IEI Centenary Publication

Dr B K Chakrabarti Memorial Lecture

A Compilation of Memorial Lectures
presented in

National Conventions of Textile Engineers

35th Indian Engineering Congress

December 18-20, 2020

The Institution of Engineers (India)

8 Gokhale Road Kolkata 700020

Background of
Dr B K Chakrabarti Memorial Lecture

Dr B K Chakrabarti, an outstanding scholar and researcher, obtained his M.Sc. Degree in Pure Physics from Calcutta University and made commendable research contributions in the fields of optics and spectrometry. He then took up teaching assignment for a short period, and later joined Indian Central Jute Committee (ICJC) (later named as JTRL and currently known as NIRJAFT) at Tollygunge, Calcutta as a scientist and devoted himself in research and made outstanding contributions in the fields of textile physics and statistical quality control. Thereafter, he obtained his Ph.D. Degree from the University of Calcutta. He also evaluated jute yarn diameter subsequently at ICJC and later joined Institute of Jute Technology (IJT) as Professor and Head, Department of Textile Science and developed a unique silver irregularity tester and introduced 2 :1 doubling in the gills in jute finisher drawing machines. He went to the UK on Ghosh Fellowship and was honoured with Fellowship of the Textile Institute, Manchester. Before leaving IJT, he became Principal for a short stint. After retiring from IJT, Dr Chakrabarti became Technical Advisor to a number of jute factories in and around West Bengal.

In memory of his dedicated service, The Institution of Engineers (India) instituted an Annual Memorial Lecture in his name during the National Convention of Textile Engineers (to be delivered in alternate year).

Dr B K Chakrabarti Memorial Lecture

presented during **National Conventions** of **Textile Engineers**

Scope for Revamping the Textile Industry in the State — an Overview

Shri B B Swain

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With the abolition of the quotas system from January 2005, the textile and clothing market has become opened up. Whether it is a boon or bane for the textile and clothing sectors is debatable. It may be said a boon, since the restrictions are removed and wide access to the world textile market is possible. It may be a bane to the Industry dependent upon the quotas, since it is now a question of the survival of the fittest. To win in the race that was started from January 2005, the emphasis will be on 'Excellent Quality at the lowest possible price and satisfaction of customer needs'.

If we look into the scenario of the Indian textile and clothing industry, there are Certain challenges that Indian Textile Industry needs to combat. In the context of that line a review has been made in the present study to focus on the scope for the growth of various segments of the textile industry in the state of Orissa, which needs an urgent attention for revamping.

Cotton production

Cotton is still the pre-dominant fibre used in Indian Textile Industry. Though the share of cotton in the consumption of all fibre has now declined to 54% in 2003-04 from 70% that was in 1993-94, the consumption of cotton in absolute term has increased from 2051 million kgs in 1993-94 to 2652 million kg in 2003-04.Though the land under cotton cultivation and production in India is quite large as around 9.0 million hectare, the productivity in India is very ridiculous as compared to other countries. The productivity in India is 313 kg/hectare, which is nearly half of the average world productivity of 553 kg/hectare.

Cotton in India is predominantly grown in Punjab, Rajasthan, Gujarat, Madhya Pradesh, Maharastra, Andhra Pradesh, Karnataka and TamiInadu and also grown in small quantities in other state like Orissa, Assam etc. As compared to the major cotton producing State, the share of other States including Orissa in respect to production and area of cultivation is very negligible. But the cotton yield per hectare is relatively moderate. Hence, efforts may be taken to increase the cotton cultivation acreage to enhance the production of the cotton in the state.

It has been a well-accepted observation of textile technocrats, researchers and cotton supplier that most of the problems lying with the quality of Indian Textiles are related to the quality of Indian cotton. Indian cotton still holds dubious distinction of being the most contaminated cotton in the World. In this context, fortunately, the southern part of Orissa has been blessed with the gift of nature to produce long staple (28.0 mm - 33.0 mm) varieties of cotton having low trash content. Further the consumption of long staple varieties of cotton by the mill is around 40- 45% of the total consumption. This shows the scope of boosting the growth of Cotton Industry in the state. It is high time to analyze the bottlenecks that restrict the growth of Cotton Industry in the State. Majority of our farmers are both educationally and economically backward. Their financial status does not permit them to adopt modern methods of cotton cultivation. They use to face innumerable problems right from cottonseed sowing to cotton harvesting.

Efforts may be concentrated on the following factors for the growth of cotton production in the state.

- Erratic monsoon,
- Low fertility, ad-mixture of sowing seeds
- Immense financial hardship of the farmers.
- Dependency on the localized moneylenders, fertilizer dealers, cottonseed dealer for credit.
- Non-availability of continuous monitoring and training facilities to educate the farmers regarding adaptation of modern farming techniques, realization of better yield, correct method of picking cotton, use of collection materials, storage techniques, packing and forwarding to avoid the contamination.

Yarn Production

Yarn is the primary components that determine the prospects of the organized textile mills, handloom, powerloom, and hosiery sectors. Due to growing demands of textiles, the total production of spun yarn has consistently been increasing during the last decades with spinning capacity increasing from 28.6 million spindles in 1994 to 34.02 million spindles in 2004 by addition of 5.42 lakhs spindles per annum. The growth of yarn production is also due to installation of more rotors in this decade, which is now around 3.83 lakh. But the trend in production of spun yarn as observed from the Compendium of Textile Statistics, 2004 shows that the cotton yarn has the dominant share of 79% of the total spun yarn during the year 1993-94. Its share has been declining to 70%during 2003-04, while blended and 100%non-cotton yarn constitute 3"0% share of total spun yarn. Blended yarn constitutes 19% and noncotton yarn constitute 11%of the total spun yarn in 2003-04 where as their share were 14% and 7% respectively in the year 1993-94.However, the cotton yarn has still dominant share of the total yarn production.

It is observed that out of total yarn production in the country, private sectors mill produce more than 93%,while co-operative and public sectors mills put together produce the remaining. If we go through the State-wise production of spun yarn, the major spun yarn producing states were Tamilnadu, Maharastra, Punjab, Rajasthan and Gujurat. Those states accounted for about 73% of the total spun yarn production during 2003-04.Where as Orissa accounted for only 0.14% of the total spun yarn production due to closure of 11 nos. of spinning mills and Ino. composite textile under co-operative and public sectors having 259340 nos. of spindles capacity. Hence, it is high time to take steps for privatizing all the closed spinning' mills for their revival and to enhance the yarn production capacity in the state.

Fabric production

The fabric production industry can be divided into 4 sectors viz., mill, powerloom, hand loom, and hosiery sectors. The analysis from the statistics as given in Table reflects that out of total fabric production of 42383 million sq.mtrs of the country during the year 2003-04, the powerloom sector contributes around 63%, followed by 18% by hosiery sectors, 13% handloom sectors and the remaining by the organized mill sector around 4% and Khadi, wool & silk sectors 2%. While during the year 2001-02, the contribution of powerloom sector was around 60% followed by handloom sectors 19%, hosiery sector 17% and remaining put together by the organized mill sector and Khadi, wool & silk sectors.

PRODUCTION OF CLOTH IN DIFFERENT SECTORS ***(Mn.Sq.mtr.)***

Type of cloth	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04	Change in %
Mill Sector							
Cotton	1111	1105	1106	1036	1019	969	
Blended	444	379	332	296	263	253	
100% Non Cotton	230	230	232	214	214	212	
Total	1785	1714	1670	1546	1496	1434	-19.66
Handloom Sector							
Cotton	5861	6376	6577	6698	5098	4519	
Blended	111	119	111	95	118	117	
100% Non Cotton	820	857	818	792	764	857	
Total	6792	7352	7506	7585	5980	5493	- 19.1
Decentralised Power loom Sector							
Cotton	5855	6291	6584	6473	6761	6370	
Blended	4356	4613	5071	5025	4695	4688	
100% Non Cotton	10478	12283	12148	13694	14498	15889	
Total	20689	23187	23803	25192	25954	26947	+30.2
Decentralised Hosiery Sector							
Cotton	5121	5217	5451	5562	6422	6182	
Blended	789	802	837	871	800	1010	
100% Non Cotton	367	355	408	634	659	655	
Total	6277	6374	6696	7067	7881	7847	+25.0
All Sectors							
Cotton	17948	18989	19718	19769	19300	18040	
Blended	5700	5913	6351	6287	5876	6068	
100% Non Cotton	11895	13725	13606	15334	16135	17613	
Khadi, wool & silk	584	581	558	644	662	662	
Total	36127	39208	40233	42034	41973	42383	+17.3

Source : Compendium of Textile Statistics 2004

The analysis of the production of different type cloth in different sectors shows that -

• The mill sector of Indian Textile Industry has witnessed a downward shift in production in all variety of cloth since 1998-99.

• In powerloom sector, the cotton and blended fabrics are fluctuating. While there is rise in rate of production of 100% non-cotton (man-made) cloth. Similar trends are also noticed in hosiery sector and handloom sectors.

• However the cotton cloth production has still dominant share in 11 sectors followed by 100% non-cotton and blended cloth. In overall the woven fabric requirement is growing at a rate of around 8.5%, where as knitted fabric requirement is growing at a rate of 10% over the last five years. Further it has been studied that the woven fabric requirement for garment sectors accounts for around 45%, where as 55% is accounted for by the knitted fabric. Hence there is scope in expansion of both decetralised powerloom and hosiery sectors.

But if we look into the state scenario, it may be said that there is non-existance of both the sectors in the state. It is now high time to think about the expansion of both the sector in the state, if apparel park is to be set in the state (which is apparently under the consideration of Govt).

Orissa have earned national and international reputation since a few centuries for their exquisite and unique style of weaving and designing. The state has rich tradition in handlooms and its product especially "IKAT" are well recognized all over the country and also abroad for their artistic designs, colour combinations and durability. Handloom Industry of the state having capacity of about 1,19005 numbers of handlooms produces a large variety of fabric ranging from course quality chaaders, dhotis, sarees, towels, gauge/bandage cloth, etc. to fine qualities and intricate IKAt design of sarees, fabrics for dress materials using yarn of silk, cotton and manmade fibres and provides livelihoods to around 4,15,261 weavers in the state.

But due to the fast change in consumer taste, demand of eco-friendly and quality fabric with zero defect, fashionable fabrics etc, our handloom industry have entered into a crucial stage to compete not only in the export market, but also in domestic market. Some of the following inherent drawbacks in the hand loom sectors of our state need to overcome:

• Non-availability of right quality raw materials i.e yarn, dyes etc.
• Poor colour fastness
• Non-uniformity of dyeing and finishing
• Poor awareness on quality
• Low productivity
• Poor maintenance of the required reed and pick uniformly

Besides, in view of the open competition in the global market, the product diversification in the hand loom sector is essential that needs prime importance. Our Handloom sector will have to stop producing ordinary mass consumption, which can be cost effectively produced in powerloom sectors. It should give emphasis to produce exclusive unique products with eye-catching design in seasons colour and high value addition. There is vast scope for handlooms fabrics globally, if we can penetrate into market segment by identifying the seasonal habits and need of Europeans and Americans. For examples Indian silk otherwise used in making apparels, scarves, kurtas etc. can also be used in manufacturing hi-couture home furnishing products which has demand in sophisticated European market. Similarly khadi can be made appealing to hi-fashion segment by our designers. Hence to retain the attention of international consumers for surviving in the cut throat competition, handloom sector needs to have constant research and development centre, CAD centre etc.

Processing Industry

Processing is the weakest link in the India's entire textile chain. At present 4400 processing units are in independent and power processing sectors. Most of the processing in India is done in decentralized sector. Processing Industry is now-a-days an essential requirement that help textile sector and garment sector to produce value added product through modern wet processing and finishing technique. In our state, the non-existence of processing unit is one of the major drawbacks that restrict the expansion of other sectors such as powerloom sectors, knitting sectors, handloom sectors. Orissa having sufficient water resources, power resources and low labour cost has the scope for the expansion of processing unit. Only awareness has to be created.

To sum up, it may be said that there is scope for the growth of textile industry in our state especially in the Cotton production, yarn production, handloom sectors and processing units. Only steps are to be taken to overcome certain hurdles. Also efforts need to be given to educate human resources through various training programme to motivate them regarding the present needs, up gradation of technology, management of financial resources required to set up industries. In view of the resources and scope available in the state, Govt. may take effort to invite potential entrepreneurs to set up textile industry in the state especially expansion of knitting sector, apparel sector, processing units etc. It will also be helpful to generate massive employment opportunity in the state as well as to strengthen economical growth.

Innovation — Key to Success and Growth

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INTRODUCTION

Manufacturing, the transformation of materials into products, is no longer a primary source of prosperity in advanced economies. The last few years have seen intense innovation activity in all areas of textiles with convergence and close cooperation between different fields. Despite considerable amount of global exposure, technological modernization and diversification, large section of Indian textile industry continues to believe in set patterns of working. The focus more or less has been towards cost effective production of commodity products. The classical strength of the textile industry based on cheaper cost is already being challenged in many products. The trend of innovation which developed in the west essentially due to complex shifts in lifestyle and awareness encouraged constant demand for newness in textile products. Innovation in design, high tech fibres and fabrics, new products and knowledge based product differentiation and specialization are the routes the west is taking today and we will be forced to take tomorrow.

To achieve sustainable advantage, manufacturing efficiency must couple with innovative new products. Companies that go beyond manufacturing low priced commodities and offer improved customer values are the winners in the new global environment. Truly innovative companies generate a major segment of their revenue from products designed within the past three to five years. Companies increasingly need completely new and innovative products to succeed in the new and fast-moving business environment.

The new kinds of textiles possess characteristics that make them useful in numerous formerly unexpected applications. Although textiles are still, mainly used for the clothes we wear and of many furnishings in our homes and offices, they are also used widely in numerous other fields. Some new textiles possess qualities that make them stain-resistant, smart etc. Innovation in textile technology continues and more unusual products will almost surely emerge. Figs, 1 and 2 shows finishing and fibre research has major attention of innovators.

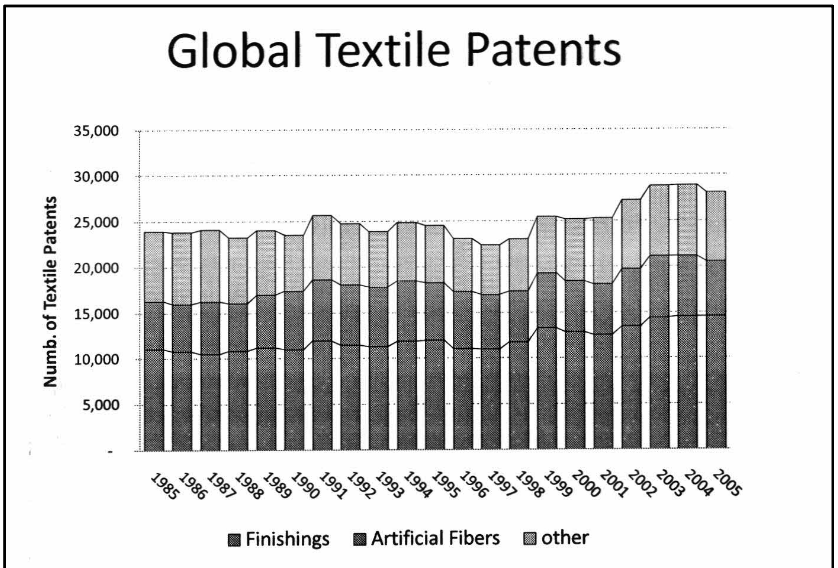

Fig. 1: Areas of Textile Patents

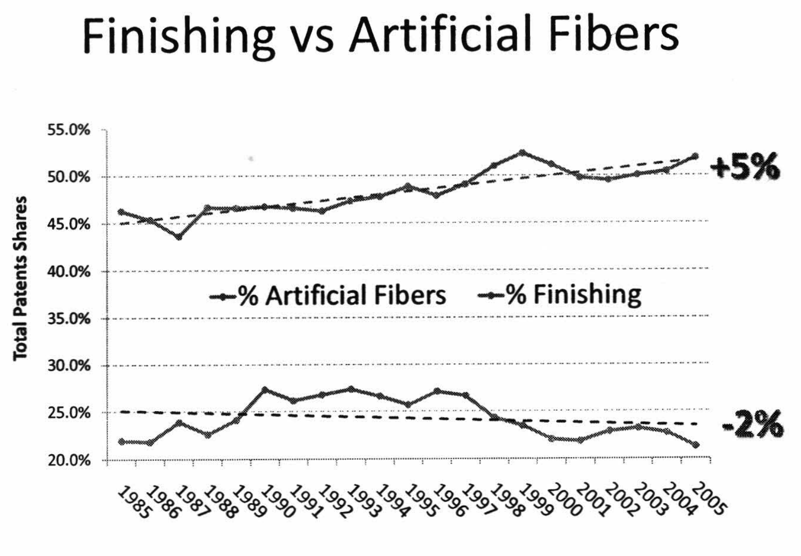

Fig. 2: Patent Activity in Fibre and Finishing Areas

FINISHING INNOVATIONS

Innovations in wet processing are being driven by consumer who has become knowledgeable and most concerned about his health, hygiene, comfort and fashion. Innovation in processing are also driven by environmental considerations, energy and water conservation requirements and development in associated technologies. In the customer driven market, specific needs of flame retardancy, antibacterial property, stain repellency, etc have further created challenges. Wet processing of textiles is the most complex stage in the manufacturing of fabric requiring immense personal attention and knowledge having potential for true value addition. It is a challenging task to attain desired appearance, feel and function right first time at competitive cost with the best of quality. The high performance standards expected in the processed fabrics by the present day consumer are to be met with right processing technology and innovations. Since the processing stage of fabric manufacture adds maximum value to the product, lot of R & D work is going on to provide specific functionalities, create unique feel and appearance in the fabric. Many new technologies such as nanotechnology, biotechnology, microencapsulation, inkjet printing, plasma processing are being used to produce innovative new products.

The technology of textile finishing encompasses very large number of finishing processes. Maximum attention is being given to produce fabrics and garments with multiple functionalities such as self-cleaning, super-hydrophobicity, antimicrobial, mosquito repellent, odour free and health promoting properties. Bio-finishing with enzymes and surface-effect mechanical finishes are considered eco-friendly finishes and being used increasingly.

The super-hydrophobic self-cleaning finishes are mostly based on the use of nanotechnology and many new methods of achieving this effect are being investigated since some of the well known processes are patented. Search is on for durable mosquito-repellent finish. Extensive studies are being carried out to find sustainable antimicrobial finishes based on chitosan, neem and Aloe Vera. Most of the deodorant finishes are based on cyclodextrin. Use of microencapsulated phase change materials and fragrances is also been made to produce value-added temperature controlled and fragrant garments. Considerable R&D is being carried out to modify surface of textiles leading to products with interesting and unique properties.

FIBRE INNOVATIONS

The driving force for important fibre developments, especially in past two decades has been the ever increasing applications for fibrous material in non-conventional sectors such as protective clothing, medical and health care products, automotive components, building material, geotextiles, agriculture, sport and leisurewear, filter media, environmental protection etc. These applications put strong demands on good performance properties such as strength, modulus, durability and dimensional stability and on functions such as flame retardancy, hydrophilicity, hydrophobicity, biocompatibility etc.

The introduction of high performance fibres in technical textiles has allowed us to enter a new era of materials revolution. These fibres are used for special requirements demanded by certain types of technical textiles applications. Such technical requirements can be high temperature protection, high impact and dynamic energy absorption capacity, high cut-through resistance, etc. In other words, high-technology or specialty fibres are normally chosen for their particular suitability to an end-use such as protective clothing for ballistic body armour, for high-risk jobs and sports, lightweight textile-reinforced structural components for aircraft, high-performance ropes for marine applications, structural panels (reinforced with fibres) for building construction and so on. Aramids (Kevlar, Nomex, Twaron etc.), glass, carbon, polyethylene, polyphenylene sulphide, polyetheretherketone (PEEK), polytetrafluroethylene (PTFE) etc. are some of the popular high-technology fibres frequently used for technical textiles.

Tailor-made special properties are very often the features of high-technology fibres. For example, today fibres can be engineered into hollow structures that are capable of providing the varying degree of porosity and strength needed in medical applications such as synthetic blood vessels, controlled drug release etc.; in chemical/water industry applications such as purification, filtration etc.; in civil engineering and many other applications.

The long-term durability, dimensional stability, etc. of technical textiles are functions of many fibre properties. For example, thermal and thermomechanical responses of fibres describe the usefulness of the long-term utilisation of a fibre in a technical textile particularly to be used in a hostile environment such as hot gas or liquid filtration, welders' suits or even textiles used in tyres. The knowledge of various fibre properties thus allows the manufacturers of technical textiles to have a logical estimation of the suitability and subsequently the durability of the materials used in a particular environment so as to minimise the risks of unwanted failure due to the interaction of stress-deformation-temperature and degradative chemical reactions.

Specific fibre properties are required for the specific technical applications. Main properties required in many of the technical applications can be grouped as follows:

1. Mechanical properties (strength, extensibility, modulus/stiffness, elastic -recovery etc.);
2. Thermal and thermomechanical properties (melting temperature, high temperature mechanical properties etc.);
3. chemical characteristics (resistance to various inorganic and organic chemicals etc.);
4. electrical properties (static build-up, dielectric behaviour, insulating nature etc.);
5. ageing behaviours (oxidative, thermal ageing etc.);
6. surface properties (adhesion, moisture transport behaviour etc.);
7. optical properties;
8. stretch and bulk;
9. moisture absorption;
10. biodegradability; bioactivity;
11. other special properties.

Improved fibre spinning techniques in melt spinning, wet spinning, dry spinning and new techniques such as gel spinning, bicomponent spinning, microfibre spinning, have made it possible to produce fibres with characteristics more suitable for use in technical textiles. It is now possible to produce man-made fibres with highly sophisticated non-circular cross sections, blends of filaments in a yarn having "differential shrinkage", splitting of bicomponent filaments, surface treatments to produce required morphology and topography.

New spinning processes and slight modification of polymer systems have enabled fibre producers to go for much higher speed of production of fibres having improved mechanical properties. High tenacity polyesters, polypropylene, etc. play a very significant role in applications such as ropes, nets, fishing twines, etc. Improvement in viscose process has resulted in Lyocell fibres with greater water absorbance and higher strength. These fibres are widely being used in making medical nonwoven products and wipes.

NANOFIBRES

Nanofibres (Fig. 3) are generally taken to be fibres less than 0.5 11m (500 nm). Electrospinning is the major production method used to make nanofibres. Nanofibres formed with synthetic fibre material can be formed with a high surface area to volume ratio and very small pore sizes in fabric form. The potential uses of nano fibres are in filtration, wound dressings, tissue engineering, nanocomposites, drug delivery devices and sensors.

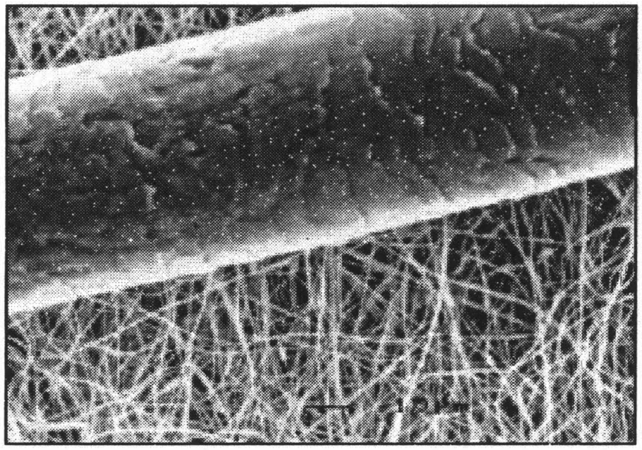

Fig. 3 Nanofibres in relation to human hair

Nanocomposite fibres consist of nanofibres containing particles with one dimension in nanometer range. The particles may be spheres, fibrils, tubes or platelets and by varying the amounts, their alignment and distribution within the nanofibres improvements in mechanical, electrical, optical, or biological properties can be obtained. The incorporation of nanoparticles of various metal oxides such as TiO_2, Al_2O_3, ZnO and MgO into fibres can confer a variety of functionalities such as UV absorption capability, electric conductivity and photo-oxidising ability chemical/biological species to the products made from these fibres. The carbon nanotubes (both SWNT and MWNT) have been used for materials in high strength and high electric conductivity end uses. The incorporation of SWNTs in a polyvinyl alcohol fibre, using a cogulation spinning method, provides nanocomposite fibres with twice the strength and stiffness of steel together with twenty fold increase in toughness. Potential end uses of this fibre include safety harness, explosion proof blanket, and electromagnetic shielding.

Nanotechnologies offer great potential for producing fibres with improved properties and performance specially suited for a number of technical textile end uses.

HIGH PERFORMANCE FIBRES

A relatively small (albeit important and growing) proportion of technical textiles, perhaps 2-3% by volume, uses the so-called high-tech fibres; aramids such as Kevlar, Twaron, Nomex, carbon fibre and high molecular weight polyethylene (Dyneema, Spectra). Both the highly temperature resistant meta-aramids (widely used in protective clothing and similar applications) and the high strength and modulus paraaramids (used in a host of applications ranging from bullet proof vests to reinforcement of tyres, hoses, friction materials, ropes and advanced composites) are now widely used. The aramid fibres, while not huge in overall terms (representing less than 0.5% of total world technical fibre and yam usage in volume terms but closer to 3-4% in value), the aramids represent a particularly important milestone in the development of the technical textiles industry.

Carbon fibres are used not only in aerospace markets but also of high technology sporting goods and industrial applications such as wind generator turbine blades and reinforced fuel tanks. As new manufacturing methods and greater economies of scale start to bring prices down, the feasibility of even larger scale applications such as the reinforcement of buildings and structures in earthquake zones becomes more attractive.

The introduction of other high performance fibres proliferated, particularly during the late 1980s, and in the wake of the aramids. These included a range of heat and flameproof materials suitable for protective clothing and similar applications (such as phenolic fibres and PBI, polybenzimidazole), ultra-strong high modulus polyethylene (HMPE) for ballistic protection and rope manufacture, and chemically stable polymers such as polytetrafluoroethylene (PTFE), polyphenylene sulphide (PPS) and polyethyletherketone (PEEK) for use in filtration and other chemically aggressive environments.

Specialty fibres are being developed for specific technical applications such as in medical textiles, protective clothing, etc. Alginate fibres, chitosan fibres, chlorofibre, electro-conductive polymeric fibre, artificial spider silk fibres are some of these.

Individually, none of these other fibres has yet achieved volume sales anywhere near those of the aramids (or even carbon fibres). Indeed, the output of some specialty fibres can still be measured in tens of tonnes per year rather than hundreds or thousands.

INORGANIC FIBRES FOR TECHNICAL TEXTILES

Glass has, for many years, been one of the most underrated technical fibre. Used for many years as a cheap insulating material as well as reinforcement for relatively low performance plastics (fibre glass) and roofing materials, glass is increasingly being recognized as a sophisticated engineering material with excellent fire and heat-resistant properties. It is now widely used in a variety of higher performance composite applications, including sealing materials and rubber reinforcement, as well as filtration, protective clothing and packaging; The potential adoption, of high volume glass-reinforced composite manufacturing techniques by the automotive industry as a replacement for metal body parts and components, as well as by manufacturing industry in general for all sorts of industrial and domestic equipment, promises major new markets.

Various higher performance ceramic fibres have been developed but are restricted to relatively specialized applications by their high cost and limited mechanical properties.

PRODUCT INNOVATIONS

A partial list some of the textile related innovations of the last century is given below:

- QTCs - Peratech
- Aerogel flexible blanket - Aspen Aerogel
- Digital screen garments - France Telecom
- NanoPel, NanoDry and NanoTouch - NanoTex
- G-Lam - US Global Nanotech
- GLARE - Stork Aerospace
- LifeShirt System - Vivometrics
- Invisibility coat - Tokyo University
- The "I" running shoe - Adidas
- Fastskin FSII swimsuit - Speedo
- Intelligent surgical sutures - rnnemoscience
- Elektex fabric sensors - Eleksen
- Self-ironing shirt - D' AppolonialEuropean Space Agency
- Mater-Bi - Novamont
- Embedded floorcoverings - Infineon Technologies and Vorwerk
- DNA markers - Applied DNA Sciences
- Gription Tex - Vibram
- Nanofibre webs - Donaldson Company
- Softswitch - Canesis
- Ingeo Fibre - Cargill-Dow
- Biosteel - Nexia
- Texcote - U-Right
- Embroidered surgical implants - Ellis Developments
- Nanogel- Cabot Corporation
- Flexible, large area polymer displays - Philips
- Nanosphere – Schoeller
- Solar-powered jackets - Technology Enabled Clothing (TEC) and ICP Solar Technologies
- Electronic textile antennas - Applied Radar
- Wonder Slim - Fuji Spinning
- Under floor heating system - Advanced Heating Technologies (AHT)
- Machine-washable suede and leather garments - Bernardo
- Coretex - Owens Coming
- Luminex - Caen and Stabio Textile
- Hydrospace - Nonwoven Research Group, University of Leeds
- Seamguard - WL Gore
- Spacer fabrics - Karl Mayer
- Single layer stretch nonwovens - Advanced Design Concepts (ADC)
- Curv - BP

- EMC shielding spacer fabric - Tissavel
- Sphere - Nike
- Optical woven fabrics - Dubar WametonlRubens Gallant
- Biomesh A2A - Cousin Biotech
- EL films - Bayer MaterialScience
- M5 - Magellan Systems
- XLA - Dow Chemical
- Radio wave absorbing material- Toray
- Three-layer nonwoven composites - Fleissner/Georgia Pacific
- Epic fabric - Nextec q
- A380 composite spoiler - Cytec/Fischer
- ZPREG - Advanced Composites Group (ACG)
- Nanocomposite coatings - InMat Inc.
- Metafloor - Lees Carpet
- Sensatex - Smart Shirt
- Ravlex PPC - Ravensworth
- Alginsulate - Graz UniversityN erpackungzentrum Graz
- Demron fabric - Radiation Shield Technologies
- Corterra fibre - Shell
- Pneumatic aircraft seat cushion - LantallRecaro
- Low temperature plasma coating - P2i
- Vent-X ART - Diffusion Textiles
- 2H filter media - Emergency Filtration Products.
- Diaplex - Mitsubishi Heavy Industries
- Spacetec - John Heathcoat
- Soric - Lantor
- ThermalShield TK - Powell Corporation
- d2w - Symphony Environmental
- 3DL - North Sails
- Inflatable loading bay system (LBIS) - Lindstrand
- Dyneema Purity - DSM
- Absolute Zero - Corpo Nove/ESA
- D3 spacer fabrics - Gehring
- Lextra Film IMD – Fiberlok
- SPT - Woolmark
- Electric Plaid - International Fashion Machines
- B9 - Consolidated Ecoprogress Technology (CET)
- Holofiber - Hologenix/Weliman
- Space tether fabrics - Culzean
- Auxetic fabrics - Heriot Watt University
- Combat Casualty Care textiles - Polartec
- eVent - BHA Technologies
- Thiolon LSR - Royal Ten Cate
- Suevo - Eybl International
- Techx - Amann
- Cooley-Brite Back-In-Black - Cooley
- Resolution print media - BBA Fiberweb
- edg - Web Dynamics
- Hyentangle WA - FiberVisions
- Textile cables - Foster-Miller
- Cool suit - Karada Italia
- p-ray fibre - Pi-Ray America/Aron Textiles
- Fibrinogen nanofibre mat - Virginia Commonwealth University
- Reverse performing smart surface - MIT
- Airvantage - Gore- Tex
- Pyro Gon - Zoltek/Leggett and Platt
- SmartPaper - Xerox

- Kinotex Fabrics - Tactex
- Bemis 3405 - Bemis
- Pursonic flat panel speakers -Purenl Bayer ISiemens BLEEX – University of California Berkeley
- Space Elevator - Institute for Scientific Research INASA

Detailed description of these innovative products can be found at the websites of the respective companies. Most of these companies have been successful and grown because of their emphasis on bring out innovative new products. Summary of these products was published by us in Asian Textile Journal in a 9 Part Series of Papers from July 2007 to March 2008.

CONCLUDING REMARKS

A number of developments are taking place in textile chemical processing to meet the new customer expectations, health and hygiene consciousness, energy crisis or environmental consideration.

The diverse applications of textile materials for technical purposes have opened up a new era of development in fibre science and technology. Existing fibres are being modified and new fibres are being developed to meet specific and stringent requirements of the technical textile applications. The critical role played by the technical textile products in most of the cases, and the undoubted advantage of their use has enabled a market of high value products. This allows the manufacturers to go for high value raw materials. In an industry where innovation has become the only means of survival, almost all the major players are engaged in research and development regarding raw materials and their applications. New and demanding applications of textiles in diverse technical uses will fuel new product developments in future. Development of other disciplines such as electronics, biotechnology, nanotechnology, etc. gives further boost and new possibilities for the development of new textiles. Innovation will be the key to success and growth of textile companies. If Indian Textile Companies want sustainable future, they must invest in developing competencies for innovation.

An Innovative Bituminized Jute Paving Fabric (BJPF) – A New Horizon in Civil Engineering Construction

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Abstract

In the last quarter of the twentieth century, a new class of materials, called, Geosynthetics, emerged in a prospective way which led to significant innovation in the design of geotechnical and geoenvironmental systems. A few examples of these innovations are the development of new geosynthetic barrier systems, which have been fully incorporated into modern landfill design, the proliferation of geosynthetics in hydraulic applications, which have often eliminated the need of conventional granular filters and drains, and the amazing advances in reinforced soil technology which have revolutionized the way in which engineers now think of walls and embankments. Additionally, the rise in demand of the infrastructure and regulations mandated for various environmental problems have been the impetus for the evolution of a number of ground improvement techniques during last couple of decades. Geotextiles have proven to be among the most versatile and techno-economically viable ground modification materials which play a significant part in modern pavement design and maintenance techniques. Several varieties of Jute Geotextile (JGT) both woven and nonwoven have been developed for a number of geotechnical end uses like improving pavement performance, soil erosion, embankment, drainage system, etc. But, the use of 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 if it has 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 generation of carbon foot-print to a large extent. This paper delineates the development of Grey Jute Paving Fabric (GJPF) followed by its bituminization with a suitable type and grade of bitumen along with other essential additives, formulating proper chemical recipe to impart necessary property parameters to the developed Bituminized Jute Paving Fabric (BJPF).The BJPF will enhance the life of the overlay thereby reducing the cost of maintenance as well as serve as a partial substitute of bitumen mastic. A glimpse of the several commercial field trials of the developed fabric on the Indian roads of different traffic volumes have been also incorporated in this paper to assess its performance and establish, thereby, its efficacy based on design consideration, selection criteria and overall enactment.

Keywords: Jute Geotextile (JGT), underlay, overlay, techno-economic viability, carbon foot print, environmental friendly, Bituminized Jute Paving Fabric (BJPF)

1.0 Introduction

Geotextiles are a class of technical textiles applied in soil to help its engineering performance(1). Geotextiles may be either man-made or natural fibrous materials. Man-made geotextiles are made of artificial fibres like polypropylene, polyethylene, polyester and some other petrochemical derivatives(2). Natural geotextiles, on the other hand, are made out of natural fibres like jute, coir, sisal and the like(3). Jute Geotextile (JGT) is a natural technical textile.JGT provides indigenous, available technologies, which have got enough potential in offering eco-friendly sustainable, cost effective geotechnical solution to many ground engineering problems(4). Although several varieties of JGT 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. 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. Application of geotextiles in flexible paved road construction is an established one and is increasing at rapid pace throughout the world(5). Geotextiles extend the service life of roads, increase their load carrying capacity and reduce rutting and other distresses (6). The effectiveness of geotextiles in stabilization and separation roles with flexible pavements has been extensively researched. It has been found that for weak subgrade (CBR less than or equal to 2%), the geotextile extends the service life of a flexible pavement section by a factor of 2.5 to 3.0 compared to a non-stabilized section(7). Further, a geotextile effectively increases the pavement section's total AASTHO structural number by approximately 19%

(8). The effect of geotextile in pavement sections with moderate strengths (CBR ranging within 4.2 to 4.5%) is that the geotextile increased the service life of the pavement section by a factor of 2.0 to 3.3 and the AASTHO structural number increased by 13 to 22%. These significant improvements are obtained primarily through the separation function of the geotextile placed at the interface of the base course aggregate and subgrade soil(9).

Asphalt concrete pavements overlays can benefit from the use of paving fabric interlayer(10). The documented field experience indicates a number of positive benefits which includes waterproofing of the lower layers, thereby maintaining higher material strengths, retarding reflection cracking in the overlay by acting as a Strain Absorbing Membrane Interlayer (SAMI)(11) as shown in figure 1, increase in structural stability by providing for more stable sub grade moisture contents. Paving fabrics can also be used in new pavements to provide the same benefits. If fabric is added and the overlay thickness is not reduced from that determined by normal methods, then an increase in performance can be obtained(12).

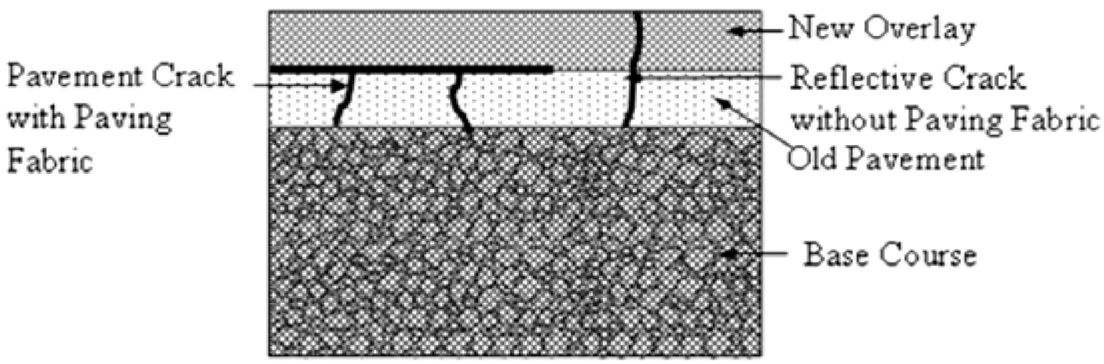


Figure 1 Application of Strain Absorbing Membrane Interlayer (SAMI)

The inclusion of a nonwoven paving fabric interlayer system significantly improves the performance of asphalt concrete overlays. This performance improvement is a result of both the water proofing capabilities and the stress absorption capabilities of the paving fabric system. Synthetic fabrics and stress absorbing interlayer (SAMI) have been effective in controlling low to medium severity alligator cracking. They may be also useful for controlling reflection of temperature cracks when used in combination with crack filling. They generally do little, however, to retard reflection of cracks subjected to significant horizontal or vertical movement(13).

Introduction of paving fabrics to asphalt overlay reinforcement paved road surfaces must be maintained when they develop significant cracks and potholes(14). The rehabilitation of cracked roads by simple overlaying, or placing an additional layer of asphalt over the old paved surface is rarely durable solution. The cracks in the old pavement eventually propagate through to the new surface(15). This is called reflective cracking. In spite of limited resistance to reflective cracking traditional overlays are still the most common approach to maintaining distressed pavements(16). Generally the thicker the overlay the longer it will last, however, the thicker overlays are more expensive(17). Many research works have been done to find out the performance of paving fabrics as an interlayer to retard reflective cracks(18). They have found that a stress relieving geosynthetic interlayer retards the development of reflective cracks by absorbing the stresses that arises from the damaged surface(19). Reinforcement occurs when a geosynthetic is able to contribute significant tensile strength to the pavement system(20). The reinforcement attempts to prevent the cracked old pavement from moving under traffic loads and thermal stresses by holding the cracks together. Newly manufactured geocomposites can provide both stress relief and reinforcement. The benefits of geosynthetic interlayers include saving to 1 to 2 inches of overlay thickness, delaying the appearance of reflective cracks, lengthening the useful life of the overlay. Most of the works regarding introduction of paving fabrics in road constructions are dealt with geosynthetic, which consists of woven, nonwoven and combination of both woven and nonwoven fabric. Use of natural fibre like jute is rare to find though it is available in abundant.

M.Ghosh, P.K.Banerjee and G.V.Rao(21) made an attempt to develop asphalt overlay fabric from jute to retard crack propagation in the Asphalt overlay. The design concept of developing asphalt overlay fabric of moderate capability made purely from jute suitable for reinforcement and moisture barrier functions for low traffic roads were taken for consideration. A leno based woven construction was selected for the purpose in order to obtain breaking strength of 30-40 kN/m and extension at peak load less than 5% in both warp and weft directions. The new developed Jute Asphalt overlay (JAO) fabric within pavement was investigated. To judge the performance of the (JAO) fabric, they made Asphalt concrete beams (ACB) with and without Asphalt overlay (AO) fabrics and the beams were subjected to cyclic mechanical loading in accelerated mode simulating the vehicular traffic on MTS (Material Testing System) to monitor the crack propagation. Both dry and hygrally treated samples of ACB s without and with Asphalt Overlay Fabrics (AOF) were subjected to cyclic mechanical loading. Under all experimental conditions they found that ACBs embedded with JAO do not exhibit any crack propagation beyond the level at which the JAO is placed within the ACB. They explained it, that JAO having grid like structure with suitable opening size help in creating proper interlocking among aggregates of the overlay and voids of the old pavement surface areas the fabric within pavement and thereby the two layers of the pavement act as single body which further resists crack growth.

The dimension of the Asphalt concrete beam of their laboratory experiment was 225 mm (L) × 75 mm (W) × 75 mm (H). A transverse notch of 5 mm depth and 3 mm base width at the beam centre was created to simulated pre-existing crack in the pavement. Asphalt overlay fabric reinforcement was placed at 20 mm above the beam specimen base for reinforcement specimen.

The tensile properties of JAO fabrics which they have developed to find in-situ performance are in the Table 1.

Table 1 - Tensile properties of JAO Fabrics

Type of Test	**Type of Sample**	**Breaking Load (CV %)**		**Breaking Elongation % (CV %)**		**Young's Modulus in MPa (CV %)**	
		Warp Way	**Weft Way**	**Warp Way**	**Weft Way**	**Warp Way**	**Weft Way**
Grab	JAO (double layer)	0.98 kN (10.2)	0.84 kN (10.9)	9.4 (7.1)	9 (5.6)	104.9 (8.9)	96.1 (9.3)
Wide Width	JAO (double layer)	24.2 kN/m (14.1)	24.8 kN/m (3.3)	5.1 (13.4)	4.9 (6.8)	79.6 (7.7)	107.0 (14.0)
	JAO (double layer)	38.7 kN/m (1.7)	36.3 kN/m (4.8)	4.9 (6.2)	5.0 (3.0)	222.0 (6.1)	185.7 (7.9)

To make effective use as an overlay fabric on existing pavements, paving fabric has to be water-proof and abrasion resistant. It has been reported that nonwoven Jute Geotextile is an extremely good receptor of hot bitumen, besides having thermal compatibility with bitumen in the range of 1900c. Woven Jute Geotextile ensures durability against abrasion and shear. 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 an overlay fabric for strengthening of the pavements as well as partial substitute of commonly used bitumen mastic in road construction. To achieve this objective, a research and development project entitled "Engineering Suitable Overlay Fabric to serve as a Cheaper Substitute of Bitumen Mastic" has been sponsored by National Jute Board, Ministry of Textile, Government of India. The project had been jointly carried out by Department of Jute and Fibre Technology, University of Calcutta and Central Road Research Institute (CRRI), New Delhi with the purpose to develop such suitable grey jute paving fabric by the combination of woven and nonwoven fabric, followed by its bituminization with suitable type and grade of bitumen, to take field trial with bituminized jute paving fabric and to monitor for accessing the performance and techno-economic viability of the developed bituminized jute paving fabric to establish its efficacy as a potential innovative civil engineering material.

2.0 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.

2.1 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.

2.2 Preparation of Woven Fabric Sample

Ten number of 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 as shown in Table 2 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.

Table 2 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 × CD)	10.5 × 11.5
(b) Elongation- at- break (%) (MD × CD)	5.00 × 5.00

2.3 Preparation of Single Layered Combined Woven and Nonwoven Fabric Sample

Similarly, ten number 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.

Photo 1: Feeding of the carded slivers for Nonwoven Fabric preparation

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

Photo 3: Combined layer of Woven and Nonwoven Fabrics

2.4 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 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 3, 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 3 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

2.5 Bituminization of Grey Jute Paving Fabric

Selected grey jute paving fabric samples, physical properties of which had been furnished in Table 4(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, 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 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 properinter-phasing resulting in peeling off of bitumen in some portions which affects the sustainability of the product in the long run.

3.0 Results and Discussions

3.1 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(22).

3.2 Physical Tests on Aggregates

Aggregate forms the major part of the pavement structure as they have to primarily bear load stresses occurring on the pavement(23). 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.

Table 4 – 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 × CD	Elongation (%) MD × 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 layer nonwoven(hessian warp batch)	850	5.2	17.60 × 19.20	5.00 × 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 × 17.25	5.00 × 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 × 26.00	6.00 × 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 × 28.35	6.00 × 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 × 31.25	5.00 × 16.00	3.76	64.86	64.34	1.25	1.28	135
VI	4 layer woven (hessian warp batch, Shuttle less Loom) + 3 layer nonwoven(Sacking weft batch)	1480	8.21	29.15 × 31.50	5.00 × 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 × 32.07	6.00 × 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 × 32.35	6.00 × 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 × 34.73	7.00 × 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 × 30.21	6.00 × 17.00	5.89	92.38	56.00	1.12	0.120	80

3.2.1 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(24). Water absorption gives 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 (25).The test results are presented in Table 5. The gradation of individual aggregates is presented in Table 6.

3.2.2 Impact Test

Toughness is the property of a material to resist impact(26). 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 7.

Table 5 Test Results for Specific Gravity & Water Absorption

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

Table 6 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

Table 7 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 %	

3.2.3 Shape Test

The particle shape of aggregates is determined by the percentage of flaky and elongated particles contained in it(27).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.

3.2.4 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(28). 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.

3.3 Physical Tests on Bitumen

Bitumen is a petroleum product(29)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 (30), softening point test(31), specific gravity test (32), penetration test (33)and viscosity test have 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.

3.4 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 to select 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 conditioning of the individual sample and weighing it to nearest 01 g. To preheat asphalt cement to 135± 2ºC.Then to submerge the individual test specimen in the specified asphalt cement maintained at a temperature of 135± 2ºC 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± 2ºC. 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. RA= $(W_{sat} - W_g)/ A_g$, 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 8.

Table 8- 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

3.5 Design of Bituminous Mixes

3.5.1 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 (34). In this method, the resistance to plastic deformations of cylindrical specimen of bituminous mixture is measured when the same is loaded at the 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:

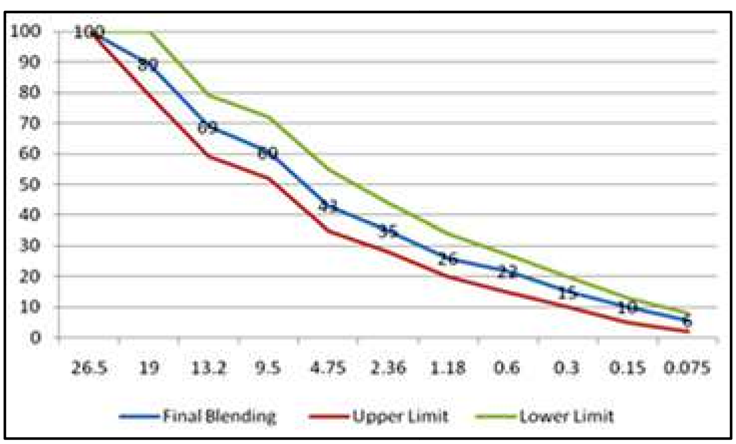
Marshall stability value, kg (minimum)	900
Marshall flow value, mm	2 - 4
Voids in total mix, Vv %	3 - 6
Voids in mineral aggregates filled with bitumen, VFB, %	65 - 75
Loss of stability on immersion in water at 60°C	> 75 %

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 9. The designed gradation along with the specified limits is shown in Graph 1.

Table 9 - 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 10. Using the above parameters, Optimum Binder Content (OBC) was found to be 5.67 percent by weight of aggregates.

Table 10- 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

The values obtained at the optimum binder content 5.67% are indicated in Table 11, as can be seen they do are meet MoRT&H specifications for BC mix.

Table 11 - 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	-

3.5.2 Beam Fatigue Testing

The flexure fatigue testis conducted to evaluate the fatigue characteristics of an HMA mixture(22). 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.

Table 12 - 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:

Effectiveness Factor (EF) = (Number of repetitions to failure for reinforced beams)/(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 13.

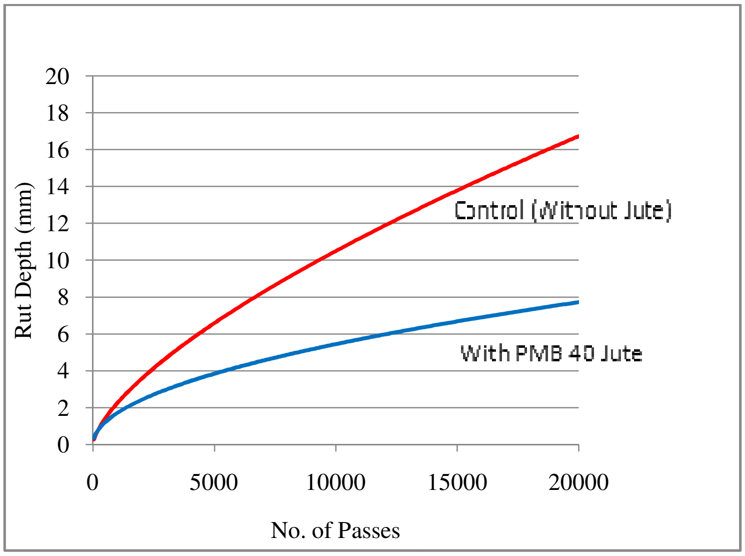
Table 13- Effectiveness Factors for Beams for Different Test Conditions

(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.

3.5.3 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 2.



Graph 2: Number of Passes Vs Rut Depth (in Wheel Tracking Test)

3.5.4 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 of the bitumen impregnated jute fabric should be done in accordance with the requirements of IRC: SP: 59-2002(35).

Table 14- 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 × CD]	38.50 × 40.00
5.	Breaking Elongation (%)[MD × CD]	11.00 × 9.00
6.	Bursting Strength (kg/cm^2)	43.00

4.0 Field Trials

Field Trials of the developed Bituminized Jute Paving Fabric (BJPF) both in pilot and commercial bulk scales have been carried out at the premises of Department of Jute and Fibre Technology, University of Calcutta, India followed by different traffic volume roads at the heart of the metropolitan city of Kolkata, India as well as in the rural outskirts. 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. 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 one year 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.

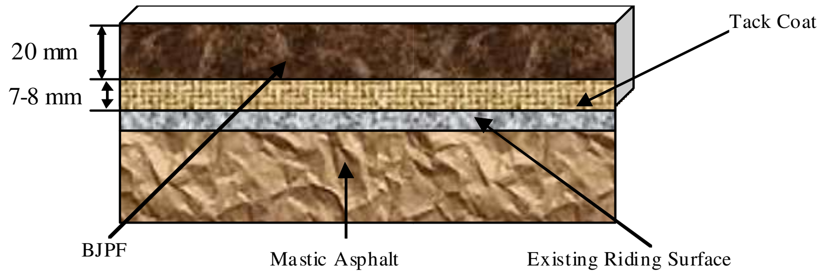


Fig. 1 Sectional View of the Design of the Field Trial with the Developed BJPF

One of the commercial full scale commercial field trials 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. This was followed by another major field trial at Contai-Beldah, State Highway-5, West Medinipur, West Bengal, India.

Some Glimpses of the Commercial Field Trial at Uday Shankar Sarani, Golfgreen, Kolkata-and SH-5 Contai-Beldah Carriageway, Paschim Medinipur, West Bengal, India

Photo 8: Cleaning of the road surface

Photo 9: Application of Tack Coat

Photo 10: Laying of BJPF

Photo 11: Laying of Mastic on BJPF

Photo 12: Placing of antiskid stone chips on masticated surface

Photo 13: Thermosealing of the joints

Photo 14: Cleaning of the road surface

Photo 15: Application of tack coat before laying BJPF

Photo 16: Laying of BJPF

Monitoring

Physical appearance of the stretch is similar to the mastic asphalt. As per the latest report and observations regular traffic is moving smoothly on the newly prepared road surface at the above mentioned sites. Close monitoring of the road is in progress and will continue for the next two years as per the expert guidance of CRRI, New Delhi, India and National Jute Board, Ministry of Textiles, Government of India, and Indian Roads Congress (IRC). Mr. S Bhattacharyya, Director General (Roads) and Mr. P Ghosh, Deputy Chief Engineer of the Kolkata Municipal Corporation along with their staff have inspected the stretch of road at Uday Shankar Sarani, Golfgreen, Kolkata. Mr. T. Sanyal, Chief Consultant, NJB and Prof. Swapan Kumar Ghosh, Professor, Department of Jute and Fibre Technology, University of Calcutta along with the research scholars have been present at the site. The inspection was made after completion of almost two years of execution of field trial and two monsoons had also been over. The condition of the road is fairly satisfactory. No potholes and cracks are found and the regular traffic is passing through smoothly. The KMC officials were satisfied with the overall performance of the road. Similarly, the ear-marked road at State Highway-5, Contai Beldah Carriageway, Pashim Medinipur, West Bengal has been observed by Prof. S K Ghosh, Mr.T Sanyal, Mr. T Saha, Executive Engineer, Kharagpur Division, PWD and his officials. Mr. A Manna, Superintending Engineer, South Western Circle, PWD, Paschim Medinipur was present at the site. The overall condition of the stretch of road is found to be satisfactory. No potholes have been found yet, excepting the occurrence of some small cracks which are thought to be due to the overlapping of the BJPF during its laying and improper shouldering of the road. The regular traffic is reported to be passing smoothly.

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 effective bituminized jute paving fabric (BJPF). The performances of the several field trials of the developed product till 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 of the premiere Central Road Research Institute (CRRI), New Delhi, India in collaboration with Civil Engineering Department, Indian Institute of Engineering, Science and Technology (IIEST), Shibpur erstwhile Bengal Engineering and Science University (BESU), Shibpur, India and National Jute Board (NJB), Ministry of Textiles, 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.

Acknowledgement

The authors express their gratitude to Jute Technology Mission (Mini Mission – IV, Scheme- 7.1), sponsored by National Jute Board (NJB), Ministry of Textile, Government of India for providing the platform to the authors to fabricate this paper. The authors are indebted to Shri Arijit Banerjee I.F.S., the then Hon'ble Secretary, National Jute Board, Ministry of Textile Shri T.Sanyal, Chief Consultant, National Jute Board, Ministry of Textile, Government of

India for their valued support at various stages of the progress of the research work. Thanks are also due to Shri D.C.Baheti, Executive Director, M/s. Gloster Limited, M/s. Gladstone Lyall Industrial Co-operative Society Ltd., Indian Jute Mills Association (IJMA), India. The authors are also thankful to the Director, Central Road Research Institute (CRRI), New Delhi, India.

Finally, the authors express their heartful thanks to the Hon'ble Vice Chancellor, University of Calcutta and Hon'ble Mayor, Kolkata, India for their kind permissions to carry out this research work alongwith its commercial field trial respectively.

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A Textile Fantasy

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ABSTRACT

The true sign of Intelligence is not knowledge but imagination: Albert Finstein

The concept of "Fantasy", a result of big time dreams such as of space travel, landing on moon or travelling many miles under the sea, much before these were actually realized in practice, has been discussed briefly. It has been suggested that such fantasies are rooted in human desire at quantum jump to a qualitatively superior life. In view of the alarming level of crisis currently plaguing human existence on planet earth such as of energy, pollution etc there is an urgent need of fantasies for finding the road to a higher level of existence. After fantasizing about a possible path to sourcing clean and boundless energy — a fundamental requirement for all our activities - imaginary outlines of novel use of textile fabrics for construction of new age flexible dwelling places as also of flexible transportation units has been presented.

Status of Salt Free Dyeing using Cationized Cotton

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Tirupur is the knit wear cluster of India and highly linked through cluster of units to produce knit wear garments. Among the various cluster involved in production of garments, the weakest link is the textile chemical processing sector as it is facing lot of problems due to closure. The implementation of zero liquid discharge (ZLD) systems has increased the cost of the dyeing thereby making most of the units difficult to meet their ends. About 60-70% of the fabrics dyed in Tirupur are using reactive dyes. Reactive dyes inevitably use salt as an exhausting agent. Approximately salt of 0.6-0.8 kg/ kg of for fabric is used for dyeing various shades apart from addition of alkali 0.1-0.2 kg/kg offabric. The dye drain along with the wash liquor is laden with high total dissolved solid content (TDS) and alkalinity. This poses a serious burden on reverse osmosis (RO) and RO reject management systems thereby making the dye units less compliant in ZLD norms. This issue can be addressed by three ways, by producing reactive dye structures which require less salt and alkali; reducing the amount of water required for dyeing (low MLR ratio) and modification of cotton substrate with cationic agents. The third route has gathered significant interest among the research and industrial fraternity because the other routes have been explored to a greater extent at industrial level. The surface modification of substrates using cationic agents has shown promise as this process eliminates the use of salt and near complete exhaustion of dyes is feasible in this route. The challenges in this route are it should be easily adoptable in existing sequence of processing (exhaust process) and should reduce or retain the same time of dyeing by conventional salt based dyeing with less consumption of water. The presentation will cover the status of the work on salt free dyeing using cationized cotton.

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