

Bituminized Jute Paving Fabric (BJPF) for Road Constructions - A Potential Innovative Approach

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ABSTRACT:In the last quarter of the twentieth century, a new class of materials, Geosynthetics, emerged prospectively leading significant innovation in the design of geotechnical and geoenvironmental systems. Geotextiles have proven to be among the most versatile and techno-economically viable ground modification materials playing a significant role in modern pavement design and maintenance techniques. With the growing environmental concern across the globe, technologists, researchers have inclined towards the natural geotextile where Jute Geotextile (JGT) is one of the potential candidates. But, JGT has been restricted mainly as underlay in road construction. Hence, there is an urgent need to design and develop a precise innovative fabric as overlay on existing pavements and other emerging civil works to stay technically and economically competitive in the global market. Such a fabric will not only prove techno-economically viable but will also reduce the carbon foot-print generation to a large extent. This paper delineates the development of Grey Jute Paving Fabric (GJPF) followed by its bituminization with suitable type and grade of bitumen to develop Bituminized Jute Paving Fabric (BJPF). The BJPF will enhance the life of the overlay thereby reducing the cost of maintenance as well as serving as a partial substitute of bitumen mastic.

KEYWORDS:Jute Geotextile (JGT), Grey Jute Paving Fabric (GJPF), Bituminized Jute Paving Fabric (BJPF).

I. INTRODUCTION

The overlay over a flexible pavement directly sustains the moving vehicular loads and acts as a cushion over the main pavement [1]. Understandably the overlay should have adequate strength and resilience to resist abrasion and shear of moving loads and to withstand the bending stress caused by axle loads [2]. Cracks [3] in conventional premixed carpet (PMC) placed as overlay develop due to inadequate bond strength of the PMC ingredients succumbing principally to sucking effects of the moving loads, penetration of rain water and temperature changes. Bitumen mastic, a combination of straight run or industrial bitumen of suitable penetration and viscosity, binder and aggregates, is now being used extensively on flexible roads as it provides a dense and impermeable sheet which does not disintegrate easily [4]. Indian Roads Congress (IRC), New Delhi has specified the mix design of bitumen mastic indicating the desired hardness number, binder content, preparation of the mix and its installation method. Studies on Jute Geotextile have revealed the possibility of developing jute-based bitumen-impregnated paving fabric mainly because of excellent thermal compatibility between hot bitumen and jute [5]. The JTM R&D Project No.14 under MM-IV, Scheme-7.1 entitled "Engineering Suitable Overlay Fabric to Serve as a Cheaper Substitute of Bitumen Mastic" sponsored by National Jute Board, Ministry of Textiles, Govt. of India, had started four years back under the guidance of Prof. (Dr.) Swapan Kumar Ghosh, Professor and Head of the Department, Department of Jute and Fibre Technology, Institute of Jute Technology, University of Calcutta, in collaboration with the Central Road Research Institute (CRRI), New Delhi, with the prime objective to develop an innovative and cost effective Jute Paving Fabric with a combination of woven and nonwoven jute fabric to serve as a cost effective reinforcement of pavement system in rural, municipal and urban road constructions. The most promising and potential outcome of this project is Bituminized Jute Paving Fabric (BJPF), which has been developed from the grey jute paving fabric, customized in a commercial jute mill and standardized with desired specifications followed by its bitumen impregnation in a commercial bitumen treatment

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plant. The Assessment of the functional performance of the developed fabrics had been carried out in the recognized laboratory of Central Road Research Institute, New Delhi before field trials under suitable conditions that can withstand the moving loads expected on different categories of roads (e.g. State Highways, Major District Roads and Rural Roads etc.) and standardization of the same.

II. 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 samples (c) the preparation of single layered combined woven and nonwoven fabric samples (d) the preparation of paving fabric samples (e) bituminization of the grey jute paving fabrics.

Raw jute fibres of different grades and quality including assorted root cutting from long jute, jute caddies etc. have been used as shown in table 1 for preparation of different woven and nonwoven needle punched jute paving fabric samples. The criteria for selection of the raw materials are fibre strength in terms of bundle tenacity, fibre fineness, breaking extension, bulk density, colour and lustre and moisture regain percentage. 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. The batch composition and oil in water emulsion that have been used for preparation of woven and nonwoven fabric samples are provided in tables 2, 3, 4 and 5 respectively.

Table 1 Physical characteristics of Jute fibres used in the Study

Fibre type	Fibre strength in terms of Bundle Tenacity (cN/tex)	Fibre Fineness in terms of Linear Density (tex)	Breaking Extension (%)	Bulk Density (g/cc)	Colour and lusture	Moisture Regain (%)
Jute (TD ₅ grade)	32.81	2.36	1.9	0.6	Creamish yellow	12.90
Jute (TD ₇ grade)	31.20	2.76	1.7	0.6	Creamish brown	12.90
Root Cutting of long jute from Bangladesh	33.61	3.11	1.4	0.7	Dark creamish brown	12.40

Table 2 Batch composition of Super Hessian Warp Batch jute woven fabrics

Sl. No.	Batch Composition	In Percentage (%)
1.	TD ₅ long jute reed without root	70
2.	TD ₅ root cutting from long jute	20
3.	Root Cutting of long jute from Bangladesh	10

Table 3 Batch composition of Sacking Weft Batch jute nonwoven fabrics

Sl. No.	Batch Composition	In Percentage (%)
1.	TD ₅ long jute reed without root	50
2.	TD ₅ root cutting from long jute	20
3.	Root Cutting of long jute from Bangladesh	30

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Table 4 Batch composition of Caddies and Waste Batch jute nonwoven fabrics

Sl. No.	Batch Composition	In Percentage (%)
1.	Jute-Caddies and jute mill line waste	100

Table 5 Batching Emulsion Composition (oil in water emulsion)

Sl. No.	Composition	Long Jute	Root Cutting and Mill Line Waste
1.	JBO (Mineral Oil type Jute Batching Oil)	140.00 lit.	150.00 lit.
2.	Nonidet-P ₄₀ (Non-ionic emulsifier)	0.60 lit.	0.60 lit.
3.	Bran Culture (a solution of pectinase enzyme)	35.00 lit.	30.00 lit.
4.	Water	1124.40 lit.	1119.40 lit.
Total volume in Litre		1300.00 lit.	1300.00 lit.

III. RESULTS AND DISCUSSION

One of the prime objectives of this study was to develop a grey jute paving fabric by combining a woven and nonwoven fabric component, having a breaking load of about 25 - 35 kN/m in both machine and cross machine directions to form the basis of an overlay fabric in road construction. In order to achieve the desired breaking load in the developed fabric, a woven fabric component was required to be fabricated which should not be having a very thick and close spacing woven structure. This is because the thicker and close spacing woven structured fabric will resist the penetration of needles during the preparation of the combined fabric by uniting the woven and nonwoven fabrics in the needle loom resulting in uneven penetration of needles as well as breaking of needles. Eventually an uneven fabric will result possessing lower strength due to poor interlocking of fibres. To obviate these problems ten numbers of plain weave samples of different areal densities lying within the range 120 to 210 gsm have been produced with the batch composition (as shown in table 2) and varying different weave parameters like ends and picks density, warp and weft grist etc. in the conventional jute loom. The strength of the fabrics produced are found to be lying in the range of 4 – 12 kN/m in both warp and weft way. 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 as shown in table 6 has been selected as the woven component for the production of the grey jute paving fabric which is a combination of woven and nonwoven fabric layers. So, to get the desired strength of the paving fabric in the above said range the samples have been planned to be prepared by combining different layers of woven and nonwoven fabrics. Therefore, as per the working plan, ten numbers of cross-laid nonwoven batts of different gsm (120-250 gsm) have been produced and subsequently combined with the selected woven fabric sample in the needle punching loom for production of single layered combined fabric. After testing and analysis of all the single layered combined fabrics they have been selected for production of the grey jute paving fabric with some desired specific property parameters as per end use requirements.

Table 6 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) (b) Weft Grist (lbs/spyndle)	6.90 × 9.50
3.Thickness (mm)	1.10
4.(a) Ends/dm (b) Picks/dm	38.00 × 33.00
5.(a) Wide – Width Tensile Strength (kN/m), (MD X CD) (b) Elongation- at- break (%) (MD X CD)	10.5 × 11.5 5.00 × 5.00

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IV. PREPARATION OF GREY JUTE PAVING FABRIC (GJPF) SAMPLES

Initially, ten numbers of Grey Jute Paving Fabrics (GJPF) samples were produced by suitable combination of single layered combined fabrics and woven fabric samples (as shown in Fig.1a to f) with the help of needle punching machine in 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 7, for assessing their geotechnical property parameters as per the end-use requirements (ASTM D 5261 1992, ASTM D 5199 2001, ASTM D 4595 2009, ASTM D 6241 2004, ASTM D 3787 2007, ASTM D 4491 1999, ASTM D 4751 2004).

Table 7 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
6.	Permittivity	D4491-99(2009)
7.	Apparent Opening Size (AOS)	D4751-04

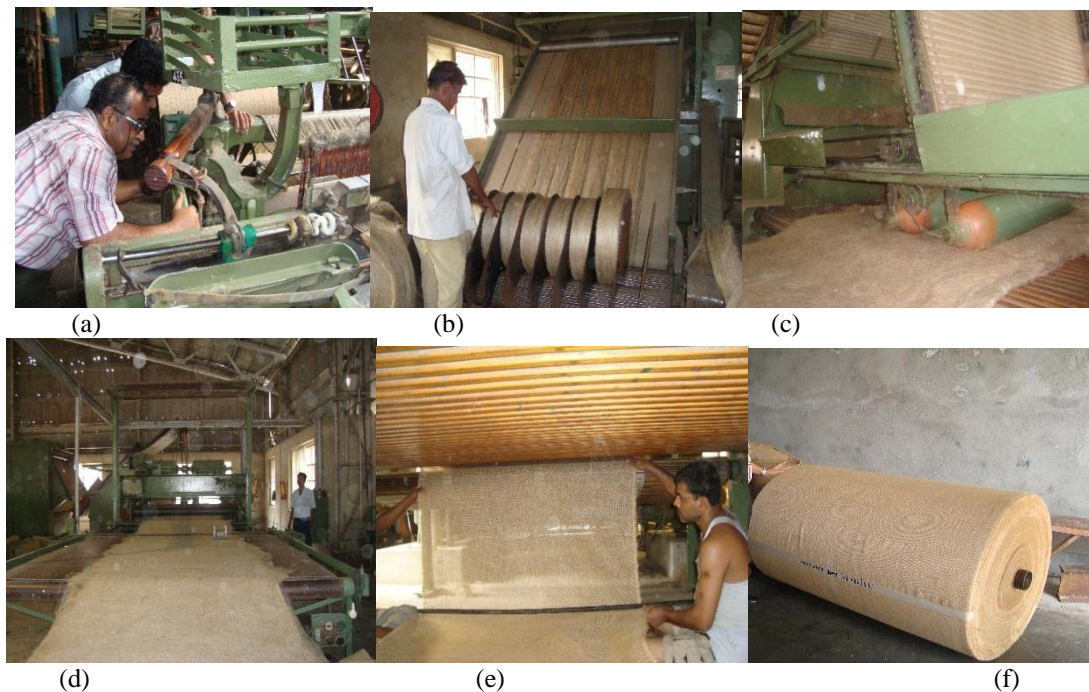


Fig.1 Preparation of GJPF samples (a) Woven fabric preparation (b) Feeding of carded slivers (c) Combination of cross lapped batt and single layer woven fabric (d) Combination of woven and nonwoven fabrics (e) Combination of combined layer of fabric with woven layer (f) Finished roll of GJPF sample

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V. BITUMINIZATION OF GREY JUTE PAVING FABRIC SAMPLES

Selected grey jute paving fabric samples, 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, SS₁, SS₂. SPRAMUL (SS₁ASTM and CQS1H) which are commercially available along with suitable chemical recipe for achieving the desired property parameters of the developed product. 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 (Fig. 2 a to c) 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, impregnating GJPF with other types of bitumen did not have proper inter-phasing resulting in peeling off of bitumen in some portions which affects the sustainability of the product in the long run. The test results of the properties of Bituminized Jute Paving Fabric (BJPF) are shown in table 8.

Table 8 Test Results of the Properties of Bituminized Jute 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



(a)

(b)

(c)

Fig.2 Bituminization of GJPF samples (a) Feeding of GJPF for bituminization (b) GJPF bitumen impregnation in sow box (c) Roll formation of BJPF

VI FIELD TRIALS OF BITUMINIZED JUTE PAVING FABRIC

Primarily the developed product has been applied for a pilot field trial at the Departmental premises in the year 2012 followed by a commercial field trial of the same at Uday Shankar Sarani, Golfgreen, Kolkata-700095, near Doordarshan Kendra, Kolkata. Apart from this, the developed Bituminized Jute Paving Fabric has been also subjected to another commercial field trial at a stretch of road, earmarked on Ballygunge Circular Road, near the Ballygunge Science College (Shri T.N.Palit Shiksha Prangan) Entrance, University of Calcutta and performance of this jute paving

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fabricated road is found to be quite encouraging. Realizing the potentiality of the developed BJPF material along with all its field trial reports and in order to establish the techno-economic feasibility of the developed product through more number of such potential field applications, National Jute Board (NJB) has approached the Chief Engineer, PWD, West Bengal with proposals to take some more commercial field trials of BJPF in high volume traffic roads like State Highways. Superintending Engineer, PWD, South Western Circle, responded to this proposal of NJB by sanctioning a stretch of road from 36 kmp to 37 kmp at SH-5 Contai-Beldah Road, Paschim Medinipur for strengthening the carriageway with the developed BJPF. Accordingly, NJB, MoT, GoI entrusted DJFT, IJT, CU to take on the responsibility of producing 3600 sq. meters of Bituminized Jute Paving Fabric (BJPF) as per the recommendations and specifications furnished by Central Road Research Institute (CRRI), New Delhi. Accordingly, the grey jute fabric with required specifications and property parameters have been produced at M/s. Gloster Limited, Howrah, followed by the bitumen treatment of the grey fabric at M/s. Maa Kali Industries, a reputed Bitumen Treatment Plant at Kolkata. The assigned supervisor of the work as well as the workers engaged in the road fabrication have been guided and trained by the DJFT, IJT, CU faculties and NJB, MoT, GoI officials regarding the tack coat application followed by laying of the BJPF and application of mastic asphalt on the laid BJPF. The proposed work has been completed at a stretch of road earmarked from 36 kmp to 37 kmp on SH-5 Contai-Beldah Road and the road traffic has started its movement regularly. So far the information received from the monitoring desk as well as from the contractor's end, that the regular traffic are passing through the experimental set-up of the road without facing any disturbance and the stretch of road is performing satisfactorily. Fig.3 (a to f) show some of the snaps taken during field trials at different sites.



(a)

(b)

(c)



(d)

(e)

(f)

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Fig.3 Commercial Field Trial of BJPF (a) Cooking of ingredients in vat (b) Cleaning of the road surface (c) Application of tack coat (d) Laying of BJPF roll in the road surface (e) Transfer of mastic over BJPF (f) Placing of anti-skid agents on the masticated surface (g) Thermo setting of the joints (h) Analysis of road surface roughness by Merlin Tester (i) Smooth traffic movement on the new masticated road.

VI. CONCLUSION

An effective Grey Jute Paving Fabric (GJPF) has been produced in a commercial jute mill followed by its bituminization in a bitumen treatment plant to produce the final Bituminized Jute Paving Fabric (BJPF). After the successful execution of the pilot field trial followed by several commercial field trials of the developed BJPF, one after the other, at the departmental premises, at Uday Shankar Sarani, Golfgreen, Kolkata-700095, at Ballugunge Science College Entrance, Ballygunge Circular Road, Kolkata-700019 and after receiving healthy and satisfactory responses regarding the performance of the same from the constant stringent monitorings, the similar fabric with the same specifications has been applied this time at SH-5 Contai-Beldah Road, Paschim Medinipur, West Bengal on a commercial trial basis to establish its efficacy for a wider way of application in the forthcoming days. Therefore, as more and more opportunities of these commercial field trials will be coming across the way, the recognition of this developed BJPF will be much more focussed as an engineering solution in mitigating the geotechnical problems, road constructions in particular, which will, certainly, provide newer scopes and possibilities for the technical textile sector, opening the prosperity for the jute sector on one hand and making world greener on the other. Acknowledging the tremendous potentiality of Bituminized Jute Paving Fabric, the Hon'ble Jute Commissioner, Ministry of Textiles, Government of India had expressed his whole hearted gratitude to K.M.C. for providing the opportunity to Department of Jute and Fibre Technology, University of Calcutta to carry out the commercial field trial of the bituminized jute paving fabrics. His Honour had even added in his view about his optimistic foresee regarding the encouraging results of the developed fabric which in the upcoming days is surely going to provide a cost-effective option for streets in Kolkata. Finally, the Hon'ble Secretary, Govt. of West Bengal, PWD, has declared one MEMORANDUM, vide No.36/1M-01/15, dated 23.02.2015, recommending the inclusion of BJPF in the departmental Schedule of Rates (SoR).

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