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GROWTH PROSPECTS OF NATURAL GEOTEXTILES

P.K. Banerjee[1] *and E.B. Unni*[2]

[1] Textile Technology Department, Indian Institute of Technology, Hauz Khas, New Delhi-110 016, India
[2] Aspinwall & Co. Ltd., Calvetty, Kochi-682 001, India

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ABSTRACT

Natural geotexiles need to be viewed more as a Geotechnical rather than only as a Bioengineering material. It is suggested that this transition is closely linked to growth in application of geosynthetic materials in India, which would necessitate a pro-active role of User Agencies especially of these related to roadways, waterways and land development. The relevant R&D institutions too need to overcome certain ingrained mental blocks and follow developmental paths outlined in this paper.

FUNCTIONAL REQUIREMENTS OF GEOSYNTHETIC MATERIALS

Solution of a geotechnical problem usually involves improving upon a number of functional characteristics of the concerned soil. Thus prevention of erosion of a river bank through application of geotextiles involve planting a suitable fabric within the soil that would permit easy flow of water without removal of soil particles (filtration) as also inducing vegetation growth on the embankments possibly by laying a soil-saver on the exposed surface. Similarly a road abutment would call for suitable reinforcing agent as also a suitable findrain to prevent build up of any pore water pressure. By way of an illustration, the functional requirements for some typical applications have been listed in Table 1. It is observed that in all these cases, a multidimensional improvement is called for necessitating probably an assembly of different types of geosynthetic materials, whereby the relative importance of different functions in any particular application can be different from another application. Accordingly, the lifespan requirement of a particular geosynthetic material should be spelt out in terms of the duration of the expected functions. Thus, for example in stabilisation of a road, the separation & reinforcement functions could be very important during the initial years but on gradual consolidation over a period of time and with an efficient operational drainage system, the two functions may gradually lose significance. In such cases it is not sensible to spend money on a geosynthetic system that would exhibit hardly any change in strength over a long period of time. In other words, cost effectivity of a geosynthetic application can be improved by avoiding overdesigning with the best available material.

Another moot point to ponder upon is the interplay between cost effectiveness vis-a-vis boundary constraints. The cost effectivity of a particular solution might be theoretically improved by employing superior and hence more costly material that would last longer. But the desired durability

Table 1: Functional requirements of some typical geotechnical problems.

	Functions							
Applications	Filtration	Drainage	Separation	Protection	Encapsulation	Reinforcement	Erosion control	Confinement
Stabilisation of soil slopes						•	•	
Reinforced soil walls		•				•		
Stabilisation of road	•	•	•			•		•
Rail-roads track bed stabilisation	•		•			•		•
Embankment on soft soil	•		•			•	•	
Landfills	•	•	•	•	•			
Erosion control on slopes							•	•
Land Reclamation	•		•			•		
River bank Protection	•		•				•	

of a particular treatment itself is a function of several factors. For example, the desired lifespan of a treatment carried out on an important and busy road is surely different from that on a less frequented one. Similarly the availability of funds or the urgency for a particular work at any instant of time might not permit the luxury of the best solution. Hence an intricate interplay of the prevailing factors at any point in space-time might lead to application of very different types of geosynthetic materials for solution of two absolutely similar geotechnical problems. The argument of cost effectiveness of superior materials that would guarantee a longer life span and less maintenance can thus be very misleading. It might be quite sensible to focus more on "Return on investment" or on "Profitability analysis".

Man made polymeric materials such as Polypropylene, Polyethylene and Polyester are considered to be chemically inert in conditions such as to be encountered in soil. Hence properties of these materials are by and large expected to remain unchanged over a much longer period as compared to natural fibres such as Jute or Coir. Such chemical inertness of the man-made polymeric materials also mean that the health of soil and water would not be effected by the presence of these foreign materials(1). However this inertness applies only to the pure and virgin materials. Polymers of such grades would be very expensive and won't be employed for production of geosynthetics. One is more likely to fine recycled raw materials employed for such end uses. Such recycled materials may not only carry traces of highly toxic substances but their chemical inertness too becomes a subject matter of speculation. No information is available in accessible literature on such non-standard materials. It is thus incorrect to assume that geosynthetics made of polyester, polypropylene and polyethylene are inert and harmless to soil.

It is apparent from discussions in the foregoing that the 'superiority' of geosynthesis made of man-made polymeric materials over those of natural fibres can be a very subjective and at times even a wrong notion.

NATURAL VEGETABLE FIBRES FOR GEOTEXTILES AND THEIR SCOPE

Natural fibres can be sourced from animals (e.g. Wool and Silk) or from plants (vegetable fibres). The limited quantity of animal fibres produced world over has very well defined apparel end uses and do not come under question as raw material for geotextiles.

The vegetable fibres can be grouped into three classes namely bast fibres, leaf fibres and seed/fruit fibres. Bast fibres are extracted from stems of plants and the other two groups are self explanatory. In terms of quantity of production, each of the bast fibres such as jute & flax, leaf fibres such as sisal and seed/fruit fibres like cotton and coir are cultivated to more than 100,000 m.t. per annum, whereby production of cotton is greater than any of these fibres by an order of 2. The bast fibres are much softer than the leaf fibres and hence enjoy a more diversified end-use. Flax, hemp and ramie are used in twines, canvases, fishnets, firehoses etc., whereas the leaf fibres are employed as cordage material or even as mats. Coir has similar end uses as the leaf fibres, whereas cotton is used mostly in apparels and jute in sacking and carpeting. All these materials can be cultivated more intensively if suitable new end uses are found out.

A fibre material would be suitable for geotextile when

1. if has reasonably good mechanical properties, and
2. it is reasonably resistant to microbial attack.

The bast fibres namely flax, hemp and ramie have very high tenacity values (between 45-66 cN/tex) and low extension at break (1.6 - 3.8%). Jute is weaker than the fibres named (Ca. 30 cN/tex) but extends almost as much at break. In tenacity, the leaf fibres are slightly stronger than jute but weaker than the other three bast fibres and in extension at break they behave similar to the bast fibres. The tenacity of coir fibres on the other hand is very low (15 cN/tex) but elongation at break much higher (around 40%). It is clear therefore that if coir and jute fibres could be used as geotextiles, so could then the other commercially produced leaf fibres. In fact trials with sisal fibres for erosion control have been reported to be encouraging(2).

The growth of microorganism on vegetable fibres depends on their chemical composition. The lignin content plays hereby an important role. In this respect alone, coir fibre with about 35% lignin content stands out as extremely resistant followed by jute (ca. 12%) and leaf fibres (about 10%). The other bast fibres contain much lower quantity of lignin (0.6 to 3.3%). Even in content of lignin hemicellulose ratio, jute, coir and leaf fibres appear to have distinct advantage over the other bast fibres. In terms of the crystallinity of the cellulose content, which also influences the biodegradability (3), no comparative results are available for these different fibres although it is quite high for the leaf fibres and low for coir.

It does appear from the preceeding short discussion that in addition to exploring applcability of jute and coir fibres for geotextile and uses, the leaf fibres should also be considered as potential raw material.

GEOTEXTILES FROM JUTE AND COIR FIBRES

Geotextiles made purely of jute fibres - also known as geojute - have been in use since fiftees, when a open meshed woven fabric was used in Europe and USA to cover exposed soil surface with a view to promoting vegetation growth thus arresting soil erosiion. This fabric also popularly known as Soil Saver, has till date remained the only commercially produced jute geotextile. Although other end uses of geojute such as for reinforcement in temporary haul roads, reinforcement in highway construction, asphatic overlay, drainage for roads etc. have been suggested (4,5) and a concerted effort has been initiated under the Indian National Jute Development Programme to develop similar products, diversified end uses of geojute is still far from a reality. This is partly due to the difficulties in designing with a material whose strength is going to fall rapidly to microbial attacks. Even in the field of erosion control, Geojute has many limitations primarily because its strength and durability are too limited for harsh applications such as steep slopes, higher altitude slopes or waterways. It also does not function well with heavy water flow and degrades too quickly in very humid condition(6).

Coir, the other natural fibre which has also been used in geotextiles over the past 20 years or so, has had a late start but already proved its worth in quite a few applications namely erosion control, reinforcement and filtration (6). Tests conducted by German Bundesanstalt for material testing on jute, sisal, coir and cotton over a prolonged period of time in highly fertile soil maintained at high humidity (90%) and moderate temperature (82°F) revealed that,

(1) whereas cotton degrades totally in six weeks and jute in eight weeks, coir still retained 20% of its strength after one year.

(2) it takes coir, 15 times longer than cotton and 7 times longer than jute to degrade.

The total quantity of coir geotextiles exported from India during 1995-96 is about 361 metric tonnes valued at Rs.15 millions which in terms of volume compare quite unfavourably with that of jute geotextiles (about 1,133 tonnes). Thus inspite of some advantages of coir fabric over jute fabric mainly in terms of robustness, resistance to biodegradation and freedom from auxiliary chemicals as well as lower raw material price, there is some inherent weakness in the production process of coir fabric which make development of new products a difficult proposition. These are discussed in the following.

Coir fibres, extracted from dry coconut husk exhibit a wide range of dimensions, varying in length between 50 and 300 mm and in diameter between approx 100μm to 400 μm (7) in such a way that longer fibres are also thicker. Thus it is an admixture of fibres differing widely in properties such as in bending rigidity and breaking load, the former varying by a factor of 16 and the latter by about 4. In the conventional spinning process this extremely heterogenous mass is bunched together and twisted to a 2 ply yarn. As a result, one can spin only extremely thick and very uneven yarns from coir fibres. This forms a very big limitation to designing suitable woven structures for diverse applications. Obviously improvement in the coir spinning process, starting with a segregation of the different components of fibre within the husk, is an important and necessary measure for overcoming this very fundamental limitation. Jute fibre spinning is in this regard way ahead and hence enjoy a definite advantage.

Coir fibres differ from jute fibres in another aspect as well; jute fibres exhibit moderately high modulus as well as high tenacity and very low elongation at break whereas coir fibres behave exactly in the opposite manner, namely moderately low modulus, low tenacity and very high elongation at break (7). This difference persists irrespective of the length of coir fibre. Logically then they form ideal partner for a blended product.

The use of geotextiles during the past two decades has increased form 10.2 million sq. meters in 1970 to 700 million sq. meters in 1990 and is projected to be 1400 million sq. meters in the year 2000 (5). Geotextiles made of natural fibres presently account for approx. 0.001% of this market. This is partly due to inaction on the part of growers of natural fibres. On the other hand industrialised countries, such as USA, have taken to a lead many years back in exploring ways and means of utilising natural fibres as geotextiles. A bitumenized cotton fabric was employed in improving paved roads way back in the '30s whereas the only 'Geojute' known to us, which was indeed only meant to wrap cotton bales, was converted into a 'soil-saver' by the soil conservationalists during the '50s. Commercially no further developments were discernible till the late '80s when concerns of ecological balance, pollution, high cost of energy and depleting sources of petroleum forced these developed countries to take a fresh look at the renewable and eco-friendly natural fibres. This has resulted in not only development of newer products such as erosion control blankets etc. but also led to some important conferences where the attention was focused only on natural fibre geotextiles. For example, in the Singapore international conference on geotextiles, geo-membranae and related products held in September 1994, a whole section was devoted to natural geotextiles only. During these concerted exercises, a clearer picture on the potential of natural fibres as raw materials for geotextiles has emerged.

Jute and coir fibres grow abundantly in our country and our share of the global production of these two fibres is 44% and 66% respectively (8). Developing commercially available geotextiles out of these materials and promoting them lies in the interest of the economy of our country. Compared to their synthetic polymeric counterparts both jute and coir fibres are very coarse materials. A very fine 4 lb jute yarn or a 300 m.p.k. coir yarn would be respectively, 5 times and 24 times thicker than a fine 50s Ne (or 110 denier) cotton (or multifilament polyester) yarn. Similarly a jute fibre (3 tex) or a coir fibre is respectively 2 times and 30 times heavier than a thick 15 denier polypropylene fibre. Consequently the products of jute and coir fibre are bulkier and heavier than those made from synthetic polymeric materials. On the other hand, having been historically employed only for low grade products such as sacking, matting etc., the jute and coir geotextiles are expected to be among the cheapest available.

In view of the existing duty structure, synthetic polymeric materials produced in our country are much more costly than those produced in the developed countries. Thus the domestic synthetic polymer industry can hardly expect to compete with their global counterparts in so far as geosynthetics are concerned. Similarly natural geotextiles would also work out to be much cheaper than the domestic synthetic ones. The multinationals enjoy on the other hand advantages such as of economy of scale, wide production and marketing network as well as ability to choose production sites across the globe to ensure the lowest unit cost. Marketing natural geotextiles globally therefore would amount to competing with these giants and their relatively low cost high performance products. Moreover in view of the high volume and weight of these natural products the cost of transport itself can constitute 50-75% of the landed cost. This erodes the competitive edge of natural geotextiles considerably. However a niche market product can to some extent absorb the price differentials. As a result jute and coir products have been selling abroad only as a specific segment of the rolled erosion control products and marketed more in the sensitive community areas and neighbourhoods in the west and not in the improvements of large uninhibited lands, which continue to use geosynthetics. It appears unlikely that any jute coir based geotextile, developed for uses other than erosion control, can get a toehold in markets of developed countries unless its exclusive character is established first. Accordingly it would be unwise to base development of new types of natural geotexiles aimed at the overseas market. Such developments should logically be targeted first at the domestic market. Hence the scope of wider application of natural geotextiles is closely interlinked with the growth in application of geosynthetic materials in India.

APPLICATION OF GEOSYNTHETICS IN INDIA

An attempt has been made to compile from published documents a listing of the different types of geosynthetic applications which have taken place in India over the past decade (9,10). These are shown in Table 2 & Table 3. It is evident from the Table 2 that the applications of man-made polymeric geosynthetics have been by and large restricted to separation, reinforcement, drainage and embankment protection of roads, stabilisation of slopes and drainage in embankments of waterways as well as drainage and separation in railways. Some geosynthetic materials have also been used for ground improvement. Although not listed in this Table, a significant quantity of geomembranes is also being used as pond and canal lining. The total amount of Geosynthetics already used in India can be roughly estimated at about 10 million square metres. Considering that the total annual consumption in North America alone is about 50 to 60 times more than our cumulative consumption over the past ten years, whereby our country is 7-8 times smaller but exhibit a comparable diversity of terrain, India can be said to be in infancy in so far as the application of geosynthetics is concerned. The awareness however has improved considerably and many user agencies are conscious about the potential of this material. A multitude of factors, among them a relatively high cost of geosynthetic materials, have contributed to the tardy progress. Nevertheless various geotechnical problems which can be elegantly solved with geosynthetics abound in our country.

Table 2 : Application of man-made polymeric Geosynthetics in India

1.	Geotextile in Water Resources Projects	
(a)	Stabilization of soil slope; drainage control in embankments and dams	1. Kakrapar canal system near Surat, Gujrat (Grouted geotextile mattress)
		2. Bardoli branch canal of Ukai canal, Surat, Gujarat (Grouted geotextile mattress)
		3. Left bank of Dhadar river near Gandhar, Gujarat (Stone gabions caged in Netlon geogrids for bank protection)
		4. Loktak hydro electricity project, Manipur
		5. Medha creek dam, Gujarat
		6. Raman hydro electricity project, West Bengal
		7. River training project in Sikkim
(b)	Erosion control of embankments; filter media to check movement of fine clay/sand underneath bank protection and guide walls	1. Farakka barrage project in Murshidabad district, West Bengal on Bhagirathi River
		2. Hiran Dam II, Veraval, Gujarat
		3. Downstream of Dharoi earth dam, Gujarat
		4. Dhadhar river near Gandhar in Bharuch District, Gujarat
		5. Salal hydro-electric project on river Chenab
(c)	French drains	1. Mahi right bank canal for agriculture drainage, Gujarat
		2. Kheda district to lower ground water table due to seepage from canal system
		3. Rammam hydroelectric project stage II, West Bengal
II	Geotextiles in Roadways	
(a)	Pavement overlay to prevent reflection cracks	1. Ahmedabad airport main runway, Gujarat
(b)	Separation and/or Reinforcement	1. Erumbur-Nellikollai round branching at km 22/8 at portanava-Vridhachalam road
		2. Command area development of Gujarat and maharashtra partly funded by World Bank
		3. Tapi command road near Surat, Gujarat
		4. Koyna bridge abutment, Maharashtra
		5. State Highways, Maharashtra
		6. State highways, Karnataka
		7. Bridge approach and abutment, Phagwara and Ludhiana, Punjab
		8. Bariely National Highway U.P
(c)	French drains	1. Harsoan village under Ghaziabad Development Authority, U.P

III	Geotextiles for Rail Bed Stabilization	
(a)	Separator to prevent mud pumping	1. South-Central Railway Vijayawada Rajmundry 560/2-4 UP
		2. Northern Railway Sandila-Balaman (Mordabad section) km 1127/13-1128/1 Dn.
		3. Northern Railway Sandila-Lucknow (Moradabad section) km 114/13-15 Dn.
(b)	French drains adjoining railway embankment for railway yard drainage	1. South-Eastern Railway (Raygada-Koraput section)
		2. South-Central Railway (Guntkal section)
		3. Northern Railway (Jammy-Udhampur rail link)
IV	Geotextiles for Ground Improvement	
(a)	Reclamation areas, roads, reclamation bund and guide bunds for construction of port and fabrication of yard for large off-shore exploration jackets.	1. Nhaba Sheva Port near Bombay
		2. On banks of Hooghly river, 16 km down stream of Halida Port.

Table 3 : Application of Natural Geotextiles in India

1.	Natural Geotextile in Water Resources Projects		
(a)	Erosion control of embankments; filter media to check movement of fine clay underneath bank protection	1. Nayachar Island, West Bengal	Bitumenized Geojute, 1992
		2. Hasanpur, Ramayanpur and Barrackpore, West Bengal on rivers Padma, Phullahar & Hooghly	Bitumenized Geojute, 1996
		3. Majuli, Assam on Bramhaputra	- do -
		4. Una, Himachal Pradesh on Beas	- do -
		5. Kedarpur R.C.C. Jetty at patharprotima Block, Sunderban, West Bengal	- do -
(b)	Erosion control through revegetation	1. Kabini Canal, Mysore	Coir nettings, 1994.

2. Natural Geotextile Roadways			
a. Erosion control of embankment through revegetation	1.	Kathgodam - Almora State Highway, V.P.	Coir netting, 1988
	2.	Meerapur - Dewal Road Muzaffar nagar, U.P.	Coir netting, 1989
	3.	Bhangi choe bridge approach, Hoshiarpur, Punjab	Jute wovens 1997
	4.	Chintalarevu bridge approach, Andhra Pradesh	-do-
b. French Drain & Fin Drain	1.	Joshimath - Mallari Road, U.P	Nonwoven Jute, 1996
	2.	Hanuman Setu flyover Delhi	-do-
	3.	Okhla flyover, N.Delhi	-do-
c. Separation and Reinforcement in soft soil	1.	Kakinada port area, Andhra Pradesh	Treated DW Twill Geojute, 1995
	2.	Kandla port trust, Gujrat	-do- 1997
3. Natural Geotextile in slope stabilisation			
a. Erosion control through revegetation	1.	Nagapathinam - Gudalore Mysore Road, (Nilgiris, Tamil Nadu)	Coir netting, 1989.
	2.	Lambidhar mines area, Mussorie, U.P.	Coir netting, 1988
	3.	Coonoor - Kundah Road (Nilgiris, Tamil Nadu)	Coir netting, 1989
	4.	Sahashradhara, near Dehradun, U.P.	Geojute, 1991
	5.	Siliguri Dist., W.Bengal	Geojute, 1994
	6.	Forest and Tea Gardens, Darjeeling, W. Bengal	Geojute, 1994
	7.	Pullangode Estate, Kerala	Coirnetting, 1994
	8.	Cachar, Assam	Geojute, 1996
	9.	Staun, Near Paonta Sahib, H.P.	-do-
	10.	Kaliasaur, Garhwal. U.P.	-do-

Paying attention to Table 3 one notices that erosion control of embankments in roadways, waterways and hilly areas has so far constituted the major functional application of natural geotextiles. This probably arises out of the historical transformation of loosely woven jute netting meant to transport cotton fibres into the so called 'soil saver'. The positive attributes of such nets in terms of high water absorption, drapability, formation of mini check dams as also bio-compatibility with soil have been discussed and highlighted in numerous publications (8,10-13). A technically less developed and less understood but physically more robust coir fibre followed similar transformation as relatively open coir mattings started finding applications in situations requiring a greater durability under more exacting conditions. In view of greater thickness of coir fibre as also the cottage level technology in converting them to yarns, only very thick and non-uniform coir yarns can be spun. Hence the coir nettings are invariably thicker and heavier than their counterparts made of jute. Inspite of coir nettings following the footsteps of 'Soil Savers', the former appears to have been actually used in India for erosion control applications earlier than jute. This is illustrated in Table 3 showing five applications of coir netting in 1988 and 1989 whereas Geotechnical applications of jute seems to have started only in the 90s. To put this matter into proper prospective it must be mentioned that this late thrust in promoting jute geotextiles in India is a direct outcome of the GOI-UNDP funded jute diversification programme and not a result of initiative taken either by the jute industry or by the user agencies. Therein probably lies the bane of the problem related to growth of natural geotextiles in India. Whether the flurry of activities in application of Geojute during 1996 and 1997 would taper off with termination of the officially sponsored jute diversification programme in 1998 or retain the momentum would depend a lot on the dynamism and commitment of the jute industry and the user agencies.

Besides Soil Saver and coir netting a limited version of woven and nonwoven fabrics from both fibres have been developed and used so far. Woven jute fabrics treated chemically for retarding rotting and bitumenised with a view to controlling pore size and providing a protective coating, have been applied in roadways as well as in water resources projects (14-16). Short term results of these field trials have been encouraging. Similarly nonwoven jute fabrics have been employed as drainage material in roadways. Coir fibres are similarly being converted to Erosion Control Blankets and countries could foresee the utility of this material long back - as evidenced by the reports contained in papers presented during seminars on coir Geotextiles held in U.S.A. & U.K. during 1991 & 1992 - develop in association with their industrial partners products such as Erosion Control Blankets and then start importing from India and Sri Lanka coir Geotextile to their specifications.

A striking feature of the natural Geotextiles developed and used so far is the very narrow product range. Every geotechnical problem is unique and would need some variation in the properties of geosynthetic materials. The polymeric geosynthetic materials are hence manufactured in great many varieties and a discerning end user should either be able to choose the right material from the shelf or be able to specify his requirements for the manufacturer to design the product. This aspect was investigated by Dey (17) who developed a Software for enabling desirable hydraulic properties to be designed in needle punched materials. The very limited and repetitive type of functional application of jute and coir geotexiles owes much to this shortcoming. A rough estimate of the total quantity of natural geotextiles used in India so far would put the value at 2-3 lakh square metres only.

CURRENT LEVEL OF PRODUCTION OF NATURAL GEOTEXTILES

Viewed against the very limited domestic consumption of natural geotextiles so far, it is not surprising that both the jute and coir sectors are heavily dependent on export for marketing whatever materials they produce in bulk. Currently the export volume of Jute 'Soil Saver' is in the region of 22 lakh square metres (1133 tonnes) which is a substantial climb down from the figure of 7000 tonnes/ annum exported in the early sixties. In 1995-96 coir Mesh Mattings were exported to the tune of 361 m.t. It is interesting to note that an unit area of Soil Saver sells at almost one fourth the price of coir Mattings in North American and European markets (12) although coir fibres are available at almost half the price of jute fibres in India. Even accounting for a higher weight/unit area of the Mesh Matting, a substantial price differential is observed in favour of coir Mesh Matting. This is clearly illustrated in Tables 4 to 6.

Table 4. Typical European Selling Prices for RECP

Material	Description	Price - \$/m^2
Jute ECM	Woven jute geotextile - 500 g/m^2	0.65 - 1.30
Straw ECB	Straw blanket stitched between two nets	1.90 - 3.00
Organic ECB	Needle punched recycled cotton waste	1.20 - 1.90
Synthetic ECB	Needle punched recycled staple fibre	1.80 - 2.20
Coir/straw ECB	50% coir fibre - 50% straw sewn between nets	2.20 - 3.50
Coir ECB	100% coir fibre sewn between two nets	2.70 - 4.00
Coir ECM	Woven coir geotextile - 700 g/m^2 Woven coir geotextile - 900 g/m^2	2.20 - 3.50 2.70 - 4.00

Table 5. Typical North American selling price for short term RECP

Material	**Description**	**Price - \$/m^2**
Jute ECM	Woven jute geotextile - 500 g/m^2	0.45 - 1.00
Straw ECB	Straw blanket with net one side Straw blanket stitched between two nets	0.65 - 0.80 0.80 - 1.10
Excelsior ECB	Wood fibre blanket with net one side Wood fibre stitched/glued between two nets	0.55 - 0.80 0.80 - 1.10
Organic ECB	Stitched paper shred or cotton waste	0.65 - 1.00
Synthetic ECB	Polyolefin film reinforced with net	0.80 - 1.10

Table 6. Typical North American selling price for medium term RECP

Material	**Description**	**Price - \$/m^2**
Coir/straw ECB	70% coir fibre - 30% straw sewn between nets	1.20 - 1.60
Coir ECB	100% coir fibre sewn between two nets	1.60 - 2.50
Coir ECM	Woven coir geotextile - 400 g/m^2 Woven coir geotextile - 700 g/m^2 Woven coir geotextile - 900 g/m^2	0.90 - 1.30 1.70 - 2.20 2.40 - 3.00

Erosion Control Blanket is the other major commodity being produced to the tune of about 500 tonnes annually by seven companies - two in Sri Lanka, two in Germany, two in U.S.A. and one in India. This commodity competes with synthetic ECBs which sell at almost half the price both in North America and Europe. It would appear from the above that coir based geotextiles, application of which was initiated only in the early '80s have a distinct appeal. A systematic development of this line of products could be advantageous for the future growth of natural geotextiles.

THE PROSPECTS AND AVENUES FOR GROWTH

Looking back at the development of jute and coir geotextiles in particular and geosynthetics in general one cannot but take note of the major historical role played by User Agencies in promoting these materials. As a corollary to the foregoing one may state that the Indian User Agencies, in particular those belonging to roadways, waterways and land development, have to take more than an academic interest in promotion of jute and coir based geotextiles. These materials are available locally at a much lower price than their synthetic polymer based counterparts and the limited experience in application of these materials has not been negative. It is definite that many ongoing constructions would benefit from the use of geosynthetics; the only question mark against the application of natural geotextiles pertains to their longevity. However it has been pointed out by many authors that leaving out cases needing permanent reinforcement and confinement, pure natural geotextiles could be gainfully employed in various geo-engineering applications where the limited durability won't be critical (4,10,13,18). Such applications would include land reclamation and consolidation, drainage of roadways and other manmade constructions and sedimentation control by silt fences. In conjunction with synthetic polymeric materials, functional requirements of long term separation and even of reinforcement can be satisfied through intelligent design of composites. This would bring applications such as of Ash Ponds, underlays in roadways and track beds in railways into the purview of natural (based) geotextiles. Moreover in many applications involving geomembrances, suitable nonwoven blankets made of natural fibres could be used as underlay to offer protection to the membrane and act as drainage material for any fluid which may collect underneath the membrane. It is quite apparent that the natural geotextiles need not carry the stigma of Erosion Control Products if the user agencies take the desired initiative.

The necessary guidance to the user agencies would have to be provided by consulting agencies and R&D Institutions who would have to play the crucial role of Interface between the user agencies and the industry. These agencies and institutions would have to work in unison, the latter developing new products as also the design procedure for specific applications whereas the former would carry out the detailed engineering and take it to the user agencies. The positive contribution that a R & D institute can play in amply illustrated by the developmental work carried out in the university of singapore during the '80s. The novel development of and experiments with Fibredrain are well documented in literature (4). Similarly the trials in land reclamation projects have also been very successful (19). These daring and imaginative uses of a raw material gifted to us by nature speak volumes of the dedication and commitment of a small group of persons. Their pioneering efforts need now to be backed up and a tradition built up by a much larger number of relevant R & D groups across our country.

The Indian research laboratories dedicated to the jute and coir fibres, namely IJIRA, NIRJAFT (formerly JTRL) and CCRI should note that.

* Jute and coir fibres are not to be viewed as competitors but should be treated as ideal partners for composite materials.
* The erosion control materials made of jute and coir fibres are very low technology products. For higher value addition, new products need to be engineered probably in conjunction with synthetic polymeric materials. The infatuation with the biodegradability and eco-friendly aspects of natural fibres should be substituted by a more healthy respect and understanding of the many other engineering properties of these materials.

Towards achieving the goals listed above, some concrete steps have already been initiated in our country. A new PVD, namely the Brecodrain (20), has been developed in India and laboratory tests have led to very positive outcome. A detailed report about the ongoing development work on Brecodrain is being presented in this conference. This drain sports a new structure, harnessing the properties of jute and coir fibres profitably and the production process is very flexible so that a wide range of boundary conditions can be satisfied.

Another important achievement concerns the breakthrough in intimate blending of jute and coir fibres (20). These two fibres are very different in their physical properties and the coconut husk contains an admixture of fibres varying very widely in their properties. The prevalent techniques employed in converting this heterogenous blend of fibres into yarn are moreover quite crude. As a result, the ensuring coir yarn is thick, non uniform and much weaker than what it should be (very low degree of exploitation). Thus before blending the jute and coir fibres, steps have to be taken to segregate the different segments of coir fires into relative homogenous groups. After suitably softening the relevant jute and coir fires, blending can be carried out to produce carded webs and slivers. Such webs and slivers have been successfully produced in industrial scale with Jute-coir blend ratios of 70:30, 60:40, 50:50 and 40:60. These slivers would be spun into roving/ yarns on the jute spinning system, ensuring thereby a product finer and superior to that of 100% coir yarns, the properties of which need to be studied thoroughly before deciding on the fabric to be engineered. Similarly the blended carded web need to be assembled into a suitable batt and converted to a nonwoven fabric. A great flexibility is available here to create fabrics in unison with yarns and fabrics of various materials. Similarly the nonwoven technology need not be restricted to needle punching only. Clearly then a new vista seems to open up for engineering different types of geotextiles based on natural fibres, as the fundamental problem of intimately blending jute and coir has been sorted out.

CONCLUSIONS

Geosynthetic materials made of man-made polymers as well as their applications have been pioneered and promoted in Industrially developed countries. So too has been the case of some products of nature fibres which were incidentally being manufactured in our country for entirely different purposes. Although the global annual consumption of geosynthetic materials has been increasing continuously, that of the natural geotextiles has been declining steadily. It is possible to arrest this downward slide and gain a rightful share for the natural geotextiles in the geosynthetics market provided the obsession with the biodegradability aspect of natural fibres is overcome and various suitable geoengineering materials developed from natural fibres by keeping in view the properties of the raw materials, the functional requirements of the applications and the desired durability of the individual functions specific to each application. As the raw materials, namely jute and coir, are cultivated in large quantities in our country and our country abounds in relevant geotechnical problems, our user agencies have to play a pro-active role in using suitable geotextiles made of blends of jute, coir and synthetic materials especially in roadways, waterways and land development. The relevant R&D organisations have to adopt a holistic approach and develop suitable geotextiles made from blends of these fibres following methods outlined in this paper. This would be beneficial not only for the future of natural geotextiles but also for the economy of our country.

REFERENCES

1. Rimoldi, P. and Ricalcati, P. (1995). Geosynthetics in environmental geotechnology: An overview, *Workshop on environmental geotechnology*, New Delhi.
2. Oosthuizen, P. and Kruger, B. (1994). The use of sisal fibre as natural geotextile to erosion control. *Proc. Fifth International conference on Geotextiles, Geomembranes and Related products*, Singapore, 871-874.
3. Batra, K. (1985). Long vegetable fibres, *Handbook of Fibre Science and Technology*, Vol-IV, Ed. M. Lewin and E. Pearce, Marcel Dekkar Inc.
4. Ramaswamy, S.D. (1994). The potential of jute assembled soil stabilisers. *2nd International workshop on Geotextiles*, N.Delhi, 77-85.
5. ITC Report. (1991). *Jute Geotextiles*, Geneva.
6. Schurholz, H. (1991). Use of woven coir geotextiles in Europe. *Coir geotextiles conference*, USA.
7. Guha, A. (1995). Characteristic physical properties of coir fibres and their compatibility with jute. M.Tech Thesis, IIT Delhi.
8. Balan, K. and Rao, G.V. (1994). Erosion control with natural geotextiles. *Proc. Intl. Seminar and Technomeet on Environmental Geotechnology with Geosynthetics*, New Delhi, 317-325.
9. CBIP report. (1994). An introduction to geotextiles and related products in civil engineering applications, New Delhi, 12-14.
10. Rao, G.V. (1995). Erosion control with geosynthetics. Committee for IGS (India) and C.B.I.P. New Delhi.

11. Ingold, T.S. (1994). The mechanics of erosion control. *2nd Intl. workship on Geotextiles*, New Delhi, 127-134.
12. Rickson, R.J. and Loveday, A.D. (1996). Technical specification and market survey of potentially important jute geotextile products. *Technical Report submitted to CFC*, Amsterdam, The Netherlands.
13. Ranganathan, S.R. (1994). Development potential of jute geotextiles. *Geotextiles and Geomembranes*, 13, 6-7, 421-434.
14. Ujlayan, S.R., Azeem, A. and Ali, A. (1994). Erosion control on slopes of banks and cuttings with Geo-jute - A Biotechnical approach. *Workshop under UNDP National jute programme*, New Delhi.
15. Sanyal, T. (1992). Control of bank erosion naturally - A pilot project in Nayachara Inland in the river Hooghly.
16. Srinivasa Murthy, B.R., Nagraj, T.S. and Manoj, M. (1994). Jute geotextile - a eco-friendly material. *Workshop under UNDP National jute programme*, New Delhi.
17. Dey, P.K. (1995). Development of a mathematical model for designing of needle punched geotextiles in hydraulic application. Ph.D. Thesis, IIT Delhi.
18. Datye, K.R. and Gore, V.N. (1994). Application and manufacturing developments for jute and related natural materials. *Workshop under UNDP National jute programme*, New Delhi.
19. Tan, S.A., Muhammad, N., Karunaratne, G.P. and Lee, S.L. (1994). Use of jute geotextile in layered clay-sand reclamation scheme. *Proc. Fifth International conference on Geotextiles, Geomembranes and Related products*, Singapore, 867-870.
20. Banerjee, P.K. (1996). Development of new geosynthetic products through blends of natural fibres. *Proc. Intl. Seminar and Technomeet on Environmental Geotechnology with Geosynthetics*, New Delhi, 337-346.