JUTE FIBERS FOR GEOSYNTHETICS - STRATEGIES FOR GROWTH

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ABSTRACT

While the use of jute in packaging, home décor etc. is well known, the use of jute in geotextiles is a largely unexplored area although it can offer vast benefits to the indigenous industry and agri-economy overall. The vast amount of research and development conducted on jute geotextiles (JGT) over the years has been briefly highlighted. In previous studies conducted on JGT, the emphasis was frequently on assessing the suitability of a particular type of JGT for a specific application. This paper proposes a shift in approach; from that of a Supply chain bringing together all the stakeholders to a Demand network using information systems. This will add 'value' to JGT and help them move up the value chain thus increasing profitability for all stakeholders and also be socially and environmentally sustainable.

Keywords: Jute geotextile, research and development, environmentally sustainable, value addition,

INTRODUCTION

The natural fibers such as jute were the forerunners of the man-made fibers used for centuries for making ropes and for manufacturing burlaps, sacks, Hessian and carpet backing. The Ziggurat, (which is part of the Aqar-quf, about 25 km from Baghdad, believed to be built in the 16th century B.C. by the Kassites,) standing presently 57 m high (original height was thought to be 78 m), was built from clay and reinforced by reed matting. Rope anchors comprising of 3 bundles of straw each of 25 mm diameter were installed (Dikran et al 1996). In geotechnical engineering isolated uses are recorded such as the trials undertaken in Dundee (UK) in the 1920's where jute burlap was used under some sections of anew road on poor subgrade (UNCTAD/GATT, 1986). Jute mesh was probably first used in erosion control and highway side-slope protection in the U.S.A. in early 1930's. According to UNCTAD/GATT (1985, 1986), jute nets have been used in for over twenty years in the U.S.A. with an annual consumption of 3, 000 t.

The International Background

Currently the production of the jute fiber in India is around 100 lakh bales and about 73 jute mills are operating in the country. Besides, there are several small scale industries in the decentralized sector producing handicrafts, decorative, twines, pulp & paper from jute and allied fibers and particle board from jute stick. As per the latest Exim Bank report on the Jute industry, the world market for geotextiles, currently dominated by synthetics is over 40 million sq. m. Immense potential also exists in the USA and Europe.

As per the International Geosynthetics Society (IGS, 2000), a Geosynthetic is a planar, polymeric (synthetic or natural) material used in contact with soil/rock and/or any other geotechnical material in civil engineering applications. Similarly a geotextile, a geomembrane and geocell are described as containing polymeric – synthetic or natural materials. On the other hand, ASTM (1997) defines a Geosynthetic,(*n*) as a planar product manufactured from polymeric material used with soil, rock, earth, or other geotechnical engineering related material as an integral part of a man-made project, structure or system. But by general nature of testing of procedures specified by ASTM, it could imply that the Geosynthetic could be only of synthetic polymers. According to the doyen of Geosynthetics technology, Professor Robert Koerner (1998) "The term *Geo*, of course, refers to earth. Acknowledgement that the materials of are almost exclusively from human-made products gives the second part to the name – *synthetics*. The materials used in the manufacture of Geosynthetics are almost entirely from the plastics industry; that is they are primarily polymers, although fiberglass, rubber, and natural materials are sometimes used." Thereby his classic book 'Designing with Geosynthetics' (4th edn. 1998) does not deal with Geosynthetics made of natural fibres such as jute and coir (co-conut fibre) which were considered as biodegradable. Giroud (1984) opines that "Natural fibres are very seldom used to make Geotextiles because they are biodegradable. Geotextiles made from natural fibres and even paper, may however, serve temporary functions where biodegradation is desirable (e.g., Temporary erosion control).

FIBER CHARACTERISTICS

Jute, a bast fiber (coming from the stem of the plant, by retting process), has a tenacity of around 30 cN/tex with a low extension at break of around 1.0 to 1.8 % . The tenacity of coir fibers (coming from the husk of the coconut, retted or unretted – white coir or brown coir respectively) is much lower 15 cN/tex, but elongation at break is much higher having range ofto 45 %. The growth of micro-organism on vegetable fibers depends on their chemical composition, particularly the lignin content. Coir has about 35 % lignin content, making it extremely resisting against biodegradation, whereas for jute it is only around 12 %. The other bast fibers like flax, hemp and ramie have much low quantity of lignin (0.6 to 3.3 %). Volume swelling of jute fiber is excellent having value of 44.3 % (Batra, 1985). This makes jute a suitable raw material for making 'sheath filter' part of pre-fabricated vertical drain.

BIODEGRADABILITY QUANTIFICATION

To address the question of biodegradability, extensive studies have been conducted at IIT Delhi over many years. Figure 1a illustrates the decay of the jute type A and type B, in Fig. 1b under differential environmental conditions. It is evident the loss in strength is much slower in saturated clay conditions and the fastest with manure. Also the degradation is much slower for heavier fabric type (a). The scanning electron micrographs presented in Fig. 2 also indicate the extent of degradation in the structure of the fiber in manure with sand. Why the fabric lost its strength totally after 24 days is evident from the total decay of the fiber.

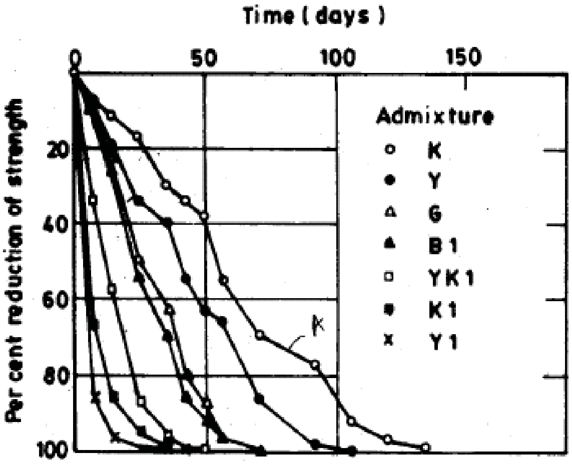

Fig. 1 (a) Loss in strength for Jute fabric type (a) under different environmental conditions.

(a) In sand at a water content of 12% (Admixture Y)
(b) In clay at a water content of 45%, i.e. above its plastic limit value (Admixture K)
(c) Sand mixed with manure in equal proportion (1:1) at a water content of 20% (Admixture Y1)
(d) Clay mixed with manure in equal proportion (1:1) at a water content of 50% (Admixture K1)
(e) Sand mixed with clay and manure in equal proportion (1:1:1) at a water content of 30% (Admixture YK1)
(f) Garden soil having an organic content of 8% at a water content of 30% (Admixture G)

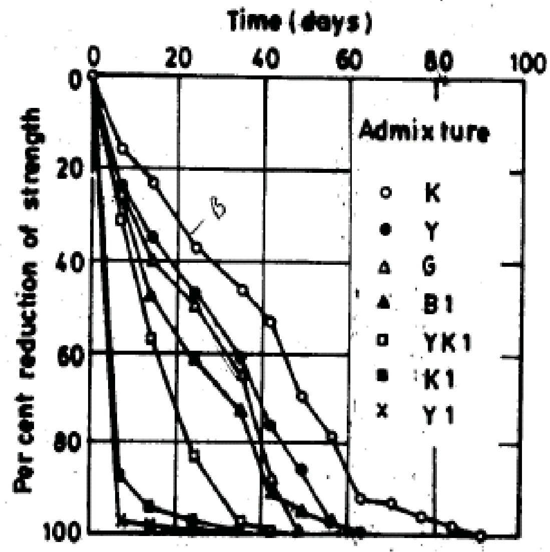

Fig. 1 (b) Loss in strength for Jute fabric type (b) under different environmental conditions

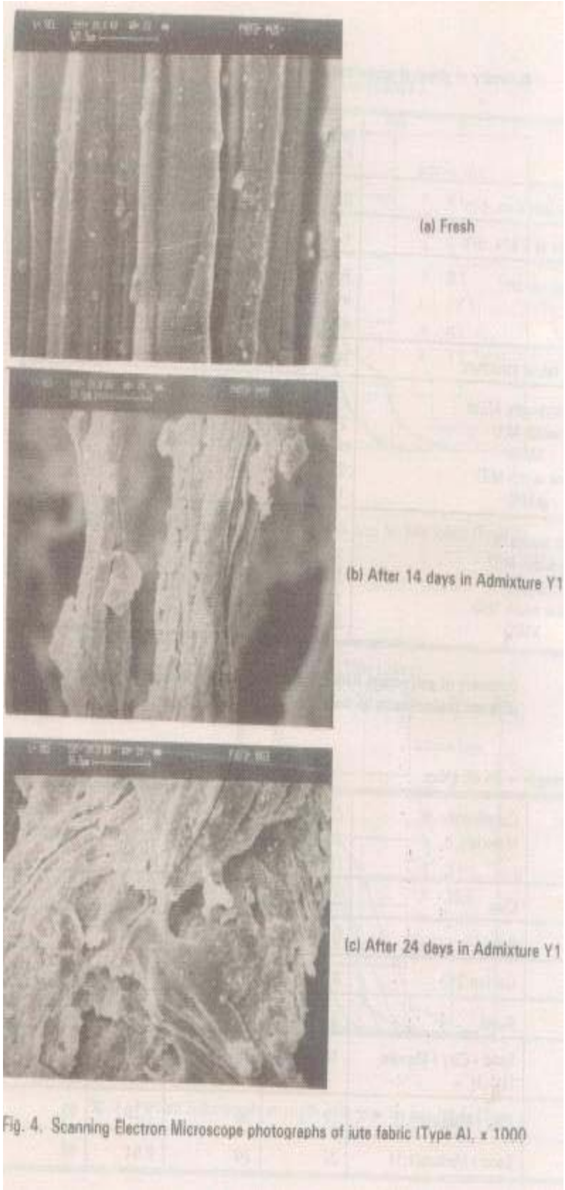

Fig. 2 Scanning electron micrographs of jute (a) fresh jute, (b) after 14 days in admixture Y1 (c) after 24 days in admixture Y1.

TESTING AND EVALUATION

Significant work has been done while the author was IIT Delhi to evaluate the physical and engineering characteristics of coir and jute geotextiles for ground improvement and RECPs. The details are now available in Venkatappa Rao et al (2009). The Bureau of Indian Standards has now brought out the Standard Test Procedures specifically for Jute and coir Geotextiles (IS 15868 – Parts 1 to 6- 2008).

Action Points

The test methods and related equipment need to be popularized in our country. Also the evaluation processes of jute Geotextiles need to be strengthened, as there is no agency to certify product being suitable for a given application.

EROSION CONTROL APPLICATION

As already mentioned earlier, the natural fibre products have long been known to serve erosion control, arising from natural processes of forest cover etc. to minimize the movement of soil cover, through vegetative cover. It is interesting to note that the first product to come out since British days in India was designated as SOIL SAVER, and probably first produced from Ludlow Mills, Calcutta. This was basically made of jute caddies (a waste by product of jute fibre) and till recently the only type of geojute being marketed. Subsequent yeoman work of IJIRA, along with inputs from NIRJAFT and IJT, and through encouragement of JMDC several new products are being developed, but they need the test of time.

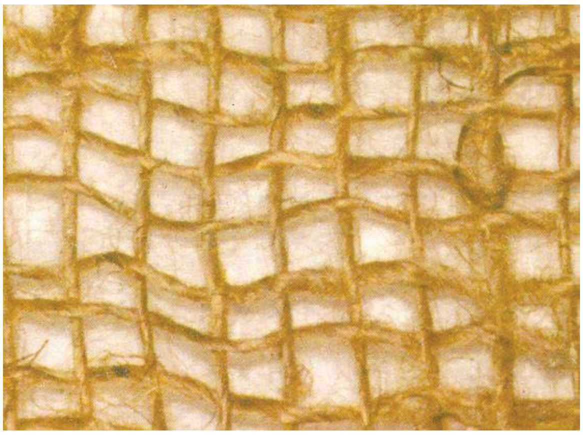

Fig. 3 The first jute geotextile (Soil Saver) made primarily using jute caddies (Ca 1940)

Juyal and Dadhwal (1996) working at the Central Soil and Water Conservation Research and Training Institute, Dehradun, have reported successful use of geojute to re-vegetate the highly erodible steep mine spoil slopes at Sahasradhara. The product used (probably made from jute caddies) was – grade 500 gsm, strand thickness 5 mm and open area – 65 %.

Sanyal (1992) has reported the successful use of geojute with mangroves planted in the interspaces for protection of eroding banks of Nayachara island in the Hugli estuary. The product used is a bitumenised jute fabric (base fabric – D.W.twill 850 g/m ^{2} with bitumen application of 80 % base weight).

In the U.S.A. the Erosion Control Technology Council (ECTC, 2001) has developed classifications of Rolled Erosion Control products as follows :

Erosion Control Nets (ECNs) –temporary, degradable planar woven natural fibre or extruded Geosynthetic meshes used to anchor loose fibre mulches

Open Weave textiles (OWTs) – temporary, degradable RECPs composed of processed natural or polymer yarns woven into a matrix, used to provide erosion control and facilitate vegetation establishment

Erosion Control blankets (ECBs) – temporary, degradable RECPs composed of natural or polymer fibres that are mechanically, structurally, or chemically bound together to form continuous matrices

Turf Reinforcements mats (TRMs)- long term non—degradable ones with synthetics fibres.

In India one calls OWTs as Erosion Control Meshes. Smith et al (2006) have carried extensive studies on the properties of of various types of RECBs available in India and overseas and brought out significant useful information.

Action Points

It is required that our products go through evaluation as detailed in Smith et al (2006) and subject them to appropriate classification, if one has to cater to the US and other International markets. Also, the QC/QA procedures need to be followed.

For Indian markets, field data needs to be obtained to identify the correct product to suit the climate, topography and soil conditions at various locations all over India.

JUTE FIBRE DRAINS

Pre-consolidation of soften soils is often aided by the installation of prefabricated vertical drains (PVD). Wide ranges of PVDs, made of synthetic polymers are being commercially used. In view of the fact that natural fibres are available in abundance in southeast Asia, a drain produced entirely from jute and coir were first developed by Ramaswamy and co-workers as reported in Lee et al (1989) and Lee et al (1994).The fibre drain primarily consisted of four coir yarns for transporting water enveloped by two-layers of jute burlap (jute Hessian cloth) acting as a filter. These are held together by three longitudinal stitches. This drain developed in Singapore is 80 to 100 mm wide and 8 to 10 mm thick. This strong and heavy drain has dry strength of about 5 to 7 kN and weighs about 3000 to 3400 g/m^2. Successful field trials at Bhishan depot were also reported by them, for Singapore mass rapid transit system for stabilizing highly compressible water logged peaty soils. Following this the IJIRA developed a similar product replacing the coir yarns with jute yarns of 10 mm diameter. It consisted of 4 jute yarns surrounded by two layers of jute burlap and is 110 mm wide and 15 mm thick. Model studies reported by Venkatappa Rao et al (1994) have revealed its performance as satisfactory. Subsequently, the author (Venkatappa Rao and Balan, 1997) developed a few varieties of natural fibre drains with jute burlap as the sheath and coir web for water flow capacity and reported discharge capacity measurements, through a new drain tester.

A simple machine has been developed at Textile Technology Department of IIT Delhi (Banerjee, 1996, Banerjee et al, 2000) that uses coir and jute yarns to manufacture 100 % natural fibre strip drains. The machine employing braiding technology (shown in Fig. 4) braids jute yarns to form the filter sheath and coir yarn as core. Typically the drains, named as 'Brecodrains', as depicted in Fig. 5 are about 7.5 mm to 12.5 mm thick in dry state and have a tensile strength of 3 kN. The properties of the drain have been studied in comparison with two synthetic drains and another type of natural fibre strip drain (Venkatappa Rao et al, 2000). In general, the properties of the drain are found to be comparable with typical synthetic drains, except that for a slightly lower discharge capacity under soil confinement. But, the 'brecodrain' performs better in the kinked condition than the commercial drains and its discharge capacity is less affected with increase in percentage of kinking compared to other commercial drains. An important feature of the jute yarn sheath is its swelling nature that allows it to function as filter without clogging. The present drain differs from the other natural drain is that it is manufactured in a single machine, and has capability of varying the width, thickness and mass per linear metre to suit different soil conditions.

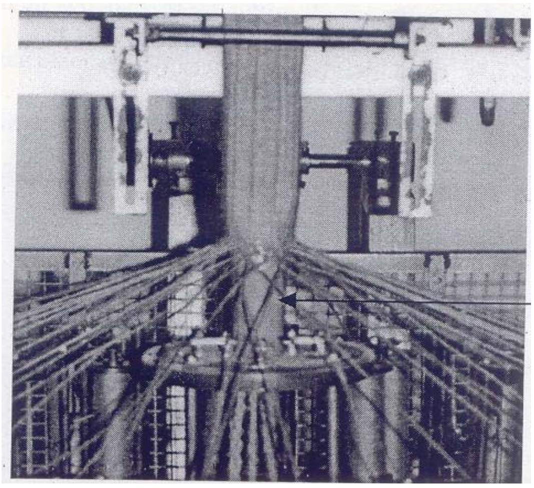

Fig. 4 Braiding machine developed at IIT Delhi to manufacture Brecodrain

Fig. 5 Braided strip drain (Brecodrain) with jute and coir yarns.

Action Points

All the drains described above despite their proven laboratory performance, are yet to be field tested. This, of course, calls for a modification in the mandrel that is necessary for installation of the drains. It is also pertinent to note that as the drain is much thicker and heavier than the synthetic one, may require a larger driving force which in turn may call for higher strength, due its higher penetration resistance.

APPLICATIONS IN ROADS ON SOFT SOILS

Considerable work has been done by Ramaswamy and co-workers (Ramaswamy and Aziz, 1989) to demonstrate that jute geotextile has the potential of being used to serve as a filter fabric as well a fabric reinforcement to stabilize and protect weak sub-grades in road construction. It is well brought out that in course of time i.e. in the first 6 to 10 months of construction the soil may stabilize yielding a better CBR value, thereafter the decay in the jute fabric is not a concern. Figure 6 shows the possible positioning of jute geotextiles in a road pavement structure and have successfully used jute geotextiles in many projects for separation, drainage etc.

A pilot project on JGT was undertaken under PMGSY programme in 2006 with the support and approval of the Union Ministries of Rural Development and Textiles in ten stretches spread over five states of Assam, Chattisgarh, Madhya Pradesh, Orissa and West Bengal covering a total length of around 48 km. The Central Road Research Institute, New Delhi was entrusted with this field research by the National Jute Board (erstwhile Jute Manufacturers Development Council). Typical results brought out for the trials in Assam by Sanyal and Mukherjee, 2011, are encouraging.

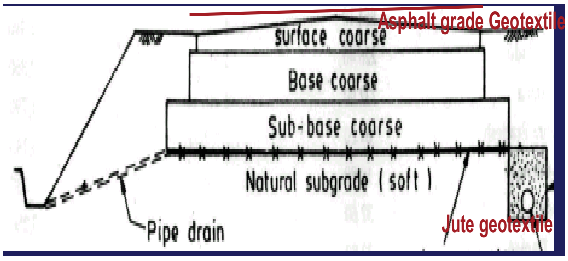

Fig. 6 Location of jute Geotextiles in a road pavement

Action Points

There is a great potential for use of jute Geotextiles in road applications, particularly on soft soils, more so for rural development. Product development accompanied by relevant field trials to bring out manuals for design, construction and maintenance of these roads is vital for their wide use.

JUTE ASPHALT OVRALAY (JAO) FABRIC

No standard asphalt overlay geosynthetics made up of natural fibres like jute has been produced so far though jute has better mechanical properties in many respects than conventional polypropylene or polyester fibres used for asphalt overlay products (Table1). Additionally, jute is eco-friendly, abundantly available in India and Bangladesh, inexpensive and known to have good adhesion with asphalt as evident from the widespread application of bituminized jute fabric. Hence, it appears reasonable to propose that asphalt overlay fabrics can also be manufactured from jute. Consequently an approach was made at IIT Delhi (Ghosh, 2006, Ghosh et al, 2007) to develop 100% jute-based asphalt overlay fabric (JAO) of moderate capability suitable for low traffic roads and subsequently its in-situ performance within pavement model in preventing reflective crack propagation under accelerated cyclic mechanical loading simulating traffic load investigated. Additionally, its efficacy to retard crack propagation after hygral loading, has also been evaluated through similar accelerated cyclic mechanical loading tests. Figure 7 shows the front side and backside view of the jute fabric specially developed for this purpose.

(a) Front side

(b) Back side

Fig. 7 Views of the jute asphaltic overlay (JAO) fabric developed at IIT Delhi (Ghosh , 2006)

The following conclusions are drawn from the results of the entire experimental programme:

(a) Jute reinforces the system to a considerable extent either in the form of fibre or fabric. Fabric reinforcement is however more effective than fibre reinforcement.
(b) Hygral treatment of even a six month period is not sufficient in damaging the jute-asphalt interface and the encased jute element too.
(c) Asphalt encasement provides a degree of protection to jute fibres against bio-degradation.
(d) Jute is very much compatible with asphalt and consequently can be effectively used as asphalt overlay material.
(e) In spite of being severely damaged, JAO fabric did not allow the crack to propagate beyond its level within ACB (Asphalt Concrete Beam). This can be attributed to the fact that JAO, having grid like structure with suitable opening size, helps in creating proper interlocking among aggregates of the top layer and voids of the bottom layer surface across the fabric within ACB and thereby the two layers of the ACB act as a single body.
(f) The opening size of the grids of an asphalt overlay fabric should be compatible with the larger aggregates of the AC mix used in pavement so that those particles can pass easily through the openings of the grid without causing significant damage to the fabric.

The Future

Currently the production of the fibre in India is around 100 lakh bales and about 73 jute mills are operating in the country. As per the latest Exim Bank report on the Jute industry, the world market for geotextiles, currently dominated by synthetics is over 40 million sq. m. Immense potential also exists in the USA and Europe. The report summarizes the present drawbacks of the Indian Jute industry. As availability of raw jute depends on the vagaries of nature, there is instability in the supply and price of jute. Till grether and Haldia (2003) have rightly mentioned that not enough is being done by the jute industry into production of new products. According to them, this may also lead to:

- price of fibres may fall making it unattractive for the farmers, who may diversify into other cash crops
- as the farmers have no core material for fuel or petrol, they may start denuding the forest wealth, which further adds to soil erosion and ultimately effecting climatic changes.

A lack of standardization and indifference to specifications has led to stagnation of the market. Greater emphasis on production and lack of professional marketing has caused deeper erosion of markets by synthetics. High labour costs, accounting for nearly 35% of the cost of the production (partly owing to absence of major technological breakthrough), has made jute cultivation energy inefficient and less lucrative compared to other crops. Excessive dependence on packaging industry has made jute synonymous with "gunny bags", thus leading to a perception problem. As a result, Jute is not able to attract new investment and has limited global production base. Apart from this, there is another common perception that the industry provides low financial return. There appears to be deficient attention to consumer preferences that has resulted in mismatch between predicting consumer's needs with respect to quality of fabric, bleaching, printing and designs.

Jute Geotextiles were identified by the industry and government as a focus area is offering major potential for all the stakeholders. Some promotional activities have been undertaken; however the future of Jute Geotextiles is also affected by the above problems which affect the jute industry as a whole.

For the above drawbacks, Venkatappa Rao and Anuradha (2008) proposed some technology based marketing strategies, which are briefly highlighted herein.

Review of research and developments, and use in India clearly points out that the potential is high for jute Geotextiles to find a prominent place amongst Geosynthetics. A recent publication by the National Jute Board titled JUTE GEOTEXTILES (2011) an anthology of papers on study, development and applications of Jute Geotextiles, is a comprehensive document. But much more needs to be done to bring them on par with synthetics – in terms of competitive product development and quality manufacture. There is a unique place for natural fibre products in limited applications. But then jute has to establish the market competitiveness with other natural fibre products even in India.

MARKETING STRATEGIES

Greater emphasis on production and lack of professional marketing has caused deeper erosion of markets by synthetics. High labour costs, accounting for nearly 35% of the cost of the production (partly owing to absence of major technological breakthrough), has made jute cultivation energy inefficient and less lucrative compared to other crops. Excessive dependence on packaging industry has made jute synonymous with "gunny bags", thus leading to a perception problem. As a result, Jute is not able to attract new investment and has limited global production base. Apart from this, there is another common perception that the industry provides low financial return. There appears to be deficient attention to consumer preferences has resulted in mismatch between predicting consumer's needs with respect to quality of fabric, bleaching, printing and designs. Jute Geotextiles (JGT) have been identified by the industry and government as a focus area is offering major potential for all the stakeholders. Some promotional activities have been undertaken, however the future of JGT is also affected by the above problems which affect the jute industry as a whole.

For the above drawbacks, this some technology based marketing strategies are now proposed. Using the popular Ansoff's Product/Market Expansion Grid (Fig. 8), as a starting point, one notes that with the currently available JGT products, there are two strategies available :

-- Market penetration strategy, and
-- Market-development strategy.

	Current products	*New Products*
Current markets	1. Market penetration strategy	3. Product development strategy
New markets	2. Market-development strategy	(Diversification strategy)

Fig. 8 Ansoff's product/market expansion grid.

MARKET PENETRATION STRATEGY

There are three major approaches to increasing current products' market share: The producers/production companies can create more awareness about the benefits of JGT and thus encourage users to increase the purchase quantity. For this, the producers also need to educate their marketing personnel about the technical properties and benefits of their products to avoid selling merely on price. Two, they could try to attract competitors' consumers (in this case say, consumers of synthetic geotextiles) by trying to identify weaknesses in the competitor's products. Finally, they could try to convince non-users of JGT.

MARKET DEVELOPMENT STRATEGY

This can again be done in three broad ways. First, new potential user groups can be identified. Second, additional distribution channels may be sought in present locations. Third, new consumer locations across the world may be identified for selling.

PRODUCT DEVELOPMENT STRATEGY

In addition to penetrating and developing markets, managements should consider new-product possibilities. Identifying opportunities higher up the value chain, would not only avoid the 'commodity' perception of JGT, it will also yield higher profits. Varying quality levels could be considered depending on the application in question. Prices of most of agricultural commodities show a long-term declining trend. Increasingly markets are signaling demand for differentiated products and in order to increase their incomes. Farmers and traders are looking to higher value options, including differentiated products. Product differentiation occurs when a product offering is perceived by the consumer to differ from its competition on any physical or non-physical characteristic including price. The differentiation can be based both on perceptual differences and also on actual product differences, based on measurable characteristics.

While developing new products, it is crucial to take into consideration, the consumer adoption process. Adoption is an individual's decision to become a regular user of a product.

STRATEGIES IN THE ADOPTION PROCESS OFAN INNOVATIVE / NEW PRODUCT

This simple model focuses on the mental process through which an individual passes from first hearing about an innovation to final adoption.

Awareness – Interest – Evaluation – Trial – Adoption.

At each step, marketers need to take appropriate measures to ensure the consumers move on to final adoption, e.g., free samples or trial periods are introduced to enable the consumer to evaluate and try the products before making a bulk purchase.

PARADIGM SHIFT

Taking into consideration that JGT are generic materials, and that based on the application, the technical specifications vary greatly, a paradigm shift from current marketing practices is necessary to leverage the three intensive growth strategies stated above. So far, in the JGT development process and jute industry as a whole, a broad supply chain model is at work. A supply chain (Fig. 9) is the system of organizations, people, technology, activities, information and resources involved in transforming natural resources to develop a product or service and move it from supplier to customer.

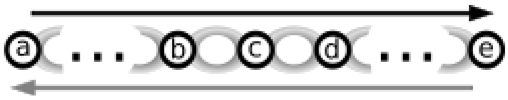

Fig. 9 Diagram of a supply chain

Fruit exports worldwide, which have directly impacted our lives by the creation a 'global food system' In setting up efficient and robust systems, latest technology, knowledge and protocols have been use for post-harvest management in areas such as long time storage, packaging concepts, cold chain management, controlled ripening and quality measurement. These innovations lead to opportunities for better quality products, lower energy consumption, lower transportation costs, more flexibility in using transportation modalities etc. New certification systems are being developed to ensure quality attributes throughout the entire chain.

CONCLUDING REMARKS

The promotional efforts being made by the recently constituted National Jute Board are sure to yield results. Translating the above detailed research to the JGT industry, a move towards a demand driven model will mean bringing changes to the production methods and techniques and developing better equipment to do so. The critical aspects are: a) understanding the application- specific potential such as in erosion control, rural roads and road pavement construction and b) use of site-specific parameters to design JGT. The design requirements will determine the characteristics and quality of jute required which will in turn be a factor to determine the manufacturing facilities required and the type of retting methods used to produce the raw fiber.

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