) as they have to primarily bear load stresses occurring on the pavement. So, naturally they have to withstand the high magnitude of load stresses alongwith wear and tear. The aggregates of different sizes (20mm, 10mm, 6mm, stone dust and lime) were obtained from a hot mix plant near Delhi, India and various physical tests were carried out on them to check their suitability for use.

Specific Gravity and Water Absorption Test

Specific gravity of an aggregate is considered to be a measure of strength or quality of the material. Stones having low specific gravity are generally weaker than those with higher with higher specific gravity values. The specific gravity test helps in identification of stone(***ASTM spl. Publication 508, 1971***). Water absorptiongives an idea of strength of rock. Stones having more water absorption are more porous in nature and are generally considered unsuitable unless they are found to be acceptable based on strength, impact and hardness tests(***The Asphalt Handbook, 2007***). The test results are presented in Table 4. The gradation of individual aggregates is presented in Table 5.

Table 4- Test Results for Specific Gravity & Water Absorption

Type of aggregates	Specific Gravity	Water Absorption (%)	Permissible Limits as per MoRT&H, 2001
Coarse aggregates (20mm)	2.62	0.50	2 % max.
Fine aggregates (13.2mm)	2.61	0.67	
Fine aggregates (6mm)	2.63	0.71	
Stone dust	2.68	-	-
Lime	2.24	-	-

Table 5 - Gradation of Individual Aggregates

Sieve Size, mm	Percent of Aggregates Passing through sieve size				
	20 mm	13.2 mm	6 mm	Stone Dust	Lime
26.5	100.0	100.0	100.0	100.0	100
19	65.8	100.0	100.0	100.0	100
13.2	4.7	84.1	100.0	100.0	100
9.5	0.3	24.5	96.1	98.9	100
4.75	0.0	0.5	14.5	96.2	100
2.36	0.0	0.2	0.4	81.7	100
1.18	0.0	0.1	0.3	58.8	100
0.6	0.0	0.1	0.3	48.2	100
0.3	0.0	0.1	0.3	30.9	99
0.15	0.0	0.1	0.2	18.9	89
0.075	0.0	0.1	0.1	9.7	62

Impact Test

Toughness is the property of a material to resist impact(***Marienfeld and Baker, 1999***). Due to traffic loads, the road stones are subjected to the pounding action or impact and there is possibility of stones breaking into smaller pieces. The road stones should therefore be tough enough to resist fracture under impact. The impact test measures the resistance of the stones to fracture under repeated impacts. The test results are presented in Table 6.

Table 6 - Test results for Aggregate Impact Test

Type of aggregates	Aggregate Impact Value (%)	Permissible Limits as per MoRT&H, 2001 (For BC)
Coarse aggregates (20mm)	19 %	24 % max.
Fine aggregates (10mm)	13.35 %	

Shape Test

The particle shape of aggregates is determined by the percentage of flaky and elongated particles contained in it(***IS: 2386 (Part 1), 2002***). The presence of flaky and elongated particles is considered undesirable as they may cause inherent weakness with possibilities of breaking down under heavy loads. Angular shape is preferred due to increased stability derived from the better interlocking. The flakiness index of the aggregates is the percentage by weight of particles whose least dimension (thickness) is less than three-fifth (0.6) of their mean dimension. This test is not applicable to sizes smaller than 6.3 mm. The elongation index of the aggregates is the percentage by weight of particles whose greatest dimension is (length) is greater than one and four fifth times (1.8 times) their mean dimension. The elongation test is not applicable to sizes smaller than 6.3 mm.

Stripping Test for Aggregates

The aggregates used in bituminous pavements should have less affinity with water when compared with bituminous materials, otherwise the bituminous coating on the aggregate will be stripped off in presence of water(***IS: 6241, 1971***). To check the stripping properties of the aggregates IS: 6241-1971 describes the procedure for stripping test. The stripping test was done on the aggregates with 60/70 bitumen. The retained coating was found to be more than 95 %, which conforms to the requirements as per MoRT&H specifications, 2001 (Fourth Revision). So, the test for water sensitivity has not been carried out in the present study.

Physical Tests on Bitumen

Bitumen is a petroleum product(***Don, 1982***) obtained by distillation of petroleum crude is used in the construction of road pavement especially in flexible pavement to withstand a relatively adverse condition of traffic and climate. Different physical tests like ductility test(***IS: 1208, 1978***), softening point test(***IS: 1205, 1978***), specific gravity test(***IS: 1202, 1978***), penetration test(***IS: 1203, 1978***)and viscosity testhave been carried out. However, the impregnation of the jute samples has been done with three different binders viz., 60/70, PMB-40 and 80/100, so the asphalt retention test has been done with all the three binders.

Asphalt Retention Testing of bitumen treated jute paving fabric

Asphalt retention is defined as the weight of asphalt cement retained by paving fabrics per unit area of specimen after submersion in the asphalt cement. The test has been done as per ASTM D 6140, "*Standard Method to Determine Asphalt Retention of Paving Fabrics used in Asphalt Paving for Full-width Applications*". The test procedure for determining asphalt retention is toselect a random four-machine direction and four cross machine direction specimens measuring 100 by 200 mm (4 by 8 in.) forming the individual test sample this is followed by conditioningof the individual sample and weighingit to nearest 01 g. To preheat asphalt cement to 135 ± 2°C.Then to submerge the individual test specimen in the specified asphalt cement maintained at a temperature of 135 ± 2°C in a mechanical convection oven. The specimen will then be submerged for 30 min. two clamps may be placed on the fabric, one on each end to facilitate handling of specimen.After the required submersion, the coated asphalt cement to be removed, saturated test specimen and hang to drain (long axis vertical) in the oven at 135 ± 2°C. This is followed by hanging the specimen for 30 min from one end and then from the other for the same time. The asphalt cement coated, saturated test specimen is then allowed to cool for a minimum of 30 min and then trim off the excess asphalt cement.The Asphalt retention is calculated as the average of the asphalt retention observed for all the specimens is as follows. $R_A = (W_{sat} - W_g)/ A_g$,Where, R_A is the Asphalt Retention in g/m^2, W_{sat} is the weight of saturated test specimen in g, W_g is the weight of geotextile test specimen before saturation in g, and $A_g$is the area of geotextile specimen before test in m^2.Three samples have been tested for asphalt retention for each type of bitumen and the average value has been reported. The test results for asphalt retention are given in Table 7.

Table 7- Test results for Asphalt Retention of jute paving fabric

Sl. No.	Type of Bitumen used for impregnation of jute paving fabric	Asphalt retention in kg/m^2
1.	60/70 Bitumen	3.4
2.	PMB-40 Bitumen	3.6
3.	80/100 Bitumen	3.7

The procedure for asphalt retention test is shown in Photos 6 and 7.

Photo 6: Jute samples ready for impregnation with bitumen

Photo 7: Jute samples after impregnation with bitumen

Marshall Mix Design Method

Bruce Marshall, formerly bituminous engineer with Mississippi State Highway Department, USA formulated Marshall Method for designing bituminous mix. The test procedure has been standardized in (***ASTM D 1559***). In this method, the resistance to plastic deformations of cylindrical specimen of bituminous mixture is measured when the same is loaded at the

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periphery at 5 cm per minute. The test procedure is used in designing and evaluating bituminous pavement mixes. The test procedure is extensively used in routine test programme for the paving jobs. There are two major features of the Marshall method of designing mixes namely density void analysis and stability – flow tests. The Marshall stability of the mix is defined as a maximum load carried by a compacted specimen at a standard test temperature at 60 °C. The flow value is the deformation the Marshall Test specimen undergoes during the loading up to the maximum load, in 0.01 mm units.

Design requirements of mix as per MoRT&H Specifications

As per the MoRT&H specifications for BC mix, when the specimens are compacted with 75 blows on either face, the designed BC mix should fulfil the following requirements:

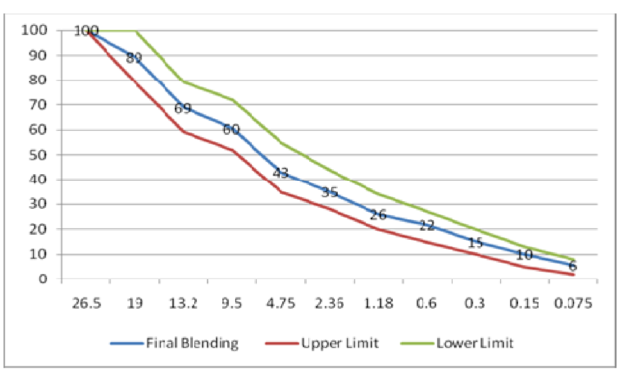
Marshall stability value, kg (minimum)	900
Marshall flow value, mm	2 - 4
Voids in total mix, Vv %	3 - 6
Voids in mineral aggregates filled with bitumen, VFB, %	65 - 75
Loss of stability on immersion in water at 60°C	> 75 %

Marshall Mix design and determination of OBC for the present study Proportioning of aggregates

For the purpose of this study, the gradation of BC mix was selected based upon the thickness of the layer. This study was carried out for 50 mm thick layer of BC as per clause of MoRT&H specification (Fourth Revision, 2001). The individual gradation of selected component aggregates and their proportioning achieved by trial and error method is given in Table 8. The designed gradation along with the specified limits is shown in Graph 1.

Table 8 - Proportioning of Aggregates for BC Mix Design

Sieve Size	Percentage of aggregates passing through sieve size						
	Nominal size of aggregates					Blend Proportion by wt. of aggregate A : B : C : D : E 31 : 10 : 17 : 39 : 3	Specified Limits for 50 mm BC (MoRT&H, 2001)
	A 20 mm	B 13.2 mm	C 6 mm	D Stone Dust	E Lime		
26.5	100.0	100.0	100.0	100.0	100	100	100
19	65.8	100.0	100.0	100.0	100	89	79-100
13.2	4.7	84.1	100.0	100.0	100	69	59-79
9.5	0.3	24.5	96.1	98.9	100	60	52-72
4.75	0.0	0.5	14.5	96.2	100	43	35-55
2.36	0.0	0.2	0.4	81.7	100	35	28-44
1.18	0.0	0.1	0.3	58.8	100	26	20-34
0.6	0.0	0.1	0.3	48.2	100	22	15-27
0.3	0.0	0.1	0.3	30.9	99	15	10-20
0.15	0.0	0.1	0.2	18.9	89	10	5-13
0.075	0.0	0.1	0.1	9.7	62	6	2-8



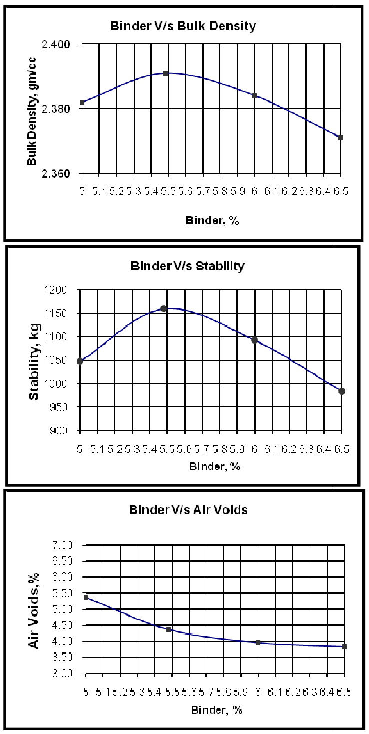
Graph1: Proportioning of Aggregates for BC Mix Design

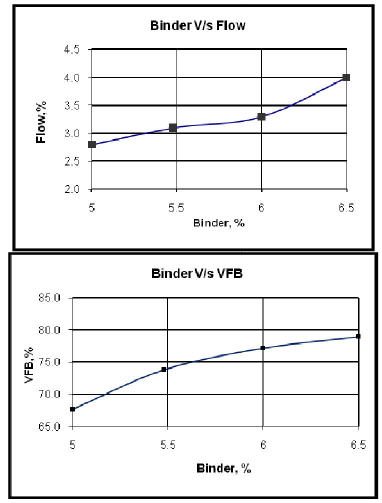
Marshall Method of the mix design as per ASTM D-1559 was carried out for determination of the optimum binder content. To determine the optimum binder content (OBC). Marshall samples were prepared at varying percentages of 60/70 paving grade binder. Volumetric and mechanical parameters obtained for BC with 60/70 paving grade bitumen such as Bulk density, Marshall Stability, Flow, and other volumetric properties were then obtained which are given in Table 9. The test values obtained are plotted graphically and shown in

Graph 2. Using the above parameters, Optimum Binder Content (OBC) was found to be 5.67 percent by weight of aggregates.

Table 9- Volumetric and Mechanical Parameters obtained for BC with 60/70 Bitumen

Binder Content, % by weight of Aggregate	Bulk Density, gm/cc	Stability, Kg	Flow, mm	Air Voids, %	Voids Filled with Bitumen, VFB, %	Voids in Mineral Aggregates, VMA
5.0	2.382	1047	2.8	5.37	67.67	5.0
5.5	2.391	1160	3.1	4.34	74.00	5.5
6.0	2.384	1093	3.3	3.95	77.17	6.0
6.5	2.371	984	4	3.82	78.94	6.5





Graph 2: Marshall Parameters obtained for BC with 60/70 Bitumen

The values obtained at the optimum binder content 5.67% are indicated in Table 10, as can be seen they do are meet MoRT&H specifications for BC mix.

Table 10 - Marshall Parameters Obtained at Optimum Binder Content with 60/70 Bitumen

Parameters	Values obtained at OBC	Specified Values as per MORT&H, 2001
Stability, kg	1160	> 900
Flow, mm	3.1	2 - 4
Air Voids, %	4.4	3 - 6
Voids Filled with Bitumen, %	73.8	65 – 75
Density, gm/cc	2.390	-

Beam Fatigue Testing

The flexure fatigue test**(*Adhikari and Zhanping, 2010*)**is conducted to evaluate the fatigue characteristics of an HMA mixture. Fatigue cracking of pavement is considered to be more a structural problem than simply a material problem. Several external factors influence the fatigue cracking in pavements, such as poor subgrade drainage, time of placement, and method of compaction and placement of the asphalt mix. The specimens for this test are 63.5 mm by 50 mm by 400 mm beams. The test is conducted in accordance to the procedures in AASHTO T 321-07. In this method, repeated haversine loads are applied at the third points of the specimen. The beam fatigue test can be conducted in controlled stress or controlled strain mode.

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Table 11 - Beam Fatigue Testing Results

(A) beam samples (with no jute)						
Strain Level (microstrain)	300		400		500	
Frequency (Hz)	5	10	5	10	5	10
Number of Repetitions to Failure (N_f)	159440	58110	112100	44120	28250	17670
(B) beam samples (with jute impregnated with 60/70 binder)						
Strain Level (microstrain)	300		400		500	
Frequency (Hz)	5	10	5	10	10	5
Number of Repetitions to Failure (N_f)	312320	153200	143640	131250	122590	55040
(C) beam samples (with jute impregnated with pmb-40 binder)						
Strain Level (microstrain)	300		400		500	
Frequency (Hz)	5	10	5	10	10	5
Number of Repetitions to Failure (N_f)	429510	159900	376900	186430	160120	112090
(D) beam samples (with jute impregnated with 80/100 binder)						
Strain Level (microstrain)	300		400		500	
Frequency (Hz)	5	10	5	10	10	5
Number of Repetitions to Failure (N_f)	198110	115390	184060	82000	125910	70900

It can be seen from the above table that there is an improvement in the fatigue life of the beam where bitumen impregnated was used since they sustained more number of repetitions.
To evaluate the effect of bitumen impregnated jute in the fatigue life, a factor called “Effectiveness Factor” (EF) has been calculated as given below:

$$\text{Effectiveness Factor (EF)} = \frac{\text{Number of repetitions to failure for reinforced beams}}{\text{Number of repetitions to failure for unreinforced beams}}$$

The effectiveness factors for the beams for different test conditions were calculated and are given in Table 12.

Table 12 - Effectiveness Factors for Beams for Different Test Conditions

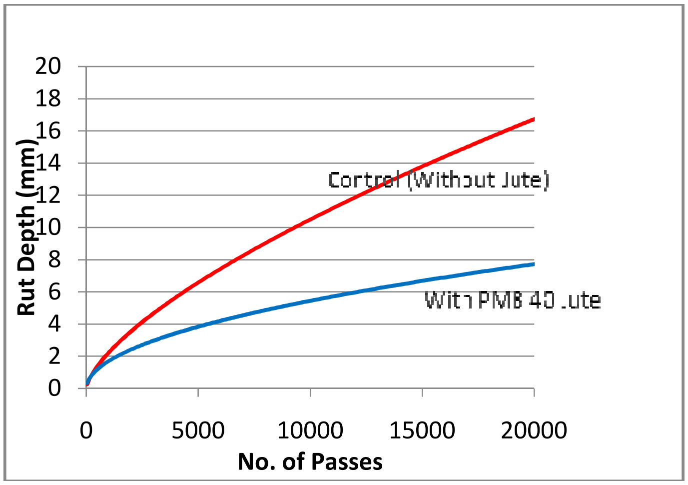
(A) beam samples (with jute impregnated with 60/70 binder)						
Strain Level (microstrain)	300		400		500	
Frequency (Hz)	5	10	5	10	10	5
No. of Repetitions to Failure (N_f)	1.96	2.64	1.28	2.97	4.34	3.11
Average value of Effectiveness Photo 8.1 Factor (EF) = 2.72						
(B) beam samples (with jute impregnated with pmb-40 binder)						
Strain Level (microstrain)	300		400		500	
Frequency (Hz)	5	10	5	10	10	5
Number of Repetitions to Failure (N_f)	2.69	2.75	3.36	4.23	5.67	6.34
Average value of Effectiveness Factor (EF) = 4.17						
(C) beam samples (with jute impregnated with 80/100 binder)						
Strain Level (microstrain)	300		400		500	
Frequency (Hz)	5	10	5	10	10	5
Number of Repetitions to Failure (N_f)	1.24	1.99	1.64	1.86	4.46	4.01
Average value of Effectiveness Factor (EF) = 2.53						

Note: The reference beam for calculating the EF has been taken as plain beam without jute.

It can be seen from the above table that average value of Effectiveness Factor (EF) was found to be highest for PMB-40 impregnated jute fabric. Also, PMB-40 gives higher values of EF for all the strain levels and frequency loadings. So, it can be concluded the PMB-40 is the most effective binder for increasing the fatigue life and will mitigate the propagation of reflective cracking. However, field performance evaluation is a must for evaluating the actual behavior under ambient climatic conditions.

Wheel Tracking Test

Wheel tracking is used to assess the resistance to rutting of asphaltic materials under conditions which simulate the effect of traffic. A loaded wheel tracks a sample under specified conditions of load, speed and temperature while the development of the rut profile is monitored continuously during the test. The wheel tracking test consists of a loaded wheel assembly and a confined mould in which a 305×305×50mm specimen of asphalt mix is rigidly restrained on its four sides. The test specimen is mounted on a table which is reciprocated a distance of 230mm on linear bearings at the specified speed of 42 passes/minute along the length of the slab. A loaded rubber tyred wheel runs on top of the specimen and the resultant rut is monitored as the test proceeds using a calibrated displacement transducer. The temperature during the test is maintained by an insulated closed chamber maintained at a constant test temperature of 50 ± 1°C. The specimens are subjected to 20000 cycles. Two specimens were tested for each mix and average data on rut depth was found out. The rut depth was recorded at mid-point of the specimen length. The slabs for this test were prepared by filling the mould with the bituminous mix and applying static load through UTM till the depth of 50 mm is achieved. Two different types of slabs were prepared for this test one is the slab with control mix (in which no jute was used) and the other is the slab in which jute impregnated with PMB-40 was laid in the bottom one-third height of the sample. The results for the wheel tracking test are plotted in graph 3.



Graph 3: Number of Passes Vs Rut Depth (in Wheel Tracking Test)

Discussions

After thorough laboratory testing of the compatibility of different types and grades of Bitumen with grey jute fabric, the CRRI scientists observed and recommended that jute was found to be effective in increasing the fatigue life of bituminous mixes. Jute impregnated with 60/70 bitumen was found to have an average Effectiveness Factor (EF) of 2.72, i.e., it increases the fatigue life by 172 % compared to samples where no jute was used. Jute impregnated with PMB-40 bitumen was found to have an average Effectiveness Factor (EF) of 4.17, i.e., it increases the fatigue life by 317 % compared to samples where no jute was used.Finally, jute impregnated with 80/100 bitumen was found to have an average Effectiveness Factor (EF) of 2.53, i.e., it increases the fatigue life by 153 % compared to samples where no jute was used.A higher value of Effectiveness Factor (EF) indicates higher potential of the developed fabric to be used for field trial as per the objectives of the project.

Based on the laboratory testing and analysis of the results obtained, the CRRI scientists recommended that jute impregnated with PMB-40 bitumen was found to have the highest fatigue life and therefore, it is recommended to be used for the purpose of field trials. Proper impregnation of the jute fabric as per ASTM 6140 should be ensured. It must be ensured that the full thickness of the jute fabric is impregnated with the bitumen. However, any excess bitumen on the surface of jute fabric should be removed immediately.The laying of jute fabric should be done with mechanized equipment capable of providing a smooth installation with a minimum of wrinkling or folding. MORT&H specifications, 2001 must be adhered to during the construction operations and strict quality control must be ensured during the bituminous construction. The laying

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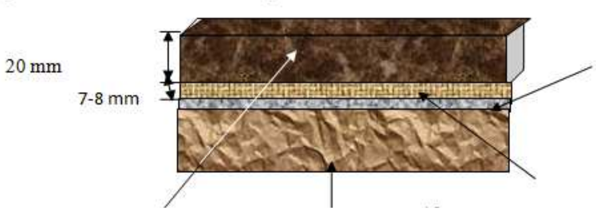
of the bitumen impregnated jute fabric should be done in accordance with the requirements of IRC: SP: 59-2002(***IRC: SP: 59, 2002***).

Table 13 - Test Results of the Properties of Bituminized Jute Overlay Paving Fabric

Sl. No.	Property Parameters	Values
1.	Mass per unit area (gsm)	3500
2.	Thickness (mm)	8.0
3.	Bitumen Add-On%	240 (approx.)
4.	Tensile Strength (kN/m) [MD X CD]	38.50 x 40.00
5.	Breaking Elongation (%)[MD X CD]	11.00 x 9.00
6.	Bursting Strength (kg/cm^2)	43.00

Field Trials

Field Trial of the developed Bituminized Jute Paving Fabric (BJPF) has been carried outat the premises of Department of Jute and Fibre Technology, University of Calcutta. The laying of the Bitumen impregnated Jute fabric has been done in accordance with the requirements of IRC: SP: 59-2002. Monitoring of the field trial as well as performance evaluation of the BJPF are going on which will be under a constant observation for at least two years. Close monitoring of the field trial is going on after every fifteen days and will continue for the next two years to assess the performance of the road under field trial. In the course of physical observation during monitoring of the road section under traffic simulated condition there were no signs of cracks and pot holes appearing on the surface of the road even after the completion of ten months of traffic simulation. Standardization and optimization of the product will be made and disseminated to the manufacturers and end users for commercial application after the completion of monitoring and performance evaluation of the product.



BJPF

Mastic AsphaltExisting Riding Surface

Fig. 1 Sectional View of the Design of the Field Trial with the Developed BJPF

Based on the pilot field trial performance, a full scale commercial field trial has been carried out over a stretch of lane of area -1000 sq. mts. approximately at Uday Shankar Sarani, Golfgreen, Kolkata India to evaluate both of the functional as well as structural contribution of the developed Bituminized Jute Paving Fabric (BJPF) reinforcement to the pavement system in a full volume traffic road (Fig. 1).

Some Glimpses of the Commercial Field Trial at Uday Shankar Sarani, Golfgreen, Kolkata- West Bengal, India

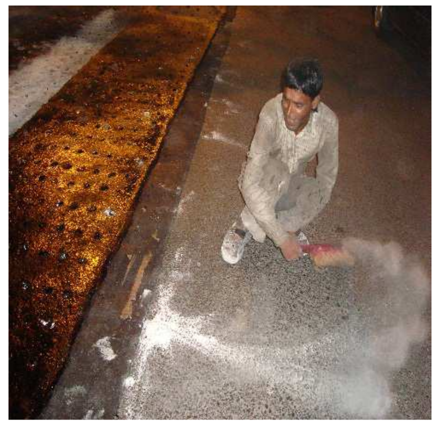


Photo 8: Cleaning of the road surface

Photo 9: Application of Tack Coat

Photo 10: Laying of BJPF

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Photo 11: Laying of Mastic on BJPF

Photo 12: Placing of antiskid stone chips on masticated surface

Photo 13: Thermosealing of the joints

Monitoring

Physical appearance of the stretch is similar to the mastic asphalt. Regular traffic is moving smoothly on the newly prepared road at the above mentioned site. Close monitoring of the road is in progress and will continue for the next two years as per the guidance of CRRI, New Delhi, and National Jute Board, Ministry of Textile, Government of India, and Indian Roads Congress (IRC)

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Conclusion

An effective grey jute paving fabric (GJPF) has been designed and engineered in a conventional and commercial Jute Mill followed by its bituminization in a bitumen treatment plant to produce an effectivebituminized jute paving fabric (BJPF). The performances of the severalfield trials of the developed producttill date are satisfactory which reflects the efficacy of the same in restoring the ecological balance on one hand and battling the generation of carbon footprint by curbing the tremendous consumption of bitumen in road construction. The performance of the developed product are being assessed on a regular basis through extensive monitorings as per the guidelines ofthe premiere Central Road Research Institute(CRRI), New Delhi in collaboration with Civil Engineering Department, Bengal Engineering and Science University (BESU), Shibpur and National Jute Board (NJB), Ministry of Textile, Government of India. No doubt, if the developed BJPF can prove its potentiality in engineering solution to the road constructions then this will not only open newer avenues to the class of Technical Textiles but also will give a huge impetus to the Jute Sector and serve the society as a whole. The developed fabric can be subjected to more number of field trials of different scales under different climatic and road conditions and can be evaluated for assessing the performance at regular intervals for having better understanding about the suitability of the developed product which will establish the acceptability of an innovative Jute Fabric-Mastic Asphalt road construction system.

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Table 3 – Test results of 10 numbers of Sandwich Jute fabrics produced at reputed Jute Mill, West Bengal.

Sl. No.	Specifications	GSM (gm) at 8.5% M.R. (actual)	Thick-ness (mm)	Tensile Strength (KN/m) MD X CD	Elongation (%) MD X CD	CBR Puncture (kN)	Bursting Strength (kg / cm^2)	Flow – rate (l/m^2/sec)	Permittivity (/sec)	Permeability (cm/sec)	AOS [O_{95}] (Micron)
I	2 layer woven (hessian warp batch)+2 layernonwoven(hessian warp batch)	850	5.2	17.60 X 19.20	5.00 X 14.00	1.89	28.82	116.40	2.33	1.21	250
II	2 layer woven (hessian warp batch, Shuttle less Loom) + 3 layer nonwoven(Sacking weft batch)	1120	5.80	19.90 X 17.25	5.00 X 15.00	2.12	30.15	100.5	2.01	1.16	190
III	3 layer woven (hessian warp batch) +2 layer nonwoven(hessian warp batch)	1035	6.80	25.00 X 26.00	6.00 X 15.00	2.86	36.00	84.40	1.69	0.948	170
IV	3 layer woven (hessian warp batch, Shuttle less Loom) + 3 layer nonwoven(hessian warp batch)	1275	7.25	23.85 X 28.35	6.00 X 16.00	3.25	41.52	67.50	1.35	0.970	180
V	3 layer woven (hessian warp batch) + 4 layer nonwoven(Sacking weft batch)	1408	10.29	28.95 X 31.25	5.00 X 16.00	3.76	64.86	64.34	1.25	1.28	135

Continuation of Table-3

Sl. No.	Specifications	GSM (gm) at 8.5% M.R. (actual)	Thickness (mm)	Tensile Strength (KN/m) MD X CD	Elongation (%) MD X CD	CBR Puncture (kN)	Bursting Strength (kg / cm^2)	Flow – rate (l/m^2/sec)	Permittivity (/sec)	Permeability (cm/sec)	AOS [O_{95}] (Micron)
VI	4 layer woven (hessian warp batch, Shuttle less Loom) + 3 layer nonwoven(Sacking weft batch)	1480	8.21	29.15 X 31.50	5.00 X 16.00	3.95	77.52	65.50	1.31	1.07	140
VII	4 layer woven (hessian warp batch, Shuttle less Loom) + 4 layer nonwoven (Caddies & waste batch)*	1506	8.47	31.48 X 32.07	6.00 X 17.00	3.98	66.28	48.32	0.964	0.818	110
VIII	3 layer woven (hessian warp batch, Shuttle less Loom) + 4 layer nonwoven(hessian warp batch)	1520	8.4	30.85 X 32.35	6.00 X 17.00	4.28	59.60	58.92	1.178	0.989	120
IX	3 layer woven (hessian warp batch) + 4 layer nonwoven(hessian warp batch)	2050	9.95	36.10 X 34.73	7.00 X 19.00	5.68	84.36	34.76	0.695	0.691	95
X	4 layer woven (hessian warp batch)+ 4 layer nonwoven(hessian warp batch)	2180	10.01	38.83 X 30.21	6.00 X 17.00	5.89	92.38	56.00	1.12	0.120	80

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