STABILIZATION OF EMBANKMENT SLOPES WITH JUTE GEOTEXTILES - A CASE STUDY IN NH-2 ALLAHABAD BY-PASS

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1.0 INTRODUCTION

Bio-engineering is the technique of utilizing vegetation in addressing geotechnical problems. Environmental uncertainties associated with man-made techniques are prompting engineers to go in for bio-engineering measures. Vegetation as an aid to artificial methods in controlling surficial soil erosion is gaining larger acceptability among engineers all over the world.

Growth of appropriate vegetation on exposed soil surface is facilitated by use of natural geotextiles such as Jute Geotextiles (JGT). Properly designed JGT laid on slopes or any other exposed soil surface provides a cover over exposed soil lessening the probability of soil detachment and at the same time reduces the velocity of surface run-off, the main agent of soil dissociation. Natural geotextiles bio-degrade quicker than its man-made counterpart but facilitates growth of vegetation quicker and better due to its inherent characteristics.

2.0 Mechanism of Soil erosion

Soil erosion is the process of detachment and transportation of soil particles by wind, water principally. Normally cohesion less soil particles are blown away by wind (Aerolian) erosion. The kinetic energy of falling rain drops causes detachment of soil particles and subsequently carried away by surface run-off.

Erodibility co-efficient of soil and impact of rain drops are determinant factors in the process.

This is guided by the nature of soil (clay content), particle size distribution and soil condition like saturation, density, permeability, plasticity etc. Dislodged soil particles flow down the slope with the overland flow, eroding and destabilizing the soil-body. Distress in the form of rills to gullies and finally to erosion ditches develops when intensity of rain fall is high and the slope is steep. These disorders will impair slope stability if not controlled with proper protective measures.

3.0 Role of Vegetation in erosion control

Ground cover is considered as the most suitable solution for erosion protection. Grass such as "Vetivar" and other appropriate species is a natural soil-binder and provides the best natural solution against erosion. In bio-engineering, plants have mainly two effects on soil hydrological and mechanical. Hydrological effects of plants are many such as interception (rain drops strike the leaves first before striking the ground soil), storage (leaves and stems hold water for some time before it eventually reaches the ground), infiltration (stems and shoots roughen and loosen the ground, enabling water to infiltrate more easily) etc. Mechanical function of plant is to reinforce the soil by binding the loose soil particles with its fibrous root system.

4.0 Role of Jute Geotextile (JGT)

4.1 Properties of Jute Geotextiles

Jute is a potent source of natural ligno-cellulosic bast fibre enriched with cellulose and hemicellulose that facilitates absorption and retention of water (Choudhury P. K et al -2008). Well-developed jute mechanical processing machineries are now available. Utilizing these machineries jute fibres can be spun to make desired quality yarns and the yarns are transformed to specified geotextile fabric for specific purposes. Different types of open weave JGT for soil erosion control have been developed and are in extensive use world wide. Technical specifications of some of these products are shown in Table -1. Cost wise JGT is the least expensive among all other geotextiles available in the market in India.

Table -1

PROPERTIES	TYPE-1	TYPE-2	TYPE-3
Weght (g/m^2) at 20% M.R.	292	500	730
Threads/dm (MD X CD)	12 X 12	6.5X4.5	7X7
Thickness (mm)	3	5	6
Width (m)	1.22	1.22	1.22
Open Area (%)	60	50	40
Strength (kN/m) [MD X GD]	10X10	10X7.5	12X12
Water holding capacity (%) on dry weight	400	500	500

4.2 Functional effects of Jute Geotextile

Open weave Jute Geotextile fabric (Type-2; Table -1) is used to cover up the slope surface initially to give protection against erosion. Jute being a coarse fibre, yarns are thick with pronounced 3-D features. Open weave JGT (weft yarns) provides a series of mini barriers (sort of check dams) across the direction of overland flow. 3-D construction of open weave JGT reducing the velocity of overland flow and opening of the fabric retain dislodged soil particles that are set to be carried away by the over land flow. Open weave JGT structure having usually 40% to 60% open area (OAR), when laid on the slope provide a partial cover to the ground and heavy strands of JGT help absorb the impact of the kinetic energy of the falling rain drops. JGT has excellent drapability. Open weave JGT can shape to follow the soil contours on which it is laid (Thomson & Ingold, 1986).

One feature of open weave JGT deserves special mention. JGT has the unique property of absorbing water up to nearly from 4.5-6 times its dry weight (Rickson & Loveday, 1998). This characteristic of jute helps in effecting storage. When soil is less permeable and precipitation is heavy, soil erosion, especially in slopes, can somewhat be controlled by overland storage and prevention of detachment of soil only. The situation calls for proper selection of the JGT-type as well as species of vegetation.

JGT is, already mentioned, hygroscopic in nature due to the intrinsic properties of jute fibre. In wet condition its flexibility increases due to absorption of water. JGT creates a moist micro-environment around the soil surface which is conducive to faster growth of vegetation. It bio-degrades in course of time (normally within 1 to 2 years) adding nutrients to the soil at micro-levels. Once vegetation starts growing, the role of JGT is taken over by it. When vegetation is fully grown, the vegetative cover provides canopy interception to the falling rain drops and protects the soil from splash detachment. The fibrous root system of vegetation penetrates the soil and reinforces the slope soil and provides long term slope stability. The choice of right species of vegetation for a particular climate and soil condition is very important. Vegetation with deep roots that thrives in a particular locality is to be selected in consultation with botanists/agronomists.

The mechanism of erosion control of slope is well understood. It can be shown that with a slope of 1:2, d = 4 mm & N = 45, it can be deduced that storage S is 0.437 litres/m^2 (Sanyal T, 2006). The pre-condition of the theoretical deduction is that JGT should be perfectly drapable. The storage capacity of JGT is further enhanced due to jute's inherent capability to absorb water even to the extent of 450% of its dry weight. Taking 450% as JGT's capacity to absorb water, the additional storage amounts to 4.50 times the dry weight of JGT, when an open weave JGT of 500 gsm is installed, this would mean an additional storage . of 4.50 times, 500 i.e. 2250 gms / sqm of water or 2.25 litres / sqm. That means the total volume of water that can be stored overland by JGT stands theoretically at (0.437 +2.25) litres per sqm or 2.687 litres per sqm when slope is 1:2, diameter of weft yarns is 4 mm and there are 45 yarns per sqm in the weft direction (Sanyal T, 2006).

JGT therefore can claim to possess the highest capacity of water storage leading all other geosynthetics. And when storage of water on overland is high, there are less chances of soil erosion for understandable reasons.

Studies carried out by Ingold and Thomson (1990) indicate that JGT installed in sandy loam soil on 1:2 slope reduced the soil loss to about 1.3 g mm^{-1} compared to 8.8 g mm^{-1} from control. With a growth of dense vegetative cover JGT can protect 99.0 to 99.9 percent soil loss with a "C" factor of .001 to 0.01 (Ingold and Thomson, 1990). Fifield *et-al (1988)* reported a yield factor (ratio of soil loss from soil covered by an erosion control system to soil loss from bare soil) of as high as 0.3, whereas after about one year with the establishment of good grass cover a value of 0.01 was recommended. Tests carried out by Ingold and Thomson further confirmed that JGT can significantly reduce the rain splash detachment of surficial soil. JGT checks soil erosion by absorbing the impact of kinetic energy of falling rain drops, arresting the downward flow of the dislodged soil particles with its 3 D structure and reducing surface run-off.

5.0 Field Application of Jute Geotextile

For the past several years IJIRA (Indian Jute Industries' Research Association) with the support of JMDC (Jute Manufactures Development Council) had conducted a considerable number of field applications with success. One such recent application in National Highway with results are highlighted below :-

Location

A Portion of NH-2 from Varanasi to Kanpur passes through Allahabad city. In order to avoid the traffic congestion of the city as well as to ensure faster movement of vehicular traffic through the National Highway - a diversion road was constructed which is known as NH-2 Allahabad By-Pass. This by-pass starts from Handia passes through Saraon and connects NH-2 after crossing River Ganga. Total length of NH-2 By pass is 82 Km.

Physical Condition of Road

NH-2 By-Pass is constructed with its road cess consisting silty-clay soil. Height of embankment in some stretches of road ranges from 10 m to 12 m. Embankment fills are finished in 1:2 slopes. As the embankment heights are appreciably high the denuded slopes were subjected to rain splash erosion with formation of rain-cuts and gullies due to surface run-off. Soil samples were collected from two sites of road and the soil reports are furnished below:

Site - I

Silt & clay	=	80% to 85%
Sand	=	10% to 15%
d_{50} of soil	=	0.033 mm
Liquid Limit	=	33%
Plastic Limit	=	20%
Plastic Index	=	13%

Site- -II

Gravel	=	1.64%
Sand	=	9.62%
Silt	=	4.00%
Clay	=	88.60%
d_{50} of soil	=	0.033 mm
Angle of internal friction of soil	=	29°
Liquid Limit	=	27%
Plastic Limit	=	16%
Plastic Index	=	11%

Surface preparation & laying JGT

The rain cuts and gullies were corrected to proper shape and level after filling in good soil followed by light compaction with wooden mallets.

Open weave JGT (Type-2; Table -1) of 500 g/m^2 was placed on the prepared shoulder beyond the road kerb to the slope and then it was rolled down on the embankment slope to cover the entire slope area. The JGT fabric was anchored properly on the soil surface. An overlapping of 100 mm at sides and 150 mm at the end was provided in the JGT fabric. 'U' shaped pins and wooden pegs were fixed on the JGT to ensure proper anchoring of the fabric on the slope.

6.0 Result of remedial measures:

After laying JGT on the slope, a thin layer of good soil (Av. thickness 25 mm) was laid on the slope and shoulder. Grass seeds were spread uniformly on the prepared slope surface before the rainy season. Sprouting of the vegetation started within 2-3 weeks on the moist soil surface. The fibrous root system of grass took care of the slope soil and the whole area was fully stabilized within one year of laying JGT. Photographs on application are given in annexure. It may be observed that the whole area was fully covered with dense vegetation.

Fig. 1 : Preparation of slope before laying JGT

Fig. 2 : Sprouting of grass through JGT

Fig. 3 : Slope treated with JGT fully covered with vegetation after six months.

7.0 CONCLUSION

Appropriately designed JGT laid on the shoulder and along the slope helped retain the soil particles and prevented detachment of soil particles from the prepared slope. Establishment of vegetation ensured stabilization of the soil on the slope surface. JGT, a bio-degradable natural geotextile, can conveniently be used for controlling surface soil erosion and help growth of vegetation as a bio-engineering measure. JGT after biodegradation coalesces with the soil and adds nutrient to it and fosters growth of vegetation. The project is being monitored objectively since January 2006 and no sign of distress has been noticed till date.

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REFERENCES :

i) Thomson, J.C. and Ingold, T. S. (1986), "Use of Jute Fabrics in Erosion Control", Report of the International Trade Centre, UNCTAD/GATT.

ii) Rickson, R. J. (1988), "The use of Jute Geotextiles in Soil Erosion Control" Proc. Fifth Int. soil Consolidation Conf., Bankok, Vol. V, 627-633.

iii) Thomson, J.C (1988), "The role of natural fibres in Geotextile Engineering" Proc. FIGC-Bombay.

iv) Fifield, J. S.; Malnor, L.K.; Ritcher, B and Dezman, L.E. (1988), "Field testing erosion control products to control sediment", Proc. 19th IECA Conf.

v) Ingold, T.S. and Thomson, J.C. (1990), "A design approach for performed erosion control systems," Proc. 4th Int. Conf. on Geotextiles, Geomembranes and related Products, Den Hang: 375-380.

vi) Rao (Prof.) G V (1995) "Erosion control with geosynthetics" - CBIP, New Delhi Publication.

vii) Juyal, G. P. and Dadhwal, K. S. (1996) Geo-jute for erosion control with special reference to mine spoil rehabilitation.

viii) Rickson, R. J. and Loveday, A.D. (1998) - "Jute Geotextiles, Techno - Economic Manual".

ix) Howell J H ; Sandhu S. C. ; Vyas N ; Sheikh R & Rana S. S. (2006) "Introducing Bio-Engineering to the Road Network of Himachal Pradesh". Published in - Journal of the Indian Road Congress, Vol. 67-3

x) Sanyal, T. (2006), "Jute Gotextile in erosion control & strengthening of sub-grades - Two case studies" Proc. IGS-CBIP, New Delhi, Publication No. 298, 2006. pp 206-215.

xi) Goswami D. N; Choudhury P. K. & Sanyal. T. (2008) - "Erosion Control of Hill Slopes of Koldam Hydel Power Project - A Case Study". Proc. National Seminar on Geo-technique in Present Development Scenario org. by Geotechnical Study Circle, Kolkata

GEO JUTE FOR EROSION CONTROL WITH SPECIAL REFERENCE TO MINESPOIL REHABILITATION

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ABSTRACT

Geotextiles have been used effectively for erosion control works and other civil engineering applications in the USA and Europe, Natural geotextiles e.g. geojute has been experimented in India also as a bioengineering measure for slope stabilization and river bank erosion control and the results are encouraging. Geojute - a heavy Woven jute mesh, helps in establishment of vegetation by protecting seeds and plants and conserving soil and moisture for growth. At CSWCRTI, Dehradun, geojute has been successfully tried to revegetate the highly erodible steep mine spoil slopes at Sahasradhara. However, care should be taken that the geotextiles are to be used at sites which are geotechnically stable with fast growing and locally adapted grasses.

Geotextile is a woven/non woven knitted structure of natural / synthetic textile fibres used various geotechnical, civil engineering and soil conservation applications. Geotextiles in the form of nets, meshes or mats have been used extensively for slope stabilization and erosion control in the USA and European countries but their use in India is not so popular. They may be broadly classified as natural or synthetic geotextiles depending upon the material of their composition. Geojute and coir nets are the commonly used biodegradeable natural geotextiles, whereas geotextiles made from synthetic polymer materials are the permanent and not biodegradeable.

In the application of geotextiles for erosion control purpose, consideration for short term and long term may be taken into account. Short term protection is given solely by the geotextile material to the soil surface, whereas long term protection is afforded by vegetation. Fifield et al. (1988) reported a yield factor (ratio of soil loss from soil protected by an erosion control system to soil loss from bare soil) of ashigh as 0.3, whereas about one year later with the establishment of dense vegetative cover a value of 0.01 was recommended. In case, long term soil protection is afforded by vegetation cover alone, biodegradable nets and meshes, usually derived from natural fibres (e.g. jute, coir, sisal etc.) are used to provide short term protection. In situations where vegetation cover alone is inadequate or cannot be ensured for long period of time and high velocity overland flow is anticipated, synthetic root reinforcing mats might be employed.

There is a good potential for natural geomats for protection of vast areas under erosion from water and wind by revegetating them, such as cut slopes along roads, railways and runways, minespoils, barren hills, terrace riser slopes, forest wastelands and sand dunes etc. In India and other developing countries, use of natural geotextiles may be preferred as they are less expensive, available from local resources and are environmental friendly due to their biodegradability.

Application of Geotextiles in India

In India application of geotextiles for erosion control is in infant stage and experiments are being carried out in different part of the country. Some of the ‘studies in India and other countries are reported as below :

Experiments conducted by Central Soil and Water Conservation Research and Training Institute (CSWCRTI), Dehradun showed that geojute mat can be successfully used for stabilizing and revegetating the highly erodible minespoils in the steeply sloping mountainous region of the Himalaya (Juyal.et.al. 1991)

In a joint project by Indian Jute Industries, Research Association (IJIRA) and Central Road Research Institute (CRRI), Geojute application was found successfully in checking erosion and establishment of grass cover on a steep hill slope (slope angle 50° - 60°) along the road in sandy loam soil and embankment (slope angle 45°) to a new bridge (loamy sand soil). Similar studies conducted for stabilizing hill slope of Darjeeling and Siliguri districts of West Bengal showed positive results. Slope angle was 60° and soil was silty clay mixed with gravels. *Saccharum munja* (munj) a deep rooted hardy grass was used for vegetating (Ghosh etal. 1993)

An indegenous bitumen coated jute mattress was used successfully for bank protection works in Nayachara island on the Hooghly estuary in the state of West Bengal (Sanyal & Chakraborty, 1993).

Revegetation with geojute effectively controlled erosion in a flood protection embankment constructed to protect Dhaka city in Bangladesh (Shahid, 1994)

A specially developed jute revetments filter was used to control bank erosion along river Hooghly at Haldia by Calcutta Port Trust (Sivaramakrishnan, 1994).

Other natural geotextiles, such as coir and sisal mats have also been used for erosion control works (Pillai, 1994) reported the use and technique of the application of coir geotextile. Oosthuizen and Kruger, (1994) have made in depth studies on the properties of sisal (Agavesislana) as geotextile for erosion control in South Africa and reported its satisfactory performance.

Natural Geotextiles for Erosion Control

The purpose of natural geotextile is to protect and support the natural enviroment for a limited time span. The task is complete when nature, through soil and vegetation, eventually provides adequate protection. The natural geotextile, therefore, provides temporary" aid for the establishment of natural vegetation used as long term erosion control. Thus it acts as a bio-engineering or engineered agronomic system for erosion control i.e. engineering and vegetative measures used in conjunction with each other to fulfill the ultimate goal of erosion controls.

Geojute for erosion control

Jute geotextile has been the most popular used one for erosion control purposes. It has been in use since fifties when it was developed and exported to Europe and USA in the name of Soil Saver or Geojute. Geojute is a structuremade of jute fibres woven into a heavy open mesh. It was mainly used for protecting newly cut slopes from erosion through growth of vegetation. Geojute has good tensile strength, is flexible, easy to install and biodegradable and is thus environment friendly. Geojute is normally available in rolls of 1.22m width and 70m length. The open mesh size of geojute netmay be 16mm x 22 mm or as per the requirement of the application site.

Table 1. *List of geojute suppliers*

M/s. Hasting Mill,

Jute Divi.of Share Digvijay Cement Co. Ltd.,

14, NetajiSubhas Road, Calcutta - 700 001

M/s. Hooghly Mill Co. Ltd.
10, Clive Row,Calcutta - 700 001
M/s. The Naffarchandra Jute Mills Co. Ltd.
2, Cooper Lane, Calcutta - 700 001

M/s. Ludlow Jute Mills
(Prop: Aekta Ltd.)
6, Little Russell Street, Calcutta - 700 071

M/s. Clive Fabrics Ltd.
22, Strand Road, Calcutta - 700 001

M/s. The Naihati Jute Mills Co. Ltd.
7, Hare Street, Calcutta - 700 001

M/s. Murlidhar Ratan Lai
15B, Hemant Basu Sarani, Calcutta - 700 001

Source :
M/s. Jute Manufacturers Deve.Council,
Ministry of Textiles, Govt, of India,
3A Park Plaza, 71 Park Street, Calcutta - 700 016

A list of some of the geojute suppliers in India is given in table 1.

Mechanism of Erosion Control

The netting structure of the geojute provides innumerable miniature check dams in the flow of runoff which trap fine soil particles arid a part of runoff, thereby improving sbil moisture status. The heavy strands of jute absorb the impact of falling rain drops and check splash erosion. The open mesh provides protection to seeds and plants sown from washing away by runoff. The jute mat also functions as a mulch to maintain humidity and regulates temperature for proper seed germination. Thus, geojute creates improved micro-environment for the growth of vegetation and biodegrades in due course (maximum 2 years) adding some organic matter to the soil.

Soil and Water Conservation

Soil and water conservation aspects of geojute are described as under:

Erosion control : Ingold and Thomson (1990) carried out studies on the erosion control characteristics of different geotextiles in sandy loam soil on 1:2 slope and found that geojute reduced the soil loss to about 1.3g mm^{-1} of runoff compared to 8.8 g mm^{-1} from control. The mean erodibility for syntheticmat was found to be about 5 g mm^{-1} (Fig 1). Rickman (1988) reported the soil loss in geojute as 14 per cent of the control. With a growth of good grass cover the protection efficiency of geojute can be in the range of 99.0 to 99.9 per cent with a crop factor of 0.001 to 0.01 (Ingold and Thomson, 1990). Tests carried out by them further showed that natural fibre net such as geojute significantly reduces the splash erosion by rain drop impact.

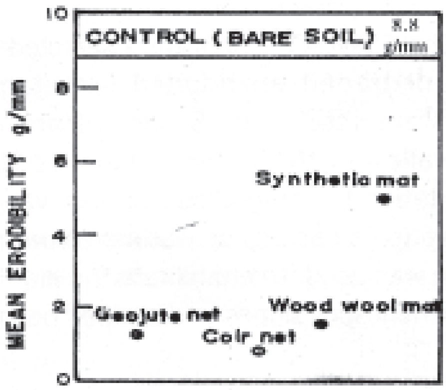

Fig. Measured erodibilities for a sandy loam (After ingold and Thumason, 1990)

Runoff control : Geojute strands absorb much of the runoff and ponded water within the miniature check dams its strands provide (about 4-6 times its dry weight). The good absorbency of geojute has much to do with its runoff control ability. Once jute absorbs water to capacity, its flexibility is increased approximately 25 per cent thereby improving its drapability, i.e. its ability to maintain intimate soil contact which further helps in reducing erosion. Ingold and Thomson (1990) reported that the runoff with application of jute net is reduced to about 15 per cent compared to 42 per cent in the control. The runoff in synthetic mat was more than that in the control **(Fig.2).**

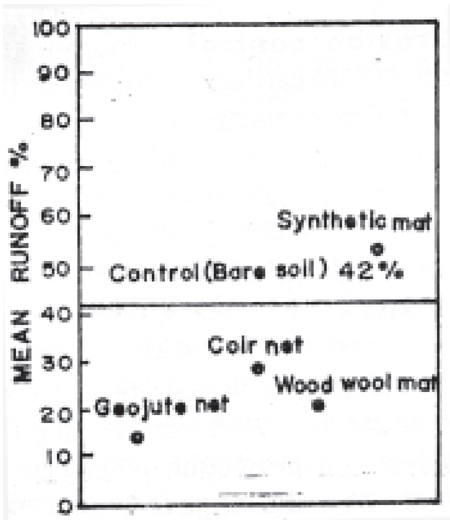

Fig. Measured runoffs for a sandy loam (After ingold and Thomson, 1990)

Rehabilitation of Mine spoil at Sahastradhara

The CSWCRTI, Dehradun selected a highly degraded abandoned limestone mined watershed near Sahastradhara in Doon valley in the outer Himalayas for rehabilitation by integrated soil and water conservation measures on watershed basis. Geojute was used to rehabilitate the highly erodible minespoil slopes as described below :

Description of the watershed

Sahastradhara limestone quarry watershed, area - 64 ha, is situated in the lesser Himalayan zone of Doon valley at an altitude from 820 m - 1310 m above m.s.l. The area receives an annual rainfall of about 3000 mm 80 per cent of which is received during monsoon months (June to September). The area is characterised with weak geology of Krol belt comprising limestone, gypsum, marble, slates and dolomite, etc. The minespoil is sandy loam in texture with high gravel content. (60 per cent of the material is greater then 16 mm size), alkaline (pH-8.0), calcareous ($CaCo_3$ 61%) and poor in fertility status (Organic carbon -0.13%, Nitrogen/ 0.02% and available P_20_5-.4 kg ha^{-1} with high infiltration rate (30 cm hr^1) and poor water holding capacity (Dadhwal, 1984; Dadhwal et al. 1992). The poor fertility of the minespoil inhibits the growth of vegetation. The watershed is having an average slope of 50 per cent, at some points the slopes are exceeding even over 100 per cent.

The unscientific mining operations destroyed almost all the vegetative cover of the area comprising mixed deciduous forest species of subtropical type. This along with high rainfall and steep slopes caused heavy debris movement from the watershed, leading to frequent vehicular disruption, entailing, a huge recurring maintenance cost of Rs. 0.1 million annually. The siltation of the river downstream led to frequent floods in monsoon destroying agricultural and other forest lands.

Geojute for minespoil rehabilitation

Surface mining operations result in a huge quantity of over burden. The over burden to mineral ratio being as high as 5:1. Mineral rejects and overburden piled up at places in the watershed were highly erodible and difficult to vegetate due to absence of top soil and poor fertility. Geojute was tried to give temporary protection to these slopes and help protect the vegetation till it establishes. The specifications of the geojute used were : grade - 500 g/m^2, strand thickness - 5mm and open area - 65 per cent. Different slopes (30-70%) covering an area of 0.86 ha were treated. Besides geojute, synthetic geotextiles like netlon (CE -131) and geocell were also experimented for their performance.

Application technique

Seeds of suitable tree species *(Acacia catechu, Leucaenaleucocephala etc.),* were spread on the area and scarified. Grass mulch locally available was spread @ 2-3 t ha^{-1} Geojute was spread on the area loosely. The two adjoining widths were overlapped by about 10 cm and fastened with jute threads. Wooden sticks were driven to hold the mesh at place. Rooted slips of grasses like Saccharum spontaneum (kans) and Thysanolaena maxima (broom grass) and cuttings / root slips/rhizomes of *Ipomoea carnea, Vitex negundo, Arundo donax* and hybrid napier were planted in openings between strands at close spacings. The technique for application of geojute is shown in **Fig. 3.**

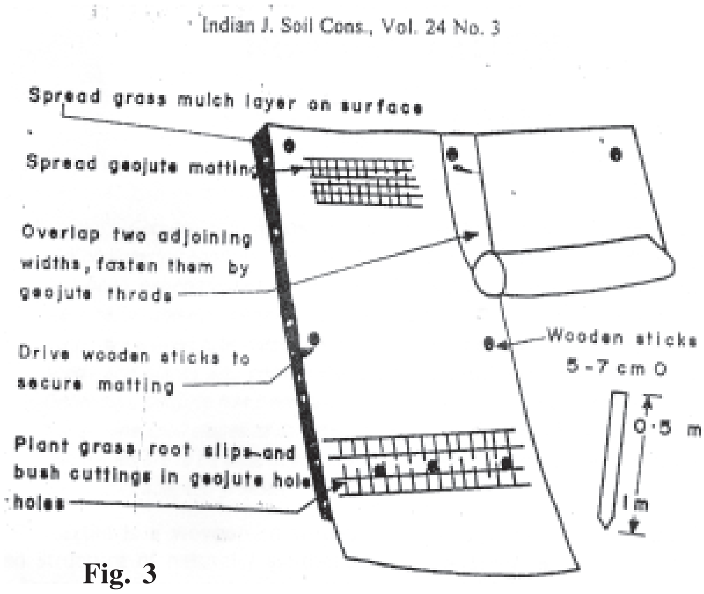

Fig. 3

Vegetation establishment

In the geojute area there was good establishment of grasses compared to control. *Thysanolaena maxima* grass recorded an yield of 3052 kg ha^{1} (oven dry) compared to 640 Kg ha^{-1} in control after 3 years of plantation. Hybrid napier when planted in contour trenches filled with good soil mixed with farm yard manure (FYM) recorded an excellent yield of 9850 Kg ha^{1} compared to 1960 Kg ha^{1} in control. *Saccharum spontaneum* also showed good performance. The grass roots provided good anchorage to the soil in the second year of plantation itself. Survival of tree species was observed to be poor. The geojute biodegraded in about two years, by then the vegetation established itself. The vegetation establishment in the synthetic geotextiles (netlon and geocell) was poor as compared to geojute. This might be due to the adverse micro-climate created by the local heating of the synthetic material.

Moisture improvement

The geojute helped in moisture conservation by 40-50 per cent. It was observed that in the geojute area the moisture content reached below wilting point in 7 days compared to 3 days only in control after a rainfall of 20 mm (in the top 15 cm layer). In seven days period, the seeds can germinate and moisture in deeper layers can sustain the tender plants. There was still good amount of moisture below 30 cm depth after one month from the day of occurrence of 20 mm rainfall event.

Application cost

The cost of geojute application was Rs.8.00/m^2, comprising of cost of geojute, labour and plantation as shown in table - 2 (Juyal *etal.* 1991). The rates varied from $ 1.50 - 3.90/m in USA in similar situations (Goldman et al. 1986). The cost of synthetic geotextiles was Rs. 110/ m^2 and was not an economically viable proposition for soil conservation programmes.

Table 2. Estimates for geojute applicaiton for rehabilitating degraded slopes (for 1000 m^2 area)

Item	**Quantity (Rs.)**	**Rate (Rs.)**	**Amount**
Geojute matting	1100m^2	4/m^2	4400
Grass mulch	3 q	100 q-1	300
Planting material	—	-	300
Installation cost (labour etc.)	1000m^2	3/m^2	3000
			8000

Recommendations and Future Needs

- The site of application of geojute and other geotextiles should be geotechnically stable. It may not be effective on sites which experience heavy runoff or debris flow.
- Specific problem of erosion of the application site and its specific requirements must be assessed considering the function of the geojute before its application. Geojute may not be used at the sites where simple or less costly measures could work effectively.
- Proper method of installation should be followed.
- Fast growing and good soil binding grasses and shrubs adapted to local edapho-climatic conditions should be planted with geotextiles.

- Attempts should be made to improve the life of jute through chemical treatment or develop combination fabrics by blending with other fibres.
- The short term and long term conservation behaviour of the geojute application under a variety of agro-climatic conditions need to be studied in detail.
- Different user agencies like roads, railways, forest, irrigation, mining etc. should collaborate for the possible application of geojute in eco-rejuvenation.
- The present high cost of geojute and other geotextiles may prohibit their wide application for soil conservation programmes.

REFERENCES

Dadhwal, K. S. (1984) Sixty per cent of minespoil material at Sahastradhara is larger than 16 mm size. Soil Cons., Newsletter, CSWGRTI, Dehradun, India, 3 (2) : 4

Dadhwal, K. S., Singh, B. andNarain, P. (1992) Characteristics of lime stone minespoil/debris from outer Himalayas of Uttar Pradesh,Indian Forester, 118(9): 650-658

Fifield, J. S., Malnor, L K., Ritcher, B. and Dezman, L E. (1988) Field testing erosion control products to control sediment. Proc. 19th IECA Conf.

Ghosh, S. N., Chatterjee, P. K. Ghosh S. N. and Palit, S. (1993) Controlling soil erosion by geojute application. Textile Trends: 1-7.

Goldman, S. J., Jackson, K. and Bursztynsky, T. A. (1986) Erosion and Sediment Control Handbook. Mc Grow - Hill Company, New York : 6-29.

Ingold, T. S. and Thomson, J. C. (1990) A design approach for performed erosion control systems. Proc. 4th Int. conf. on Geotextiles, Geomembranes and Related Products, Den Haag : 375-380.

Juyal, G. P., Katiyar, V. S. Sastry, G, Singh G, Joshie, P. and Arya, R. K. (1991) Geojute for rehabilitation of steep mine spoil areas, Bull T-26/D-19, CSWCRTI, Dehradun.

Oosthuizen, P. and Kruger, D. (1994) The use of sisal fibre as natural geotextile to control erosion. Proc. Fifth Int. Conf. on Geotextiles, Geomembranes and Related Products, Vol.2, Singapore : 871-874.

Pillai, M. S. (1994) Protection to the side slopes of Kanini river. Proc. Fifth Int. Conf. on Geotextiles, Geomembranes and Related Products, Vol.2, Singapore : 887-889.

Rickson, R. J. (1988) The use of geotextiles in soil erosion control. Proc5th Int. Soil Cons. Conf. Bangkok, Thailand, Vol. V, : 627-633.

Sanyal, T. and Chakraborty, K (1993) Application of Jute Mattress in the bank -protection works in the Hooghly Estuary, Geotextiles and Geomembranes, Eleseveir Science Publishers Ltd., England.

Shahid, A. S, M. (1994) Geojute provides long lasting erosion control. Proc. Fifth Int. Conf. on Geotextiles, Geomembranes and Related Products, Vol.2, Singapore,: 895-898. ,

Sivaramkrishnan, R. (1994) Jute geotextiles as revetments filter for river bank protection. Proc Fifth Int. Conf. on Geotextiles, Geomembranes and Related Products Vol.2, Singapore : 899-902.

REMEDIAL CONCEPT WITH JUTE GEOTEXTILE IN A COMPLEX RIVER BANK EROSION PROBLEM

Tapobrata Sanyal

ABSTRACT

Soil stabilization by laying of an appropriate type Geotextile is an established concept. Use of treated Woven Jute Geotextile for prevention of riverbank erosion has documented records of its effectiveness. In rivers with flow-complexity, use of Woven Jute Geotextile and for that matter, any Geotextile, may not work. There is need to regulate the flow by engineering measures to attain effectiveness.

This paper discusses the hydraulic complexity in a tidal river in West Bengal, India (River Ichhamati) and present a remedial concept by concurrent use of treated Woven Jute Geotextile and appropriate engineering measures for prevention of bank-erosion.

1. INTRODUCTION

1.1 River Ichhamati in the southern part of West Bengal, India bordering Bangladesh experiences two-way flow in its lower reach. River Ichhamati, like all other rivers in the Gangetic delta, is yet to attain stability of its course due to on-going geological adjustments. Bank erosion of rivers in this region is a regular feature, especially in the post-monsoon season, due to continual flow re-orientations. Conventional graded stone filter, "porcupines", "sausages" etc. do not work in the event of flow hugging the bank and vortices and are washed away. Geotextile could be the answer if used in conjunction with appropriate engineering measures.

1.2 In this paper, a remedial concept with treated Jute Geotextile aided by appropriate engineering measures is proposed in a badly eroded river bank on the river Ichhamati.

2. CHARACTERISTIC OF RIVERS IN THE SOUTH OF WEST BENGAL

2.1 As already indicated, rivers flowing through the alluvial tracts of the Ganga-Brahmaputra delta frequently change their courses in their attempt to find die most convenient and the least resistant paths. Rivers in this region have numerous meanders on way. Meanders are cut-off when the two ends of a river veer so close to each other as to prompt the flow following a straight path instead of the circuitous one. Gradient -both longitudinal and transverse- and lithologic composition of bank-soil play a significant role in choosing the most convenient flow path by a river in such a region. Continual re-orientation of the flow-matrix in a river-region has a direct effect on bank-erosion. When the flow velocity is high and the flow hugs any of the banks, chances of bank erosion are obviously enhanced. Vortices close to the bank are also instrumental in causing erosion. In tidal reaches, salinity - intrusion creates a density gradient, may generate layered flow resulting in bed-shear.

3. FEATURES OF THE AFFECTED STRETCH OF THE RIVER ICHHAMATI

3.1 River Ichhamati is sustained in its lower reach by tidal ingress. Its upland discharge is insignificant excepting during the monsoon. The river-bed undergoes aggradation reducing its cubature and its carrying capacity.

3.2 In the tidal reach of the river, the flow matrix seldom remains uniform due to fluctuating tidal flux that changes every day due to meteorological reasons. The change in flow-pattern affects sediment-transportation within the river resulting in unpredictable patterns of accretion and erosion.

3.3 Tackling of bank-erosion, understandably, in rivers of this nature is not easy. Bank-stability cannot only be attained by the conventional filter mechanism. Additionally, there is need to divert the flow away from the banks through appropriate engineering measures like spurs.

4. LOCATION & CHARACTERISTICS OF THE AFFECTED STRETCH

4.1 An island has developed within River Ichhamati near Hasnabad, a small town in the district of 24 parganas (south), West Bengal in India. The island, popularly known as "Machhranga Dweep", raised its head nearly 50 years back as a result of continued accretion of the river bed in the area.

4.2 In fact, a no-velocity zone within the river was created due to bifurcation of flow (see fig. 1) of the river. Concurrently, the flow-paths were also changing. The flow through the channel to the north of the island was less than that through the channel to its south. The situation has reversed at present with the channel to the north of the island carries the dominant flow. This is one of the prime reasons of the severe erosion at the northern end of the island. Erodability of the silty deposits on the island fails to resist the erosivity of the flow caused due to its tendency to hug the bank of the island in this area. Vortices were however not noticed. The maximum flow velocity in affected area is of the order of 3 metre/sec.

4.3 Evidences reveal that the rate of erosion is of the order of 5 metres/year. Fluctuations in tidal levels are in the range of 4 to 5 metres which vary everyday due to tidal variation. The river in the reach experiences semi-diurnal tides.

4.4 Geotechnical investigations reveal that the soil composition is dominantly clayey silt upto a depth 5 to 6 metres and sandy silt between 6 to 19 metres and silty sand beyond 19 metres.

4.5 Flow-angles vary during ebbs and tides as the two flows never follow the same path which is a normal feature in tidal rivers.

5. REMEDIAL APPROACH

5.1 It is now generally established that stabilization of river-bank soil can be attained normally within 2 season cycles in case of rivers with unidirectional flow and 4 season cycles with flow reversals when Geotextile is used over a prepared river bank (Sanyal 1992, Sanyal & Chakravarty 1994). The field trial in the estuary of the river Hugli (off the docks at Haldia) at Nayachar island has corroborated this notion under a far more severe hydraulic situation, Geotextile - both man-made and natural - can help stabilize the bank soil by performing the basic functions of separation, filtration & drainage. But if the source of the problem remains unattended, Geotextile cannot be effective singly. Concurrent engineering measures are to be taken to divert the flow away from the affected bank. This can be done by construction of repelling spurs which, besides eliminating the chances of vortices, will repel the flow away from the banks. This will help the bank treated with Geotextile attain a near state of equilibrium with tidal fluctuations as the only variant.

5.2 The success of Nayachara-experiment stated above has prompted to make use of woven

Jute Geotextile in commensurate with the average particle size distribution of the bank soil (to be done more precisely later) and its permeability. The woven JGT will be treated with a natural additive (developed at IJIRA) which would ensure its effective life upto 5 years. This is a better alternative to bituminizing the fabric as was done in the case of Nayachara field trial because of the following reasons -

— drapability of raw JGT will not be affected

— degradation of the fabric will be delayed

— cost of the treated fabric will be less

— growth of vegetative cover over the fabric and the overlying armour will not be affected.

5.3 Spurs are proposed to be built of sausages filled with bricks and weighing not less then 50 kg individually. Armouring over JGT will also be done with the same material. The reason of using brick-sausages is to reduce the cost as bricks are made locally and far less costly than stone boulders.

5.4 Two types of spurs with trapezoidal sections are proposed. The first type (1.5 m top/ 10.3m bottom x 2.5 m ht) will be used at internals of 40 metres along the 500 metre long eroded bank-stretch. Spurs will be of a length of 16 metres to be placed at right angles to the flow direction. The second type of spur (2m top /16m bottom x 4m ht) will be built at the nose of the island which experiences continuous thrust of flow from opposing directions. This will be placed tangentially at the nose of the island with suitable orientation.

5.5 Concurrently. Woven Jute Geotextile of the appropriate variety commensurate with the average grain size distribution of the bank soil and soil permeability should be laid on the affected bank after grading and preparing it to a geotechnically stable slope. The treated slope should be overlain by a layer of armour made of crated bricks weighing at least 50 kg individually. The roughness of the brick armour will induce siltation shortly. Attempt may be made to plant suitable mangrove species that usually thrive in estuarine waters having varying salinity. Expert advice may be taken regarding selection of mangrove species.

6. CONCLUSION

Under normal flow-conditions of a river i.e. where the flow is not very close to the bank, laying of the right type of Geotextile overlain by armour should work. The eroded bank has to be prepared to a geotechnically stable slope before the chosen Geotextile is laid. In case of hydraulic complexity, where flow is perilouslyclose to the river bank with or without vortices specially in two-way rivers, concurrent engineering measures need be adopted. Erosional problems can be treated effectively with Jute Geotextile provided the eroded area is allowed to remain in a state of equilibrium within an acceptable range.

ACKNOWLEDGEMENT

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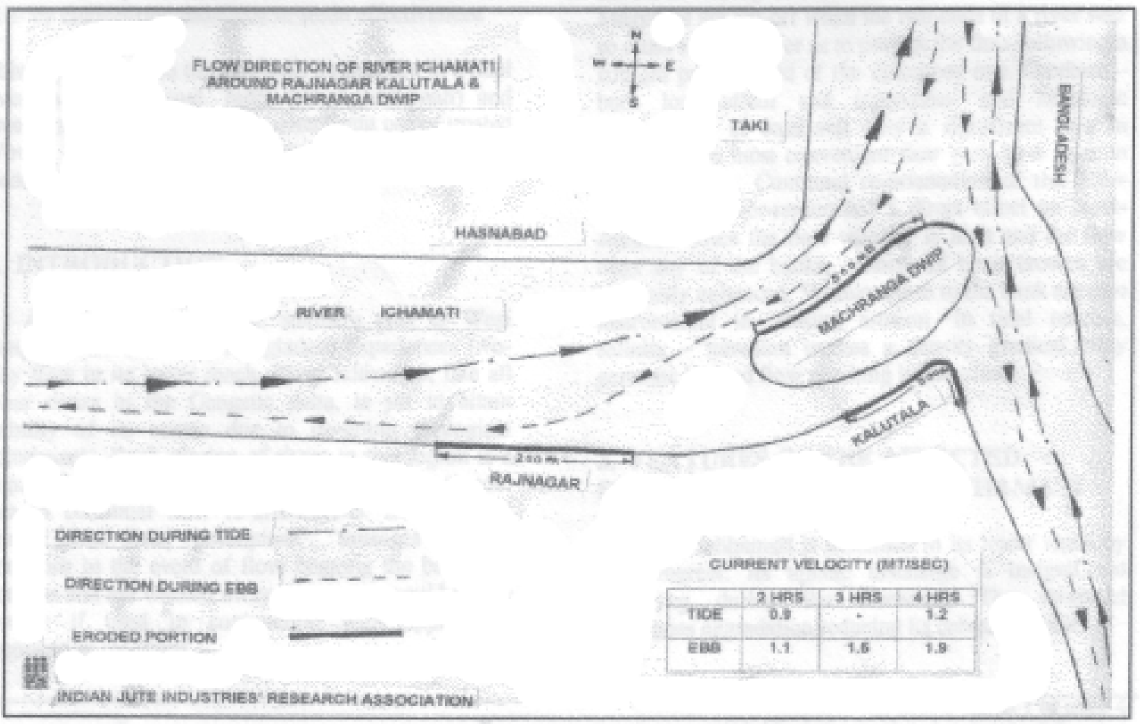
REFERENCE

Sanyal, T. (1992) - A Pilot Project in Nayachar Island in the River Hugh, CBIP, Jan. New Delhi, pp. 131-137.

Sanyal, T. and Chakraborty, K. (1994) - Performance evaluation of Geotextile - An Indicator of its Viability in the River Training Measures in the Hooghly Estuary, Proc. 59th R&D Session CBIP, Vol. 2, pp. 93-96.

Bank Erosion of River Ichamati at Machranga Island



SCHEMATIC DIAGRAM OF RIVER ICCHAMATI AT THE AFFECTED REACH (not to scale)

CONTROL OF BANK EROSION NATURALLY - A PILOT PROJECT IN NAYACHARA ISLAND IN THE RIVER HUGLI & APPRAISAL OF PERFORMANCE

Tapobrata Sanyal

SYNOPSIS

Conventional methods of bank protection tried in the erosion-prone stretches of the Hugli-estuary have proved to be a highly costly proposition in respect of both capital investment and recurring maintenance costs. Cost of indigenous geosynthetics is still too high to admit its wider use. It is for this reason and with a view to improving the ambient ecology, Calcutta Port Trust under the control of the author, has embarked upon a pilot scheme using geojute in place of geosynthetics with mangroves planted in the inter-spaces for protection of eroding banks of Nayachara Island in the Hugli esturary. The primary results are encouraging. The article delineates measures adopted and the situation on date hinting at future trials in this direction.

1. INTRODUCTION

Erosive activities of the river Hugli, the tidal stretch of the holy river Ganga in India, have been for long a subject of study and research by the hydrologists. Enigmatic behaviour of the river destroys land mass in one place and builds up new areas elsewhere through a continuous process of siltation and erosion, accretion and scouring. Nayachara Island is one such land mass which has grown out of accretion of alluvial deposits in the midst of the river Hugli over the years. Located 21 nautical miles from the face of Bay of Bengal, the island plays a significant role in so far as navigability of the shipping route to the Ports of Calcutta and Haldia are concerned. The land mass divides the flow of the river into two channels -Haldia and Rangafalla - on either side of it (Figure 1). The usual route of ships to Calcutta Dock System and Haldia Dock Complex is along Haldia Channel which is fast deteriorating on account of spatial advancement of Jiggerkhali flat inside the channel. Calcutta Port Trust has almost completed a massive 2.8 kilometers long guide wall springing from the north of the island primarily to divert some of the flux during ebbs. Recessional dredging of Jiggerkhali flat which is designed to scoop out about 6 million cubic meters of river-spoil also is on the cards. Meanwhile, a deep gutter has developed running close to the western side of the guide wall and then hugging the western face to the island after a diagonal turn. This development coupled with effects of waves included by wind & ships results in erosion of the western bank of the island up to a stretch of 2 kilometres from the north. The extent of erosion is about 150 metres in the course of the last 7 years. For obvious reasons, the erosion has to be contained to retain the configuration of the western back - line of the island to reap the effects of the guide wall and dredging. Conventional methods of river training measures like construction of spurs (Figure 2) and revetment with laterite boulders underlain by geotextiles have been tried.

All these measures seems to be too costly needing huge capital investment. It is for this reason and with a view to improving the ambient ecology, a pilot scheme of protection of the eroding bank of the island through natural means with geojute was undertaken one and a half year back. The results of the experiment arc encouraging. The article delineates measure adopted and the situation on the date besides hinting at future trials in this direction.

2. Other Features of Bank Erosion

Delta-building activities of the river still continues though at a slower rale. This is one of the reasons why the hydraulic characteristics of the river Hugli and, for that matter, the group of anastamotic rivers that spreadeagle the southern part of West Bengal in India and Bangladesh are prone to changes.

The multiplicity of variable parameters that influence the sediment transportation characteristics and the flow-pattern of the river Hugli in its estuarine reaches makes precise prognosis of its behaviour difficult or perhaps impossible. The oscillation of the seaward boundary, unknown variation of diffusion characteristics, frequent variations of wave energy due to change in the speed and direction of winds, uncertain characteristics of waves induced by ships, Coriolis forces, littoral drift, varying salinity intrusion and above all the persistent imbalance between the unsteady upland discharge and the varying tidal propagation characteristics are factors which can never be fully controlled. That is why, the approach to control of erosion in the river banks of this estuary has to be exploratory in nature.

The erosive activities in this region are not also uniform throughout the year. Erosion is most pronounced just after the freshets when the upland discharge is its peak, especially in the months of August and September. Prefreshet season i.e., from March to May has the predominance of nor westers. Bank erosion at high levels during the period is caused due to wind-induced waves. Prefreshet season from November to February is the period of normalcy when the erosive activities cease & accretion starts and continues.

3. Geohydrological Data

Tides	-	semi diurnal with periodicity of 12.42 hrs.
	-	Average flood period - 5 hrs. Average ebb period - 7.42 hrs.
Tidal Range	-	Maximum spring - 6.25 metres.
	-	Minimum neap - 0.71 metre
Current	-	Peak velocity in spring - 3.0 metres / second
Wind	-	Mid-April to mid-September - strong south westerly winds.
	-	March to May - Nor'westers reaching up to 9 in Beaufort Scale.
Wave	-	Wind generated waves - maximum 1.6 metres high.
	-	Periodicity - 6 to 8 seconds.

4. General Composition of Bank Soil

The tests undertaken by Hydraulic Study Department of Calcutta Port Trust reveal the following soil - composition of the bank soil of the island :

Sample No.	Depth	Med. Sand 2-0.425 mm %	Fine 0.425-0.075 mm %	Silt 0.075<0.002 mm %	Clay <0.002 mm %
1	3	-	0.50	65.50	34.0
2	6	-	0.30	61.70	38.0
3	9	0.32	50.80	48.88	-

Organic matter-content ranges from 0.5% to 2%. Soil reaction varies between acidic and alkaline subject to seasonal variation. Salinity usually ranges from 6 ppt. during freshets to 18 ppt. in the post-freshet season.

5. Approach to Control of Erosion

Approach to control of erosion should be three-pronged :

a) Preventing migration of soil particles from the bank.

b) Providing escape-routes to the confined water to neutralise the differential overpressure.

c) Entrapping silt through extraneous contrivances.

Geosynthetics have proven records of efficacy in performing functions as in (a) & (b). Geojute, a fibre made entirely from jute smeared with resistant chemicals, has been tried for this purpose in the eroding bank of the island over an area of 3000 sq'. m. in a vulnerable stretch of the island.

Regarding the function in (c), conventional hollow contrivances like bamboo cages with bricks fixed on to them, concrete hexapods etc. are in general use all over the country. Extensive mangrove-vegetation over geojute may provide a pragmatic substitute form economical and environmental considerations. Trial in this direction has just been given in this region. Results will be made known in due course.

6. Why Jute Geotextiles ?

The advantages of jute geotextiles are :

(i) Being biodegradable it decomposes to add rich organic nutrients to the soil, promoting rapid growth of vegetation.

(ii) Environmentally safe and congenial, being a natural produce.

(iii) Economical. Jute grows in abundance in West Bengal of Tndia and Bangladesh.

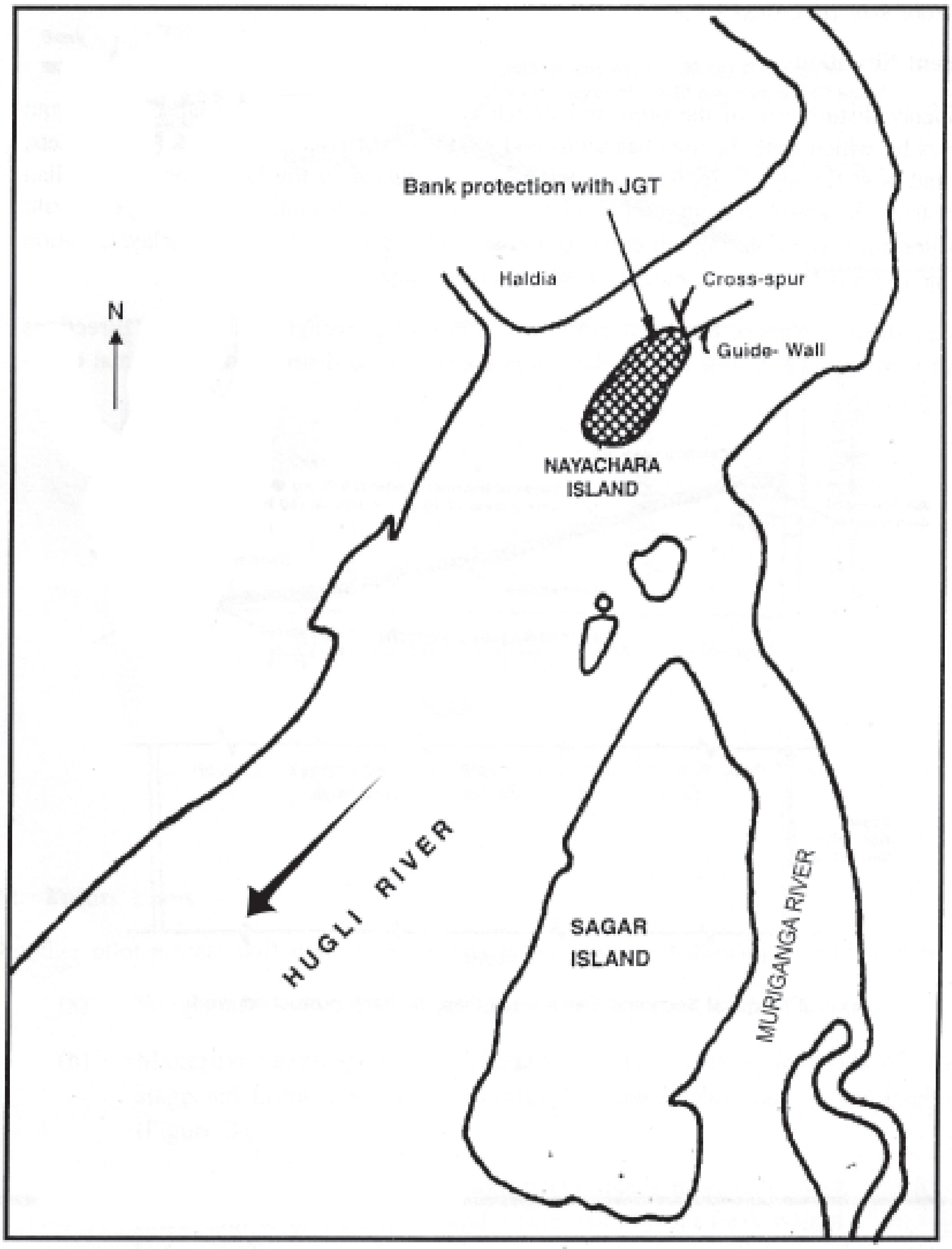
Rot-resistant chemical lias been smeared over geojute in this trial to defer degradation of the naturallfibre by about 3/4 years by which time mangroves will grow sufficiently and attain strength to dissipate wave-energy and to induce siltation.

7. How Mangroves Function ?

Mangroves (Mangals) thrive naturally in brackish water in places alternated by wetting during high tides and drying during ebbs at a regular periodicity. These features made mangroves ideally suited to banks in estuarine reaches in rivers for their growth. Mangroves have special characteristics ingrained in them for their survival and growth in coastal and estuarine reaches. The growth of mangroves is dependent on various parameters like inter-tidal reach, substratum salinity of soil and water inundation period etc. The prop or knee roots can certainly entrap slit while sediment laden water flows through. It has been found on some trial that mangroves can dissipate wave-energy in rivers by about 40%.

8. Provision of the Instant Pilot Scheme

The pilot scheme envisages laying of jute geotextiles in the portion shown in Figure 2, topped by a dry revetment of laterite boulders - 800 kg/m.sq. (individual weight of boulders - 10 kg. to 30 kg) after cutting the bank to a slope of 1:5. The scheme was completed in the month of April, 1990 and the stretch has been under close observation since then.



NOT TO SCALE

KEY MAP

Figure 1

9. Specifications of jute geotextiles Used

Material - Bitumenised jute fabric (Base fabric - D.W. Twill - 28" , 8 x 12 - 850 g/m.sq.) Bitumen application (both sides) - 80% on the weight of fabric.

1. Total weight gm/sq.m - 1538
2. Thickness (mm) at 100 g/cm.sq. - 2.83
3. Breaking strength (kgf)
   (strip - 20 cm x 5 cm)
   Warp - 168.8 (33.08 kN/m)
   Weft - 143.8 (28.21 kN/m)
4. Elongation at break (%)
   Warp - 11.8
   Weft - 13.5
5. Puncture resistance (Kgf/Sq.cm). - 37.9
6. Air permeability ($m^3/m^2/min.$) - 16.2
7. Water permeability at 10 cm Water column ($l/m^2/sec.$) - 20.4
8. Pore size (microns) - 150

10. Present Situation

No subsidence/disturbance of the protected stretch has been noticed after a lapse of one and a half years by which time the area has withstood effects of different flowcycles (pre-freshets, freshets and post freshets). Jute geotextiles samples have been tested in the laboratories of Indian Jute Industries' Research Association (IJIRA), Calcutta, though undisturbed samples could not be collected after removing silt-covered and silt-bonded heavy boulder-overlay. Siltation over the period has been to the extent of 50 cm on average.

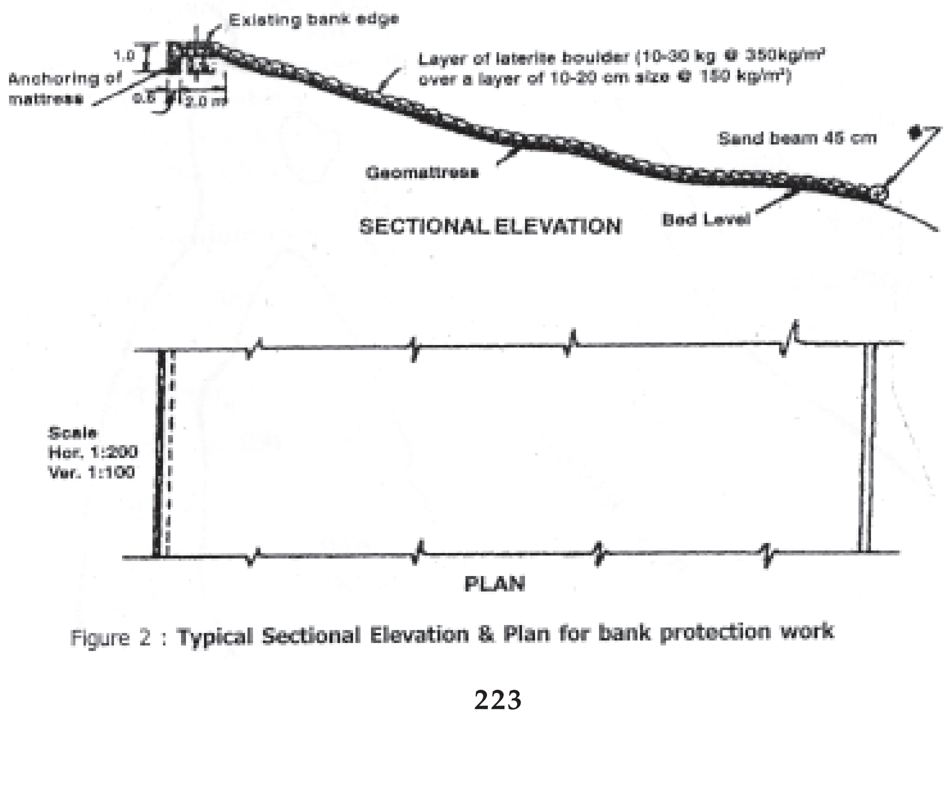


Figure 2 : **Typical Sectional Elevation & Plan for bank protection work**

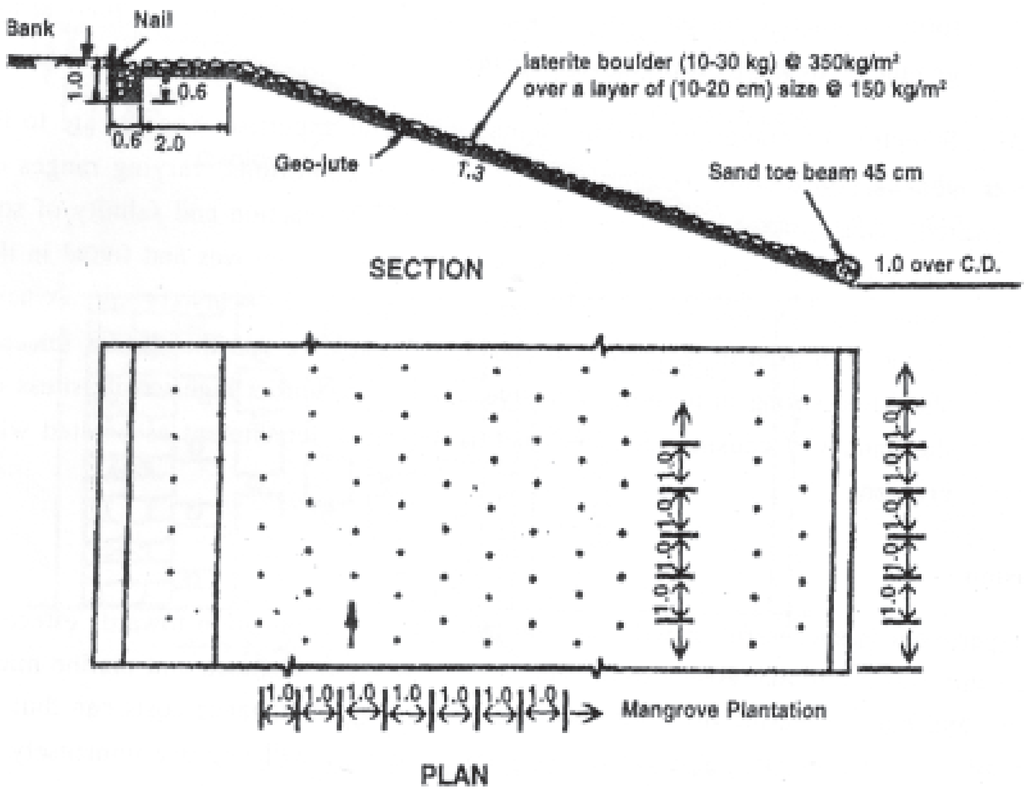


Figure 3 : **Typical Sectional Elevation & Plan for bank protection & mangrove plantation (Boulder type)**

Test results show that there has been reduction in breaking strength in both the directions (warp and weft) by about 70% though there was seemingly no distress and functional debility in the geojute.

11. Future Plans

Another pilot project will start from December, 91 with the following modified provisions:

(a) Weight of overlay will be reduced to 500 kg/m.sq. from 800 kg/m.sq.

(b) Mangrove seedlings will be planted simultaneously at intervals of 1 m in a staggered fashion cutting holes through jute geotextiles fabric laid on the bank slopes (Figure 3).

(c) A small portion will be tried with pocket made in jute geotextiles fabric which will be filled with local earth/river sand. This will account for a weight of approx. 350 kg/m.sq. (Figure 4). Passages in between pockets will be used for mangrove plantation. If the experiment is successful, the high cost of boulder overlay can be eliminated. Jute geotextiles will have a cover of earth. It is admitted that there are certain limitations to this plan but the experiment is worth-trying specially considering the economy such modified measures can effect.

(d) Another portion will be tried with treated second hand gunny bags filled with local earth mixed with *5%* of cement as a substitute of laterite overlay (Figure 5.)

12. Constraints

(i) As mangroves take 3/4 years to gain in strength, jute geotextiles must be able to perform

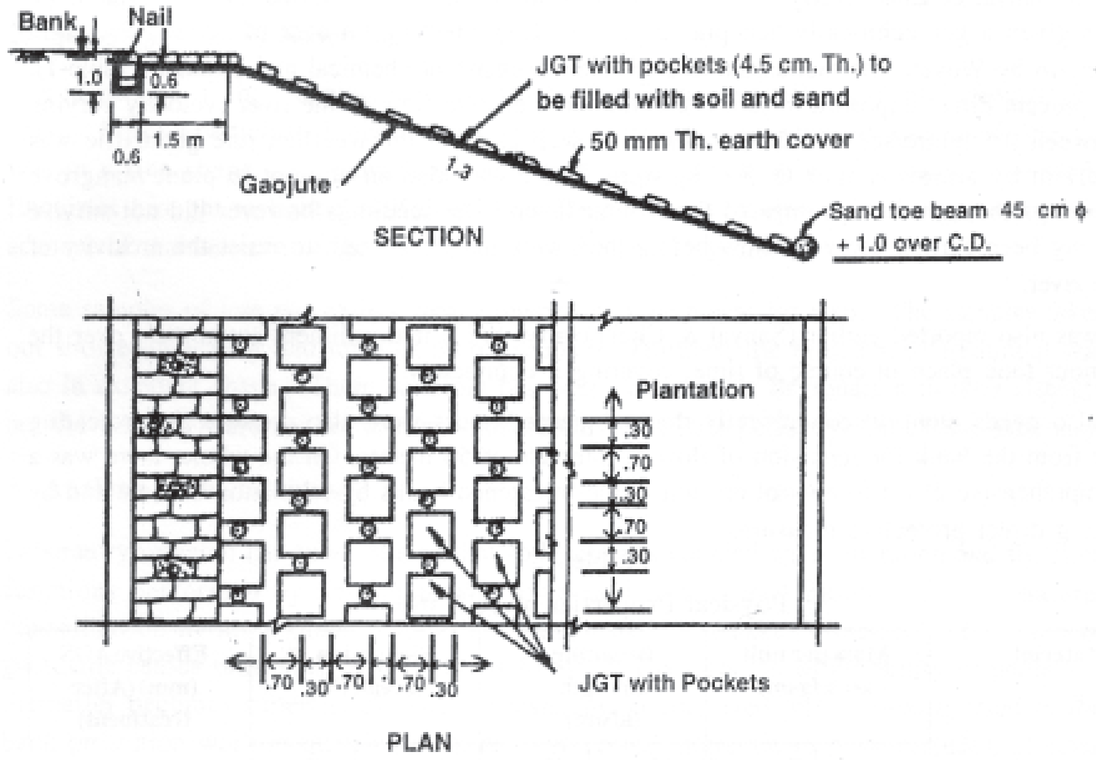


Figure 4 : Typical Sectional Elevation & Plan for bank protection & mangrove plantation (JGT with pocket type)

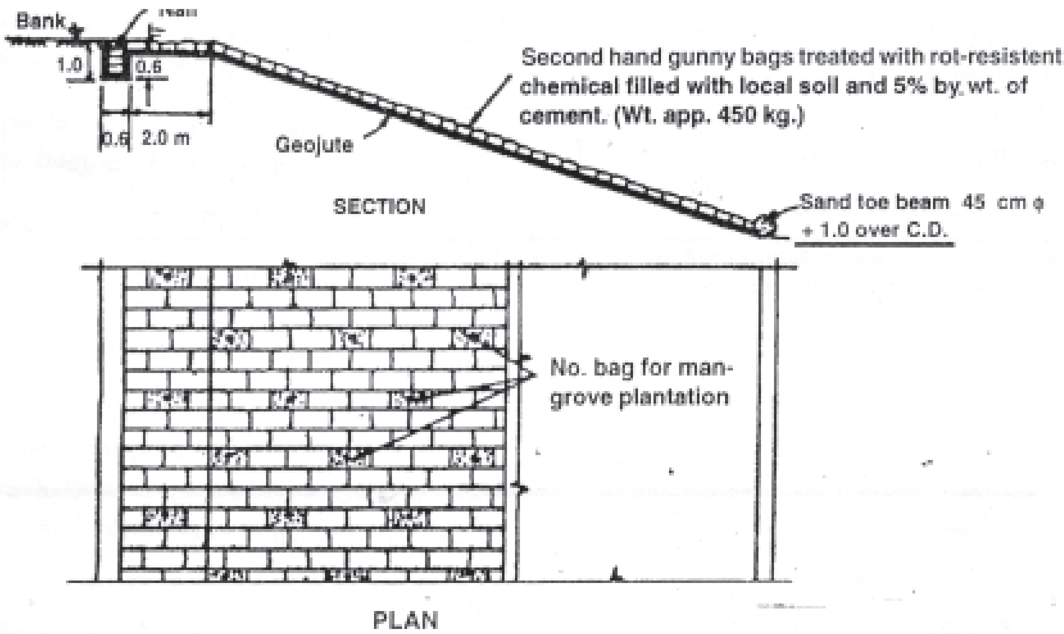


Figure 5 : Typical Sectional Elevation & Plan for bank protection & mangrove plantation (Gunny bag type)

its function for the same period. Efficacy of rot-resistant chemicals in the geojute to defer its degradation is being observed.

(ii) Selection of mangrove species demands special expertise. Species are to be chosen considering its adaptability to the soil conditions, varying ranges of inundation during tides, changing degrees of soil reaction and salinity of soil and water. Though there arc about 64 species of mangroves and found in the 'Sundarban's which have grown spontaneously over the years, I 1 species have so far been tried- in Nayachara Island. It is imperative that the species selected should be strong in tension as erosive actions may inflict high tensile stress on the bank soil causing cleavages before physical detachment associated with erosion.

CONCLUSION

If the experiment is successful, it will open up new areas of application towards effective erosion control at a minimal cost. Besides, mangroves will attract fauna and marine micro organisms and nurture marine life. Not only huge recurring maintenance costs can thus be substantially curtailed or even eliminated, the ambient ecology will improve immensely.

ACKNOWLEDGEMENT

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RIVER BANK PROTECTION WITH GEOJUTE : AN EFFICIENT COST EFFECTIVE METHOD

B. C. Chattopadhayay
(Ms) S Chakravarty

Geojutes currently being used in river bank protection works as erosion control measures in different parts of the world. Some of the case histories exemplifying effective, economic and ecofriendly applications ofgeojute to solve different geotechnical problems in India and abroad are highlighted. The design approach involving jute fabric for purposes of erosion control is presented. The suitability of jute geotextile in this arena as can be adjudged the merits depiciting its usage and also inferred from its performance at various application sites in India is extremely satisfactory. Hence, the future of geojute does seem very strong for continued growth in this sphere, merely by extending the present state-of-the art.

Keywords : Erosion Control; Geojute; Uniformity Coefficient; Apparent Opening Size; Linear Coefficient of Uniformity.

NOTATION :

d_n	:	Particle size corresponding to natural soil grading curve.
d^1_n	:	particle size correspoding to recon-structed linear soil grading curve.
d_{50}	:	grain size of the soil corresponding to which 50% by weight is finer.
k_g	:	coefficient of permeability of the geotextile filter.
K_s	:	permeability coefficient of the soil.
O_{95}	:	apparent maximum opening size (AOS) which 5% or less by weight passes through the fabric.
t_g	:	thickness of the geotextile.
U	:	conventional coefficient of unifor-mity as obtained from the 'S' shaped curve and defined as, $U = {}^{d}{}_{60}/d_{10}$
U^1	:	linear coefficient of uniformity as obtained from the reconstructed particle size distribution curve and given by, $U^1=d^1{}_{60}/d^1{}_{10}$

INTRODUCTION

Geotextiles are being progressively used in different branches of subsurface engineering works. Such application of geotextiles are not only making construction possible in many difficult situations, but also resulting in efficient, less time consuming and cost effective constructions. Thus, with the increasing relevance of geotextile in civil engineering, it is imperative to disseminate the prevailing knowledge in this area, along with the broader perspective of exchange of notions, to foster need-based research and co-ordinate developmental efforts. With this objective, the design trends relating to river bank protection using geojute, leading to a cheaper, quicker and efficient methods is presented in this paper.

The problem of bank protection is acute in many countries of the world. Wide-spread and indiscriminate activities to sustain the global population, causes soil erosion from the top surface of natural earth or from manmade surfaces. Breaching of bunds,'over long stretches and erosion of river banks along the courses, are recurring events which not only produce inundation and hinders agriculture, but poses a threat even to human and wild lives, and creates a situation where a lion's share of the hard pressed budget is consumed for the repetitive and expensive repairing works to rectify damages.

Geojute has been recommended as a pioneering material for erosion control purposes where it has established itself convincingly as a superior agent. For surface erosion control geojute has been and is being used in advanced countries for a long time, e.g., works at UK(1920)[1], Burma (1955)[2], Colorado (1970)[3], Ohio (1991)[3], Mississippi (1987)[3], Alabama(1988)[4], Switzerland(1988)[4], Singapore, Malaysia, Indo-nesia (1989)[5], etc are only some of them. The major factor of erosion stems from water related actions. The process is initiated by the impact of rain drops, which detaches soil particles on hitting the bare surface and simultaneously the flowing water transports them. The jute fabric is being widely used in recent decades in developing countries to mitigate both the surface soil erosion as well as that due to moving water body[6-12].

Consequence of Geojute Placement

Geojute, a coarse, natural fibre of jute has an open mesh structure. It generally consists of heavy, woven jute matting made from 100% jute yarn. The design, physico-chemical characteristics and other unique features of the Jute fabric are operative in moderating the major components accompanying the erosion phenomenon. A bevy of new jute geotextiles have already been fabricated by the Indian Jute Industries' Re-search Association (IJIRA)[13] to suit different geotechnological usage. These have been successfully implemented in Assam, Barrackpore, Darjeeling, Digha, Kanpur, Siliguri among several other places. These fabrics in several varieties are available from different mills located in and around Calcutta. In all applications cited, geojute performs the function of separation, filtration, drainage and erosion control as the situation may demand.

The functions of geojute in case of river bank protection are mainly that filtration and separation. As a filter, it arrests the migration of fine particles by water current of the freely flowing water which otherwise scours the soil from beneath the bank , making it unstable. Further, to absorb the wave actions, a suitable armour is built with boulders or brick Block, over the geojute laid on the bank. Boulders are thus separated from the soft soil, preventing them from going into the soil by the jute fabric, till it consolidates to take the load of the boulders. The geojute acts as a catalyst in developing a natural graded filter (Fig. 1) by interaction with the soil bed. In conven-tional practice, a thick mineral filter requiring bulk of material belonging to different grades, usually consuming lots of money as well as time for proper placement is generally resorted to.

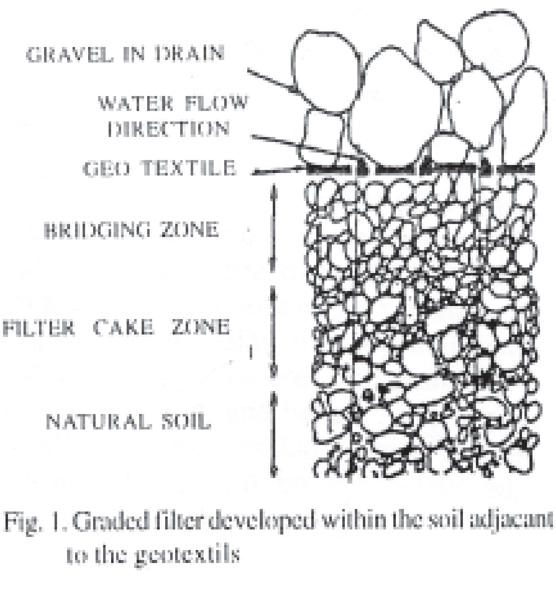


Fig. 1. Graded filter developed within the soil adjacent to the geotextils

Criteria for 'Filter Cake' Formation

The following serve as necessary pre-requisites for the formation of the 'filter cake' :-

Pore size distribution.

It is feasible to obtain a geotextile, the apparent opening size of which is compatible with the soil particle size distribution. If the pores are too large, uncontrolled soil piping may ensue leading to internal erosion and suffusion. If the pores are slightly too small, then there will be insufficient initial $_t$wash of fines, to promote the aforesaid formation rapidly. While if the pores are even smaller, the geotextiles will be prone to the risks of severe blinding, blocking and clogging with time.

Permeability

The permiability of the geotextile should be adequate to cope with the discharge of the fluid from the soil. Hence the coefficient of permeability should be of an order which would be sufficient to ensure that generation of excessive hydrostatic pressure is avoided.

Geojute-Edge Over Conventional Norms

Traditional methods of controlling erosion is to shield the soil particles from the moving water with a flexible protective structure. A mineral filter is introduced between the soil to be protected and a top layer of rip-rap or stones or concrete or brick blocks of pre-designed weights. Though each of these different forms have their practical utility, there'are quite a few disadvantages allied with their adoption, some of which are :

- large quantity of material of different grades,
- infiltration of underlying materials,
- scour causing damage to the toe of rip-rap,
- mineral filter are many times thicker than the geojute layer, by a factor of around 100,
- failures cannot be prevented even when light weight concrete blocks are used,
- long term degradation of the exposed sections of gabion mattresses due to ultraviolet light,
- difficulty in controlling the quality of construction,
- problems involving transportation of the huge quantity of raw materials,
- high cost,
- long time of construction,
- may not always be possible to adopt these techniques in emergency.

The use of geojute filter can simply construction of the erosion control measures where it replaces several layers of granular filter beneath the rip-rap armour stones. It can be used in similar manner below gabion mattresses or articulated concrete blocks. Application of geojute has certain advantages, a few of which are discussed here:

- proven performance of the desired functions as compared to available alternatives,
- improvement in quality control,
- case of handling , transporting and storing of jute rolls/bales.
- economy in cost,
- lesser time of construction,
- amenable for swift installation,
- ecofriendly, congenial, reliable and renewable resource, being a natural, biodegradable product.

Design Parameters for Geo Jute

Specification

A suitable geotextile should be chosen after analysing the following aspects.

Soil retention : To restrain a soil particle of diameter d, it has been suggested that significant pore space opening of geotextile, taken as 0_{95}, should be slightly smaller than the size d. The particle size dis-tribution curve of the base soil obtained from the grain size analysis is generally a S-shaped one. In reality, the very finest and the coarsest particles are only small fractions of the whole, and hence, have negligible effect on the filtration process. So the original curve could be reconstructed, idealising it to a linear one (Fig. 2).

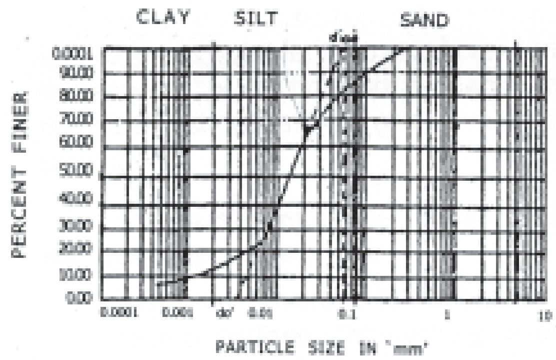
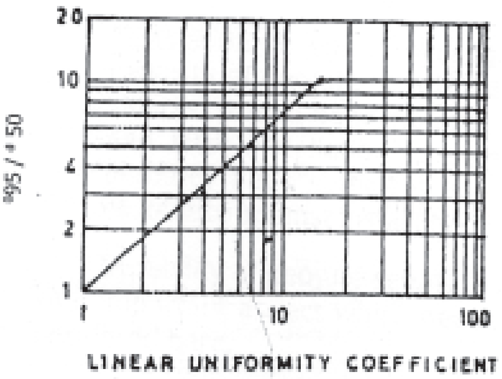


Fig. 2. Linear reconstruction of soil particle size distribution.

The central straight portion is then extrapolated and used to determine the lin-ear coefficient of uniformity which under this new condition is denoted be U^1 as against the conventional U. To retain the soil particle of $d^1_{60}/$, it can then be shown that $O_{95} = (U)^{0.2}\, d_{50}/$. The concept of providing restraint to soil particles with size d_{95} or larger is generally adopted. This leads to the design chart for different values of U^1 (Fig 3). However, 0_{95} value soil should not be greater than 200 mm for soils composed of more than 50% silt with little or no cohesion present.



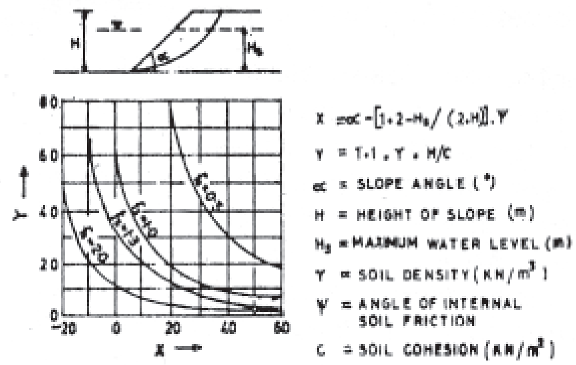


Fig. 4. Slope stability as a function of slope geometry and soil shear strength

Fig. 3. Design chart based on positive retention

Hydraulic requirements : Co-efficient of permeability of the geotextile filter (kg), should be lighter than that of the soil, k_s^{15}. The permeability requirement has been developed as :

$k_g > (t_g.k_s)/5d_{50}$. But since permeability of the soil is influenced by several factors, it is suggested that, $k_g > 100k_s$.

Survivability : To guard against the desired properties being impaired by the construction process, it is necessary to specify a geotextile with mechanical properties, namely, puncturing, tearing resistance and tensile strength, which make it hardy enough to withstand the installation process. This is so because perfomations may result which are several times larger than the pore size assumed for design. Again , an obvious by product here is the potential damage caused by slurry which may blind the pores of the geotextile, thus reducing its permeability, which may leave it useless as a filter. All these can be minimised by a balanced selection of a construction process, fill material and the robustness of a geotextile as indicated by the minimum threshold values of required mechanical properties.

Bank and bed geometry / geotechnical failure mechanisms : These are the ones associated with the global and the local stability. Generally the slope height and the slope angle govern the calculations (Fig. 4).

Nature of vessels plying the waterway : This needs to be taken into account as they are responsible for creating waves of various magnitudes and frequencies.

Revetment uplift : The geotextile uplift may be prevented by ensuring a suitable cover such that the downward force from this surpasses the upgrade force due to water pressure beneath the geotextile.

Rip-rap : This should be designed against the dynamic forces generated from waves as done by conventional method for break waters.

Soil loss limitations : The aim of any erosion control system is to restrict soil loss to an acceptable, tolerable level during the service life of the system. Hence, this component should also be given overall consideration.

Properties of geojute essential in the current context are :

- Adequate coverage to the erosion affected surface, thus aiding in augmenting vegetative growth
- Drapability with the surface contour
- Water absorbency to reduce the run .off velocity
- Exhibit sufficient tensile strength and
- Resist substantial amount of dynamic installation stresses.
- Geojute has been found to possess the above mentioned properties for its use in this application.
- Standard geojute has a coverage ranging from 30% to 60%,
- Drapability of geojute is very high and increases by 25% when wet,
- Jute can absorb water to the extent of more than five times its own weight,
- Woven geojute has a tensile strength ranging from 7kN/m to 22kN/m which is sufficient here, and Tests at BE College to investigate the capacity of geojute to withstand developed due to handling both during and after installation revealed that geojutes have sufficient amount of resistance against installation impact.

Durability of geojute seems to be another important aspect which needs to be considered here.

Geojute are completely biodegradable and their biodegradability has been questioned while adopting them. However, what is less realised perhaps is that it is this particular property which imparts the greatest positive aspect for effective geojute utilisation. This degradation may be retarded by giving the jute fabrics necessary chemical treatment which may impart some sort of resistance to geojute against microbial attacks. For example, rot resistant bitumen treated geojute has been successfully adopted for river bank protection purposes. In this aforementioned application, the long term durability and strength loss on ageing of geojute is insignificant as the function of geojute here is limited to the formation of the 'filter cake', Once this natural filter is formed (which usually requires one season during which the geojute does not decay) it matters less whether the geojute stays in its place or decomposes. What assumes importance here is the choice of the geojute and its compatibility with the soil to be saved with respect to the factors already discussed. A chart for this proper selection of geojute for different field conditions has been prepared for ready guidance of end users (Manual for use of jute geotextiles for civil engineering applications).

Notable Applications

Before proceeding further, it seems pertinent to discuss two special circumstances under which geojute has been ef-fectively utilized for river bank protection.[16]

In the first case, water may be freely flowing as in rivers and canals, when it tries to abrade soil particles from the banks. Both the velocity and the volume of flowing wa-ter may fluctuate from a very high value during the rainy season to a lesser one at summer. Here, with increasing severity of flow conditions, susceptibility to erosion also rises.

In the second case, water may flow through a permeable soil stratum and at the exit point, may erode the soil particles. Similar condition may occur in case of barrier to flow, like in earth dams or in canals where the existing groundwater table is at an elevation higher than the top water level in the canal. The situation may become even more alarming when the canal is dry. The canal lining will then be subjected to high bursting stresses and the soil below it may give way and be eroded. Subsequently, due to lack of support, concrete blocks at the sides would slide down causing more soil from there to spill over the canal section, filling it fully or partially.

In both the above cases, the bank soil can be dressed with geojute to check such occurrences (Fig.5).

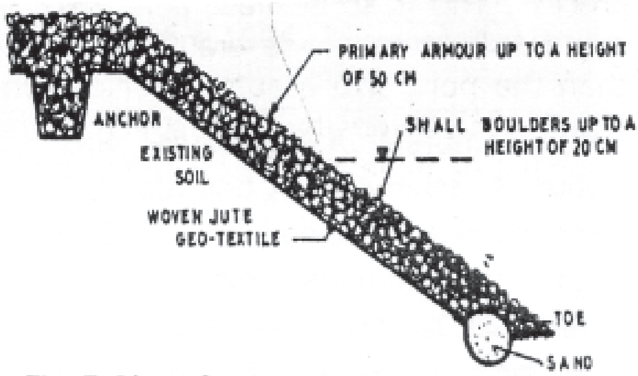


Fig. 5. Plan of revetment with jute geotextile

Some such applications of geojute[17] under similar situations, which deserve mention are the works completed at the follow-ing places:

- Nayachar, in Midnapore, where 1.5 km length of the bank of River Hooghly was treated with jute geotextile to protect it from an erosion rate of 20 m per year[18].
- Hasanpore, in Murshidabad, where a stretch of 50m of the right bank of the River Padma was protected with jute filter.
- Ramayanpur and Bhaluka, in Maldah, where the embankment on the River Phulahar was saved from a vulnerable state by using jute fabric over a stretch of 400 m.
- Bangladesh, where a 24 km long flood protection embankment was erected and jute geotextile laid to prevent the slopes against erosion[19].

DISCUSSION

The exercise would remain incomplete without incorporating the economic benefits derived from bank protection works involving geojute. The jute geotextile priced at Rs. 40/m^2 of the material[20] is cost effective compared to that of mineral filter. Fur-ther the freight charges along with the labour cost is much higher in the latter case where both the proportion and the control assumes significance. However, the control is still affected as gradation maintenance becomes difficult to achieve in cases of emergency and even otherwise, and hence quality is hampered. Besides, there is possibility of material pilferage and irrespective of all these, the performance of the mineral filter may not fulfil expectations. Against this tedious, meticulous job stands out the easy installation process to be followed with geojute application engaging unskilled, cheap labour with very little or no quality control required to be catered to. Thus, judging from all respects, geojute application for river bank protection does seem to be quite appropriate in the present context.

REFERENCES :

1. J.R. Bell, et al, 'Construction and Analysis of a Fabric Reinforced Embankment.' Proc Int. Conf on Use of Fabrics in Geotechnics, Paris 1977.
2. W.J. Slim. 'Defeat Into Victory' War Memories, World II, 1995.
3. ITC, 'Jute Market Promotion Project', UNCTAD/GATT,1985.
4. J.N. Mondal, 'Geotextiles In India' in 'Geosynthetics World', Wiley Eastern Ltd., New Delhi, 1994.
5. S.L. Lee, S.D. Ramaswamy, M.A. Aziz, N Dasgupta and G.P. Karunaratne. 'Fibredrain for Consolidation of Soft Soils'. Proc. Post Vienna Conf. On Geotextiles, Singapore, 1987.
6. T. Sanyal and K Chakraborty, 'Appli-cation of a Jute Mattress in the bank Protection Works in the Hooghly Estuary;. Geotextile & Geomembrane, vol.13, 1994.
7. G.P Juyal, G. Sastry and M S R M Rao. 'Rehabilitation of a Mined Area in Himalayas by Geojute and Other Measures'. Proc 5th Int Conf of Geotextiles, Geomembrances & Related Products, vol. 2, Singapore, 1994.
8. M.R Talukdar, A.K. Maiumdar, CR Debnath and A. Majumdar. 'A study of Jute and Polypropylene Needle Punched Non Woven Fabrics for Geotextiles.' Proc. 1st IGC On Reinforced Soil & Geotextiles, Bombay, 1988.
9. J.N. Mondal and SY Mhaiskar. 'Application of jute Geocell for Low Cost Embankments and Pavement Construction on Soft Soil', Symp on Biocomposites & Blends based on jute &Allied fibres, New Delhi, 1994.
10. A. Azeem and A AN 'Erosion and Con-trol Techniques for slopes of Banks and Cuttings'. Proc IGC, vol.1. Calcutta, 1992

11. HJ Howell, EJ Clark, J.C. Lawrence and I Sunwar. Vegetations structures for stabilising Highway Slopes, a Manual for Nepal'. UK-Nepal Eastern Region Interim Project on Maintenance & Rehabilitation, Nepal, 1995.
12. 'Proc Nat, Sem, on Jute Based Geotextiles', CRRI, NEW DELHI, 1996.
13. U Dutta, P. K. Chatterjee and K Jayachandran 'Jute Geotextiles—a Scope for Entrepreneurs', Proc Work-shop on Jute Geotextiles, Guwahati, 1997.
14. N.W.M. John 'Geotextiles', Blackie, Glasgow & London 1987.
15. J.P. Giroud 'Review of Geotextile Filter Criterion', Proc 1st IGC on Reinforced Soil & Geotextiles, Bombay, 1988.
16. B. C. Chattopadhyay, 'Application of Geoiute-Two Special Cases', Proc Workshop on Jute Geotextiles, Calcutta, 1997.
17. U. Dutta, P. K. Chatterjee, S.N. Ghosh, B.C. Chattopadhyay and A. Ghosh, 'Jute Geotextiles for River Bank Protection'.. Proc Nat Sem on Jute Based Geotextiles, New Delhi, 1996.
18. T. Sanyal, 'Control of Bank Erosion Naturally', Proc Nat Workshop on Role of Geosynthetics in Water Resources, New Delhi, 1992.
19. A.S.M. Shahid 'Geojute Provides Long Lasting Erosion Control'. Proc 5 th Int. Conf. on Geotextiles, Geomembrances &Related Products, vol. 2, Singapore, 1994.
20. B C Chattopadhyay. 'Ground Improvement With Natural Fibres. 'Summer School on Ground Improvement Technology, B E College, Howrah, 1997.

JUTE GEOTEXTILE IN EROSION CONTROL & STRENGTHENING OF SUB-GRADES - TWO CASE STUDIES

Tapobrata Sanyal

ABSTRACT

Jute-based geosynthetics is finding increasing acceptability among geotechnical engineers primarily because of its eco-concordance, facility of production of tailor-made fabrics and price-competitiveness. However, civil engineers are still apprehensive about its long-term effectiveness on account of its bio-degradability. The paper points out that long life of geosynthetics is not a technical necessity in view of the fact that time taken by a given type of soil to consolidate optimally is barely 6 to 7 months in the laboratory. A FS of 4 to 5 is considered adequate for attaining the condition in different types of soil under different loading parameters. The paper also discusses the mechanism of erosion control on surface and in the riverbanks followed by a case study in a river in West Bengal. In another case study on strengthening of sub-grade in a road also in West Bengal, the mechanism of functioning of Jute Geotextile has been discussed. Both the case studies confirm suitability of Jute Geotextile in such applications.

1. INTRODUCTION

Two aspects that often elude attention of geotechnical engineers who recommend and use geosynthetics for improved soil-performance are —

- geosynthetics act as change agents of the soil on or in which they are laid
- consolidation is a time-dependent process.

On the first aspect the common perception is that the fabric has to stay on or in soil during the entire period of the expected life of the structure. This idea has given rise to the requirement of long durability of the fabric. But in reality the situation is a bit different. The improved soil performance of the soil is brought about by the efficiency of the geosynthetics to function as filter and drainage medium in the initial stages for a limited period. Under extraneous loads, both the pore water and the top layer of the soil are forced out of their positions. With the right porometry and tensile strength of the fabric, the soil layer remains in position and the pore water is drained along and across it, helping the soil to consolidate naturally. Separation and initial strength of the geosynthetics obviously play an important role. The consolidated soil due to expulsion of water primarily exhibits improved bearing capacity. Time taken for natural consolidation of soil depends on its characteristics and also on the nature,extent and sustenance of the external loads. Laboratory studies have revealed that usually 6/7 months are needed to maximize soil consolidation with woven Jute Geotextile (Ramaswamy-1989). Considering the probable variation in soil composition and the extent of loads, a factor of safety of 4 or 5 is considered sufficient on the basis of field inputs. In other words, a period of two or three season cycles is deemed adequate to maximize consolidation of soil. Durability of geosynthetics beyond three years is therefore technically redundant.

In regard to the second aspect, it has been observed that consolidation, being basically riddance of pore water from soil, depends not only on the extent of load that is principally dynamic, but also on its sustenance. Applied stresses are converted to effective stresses when pore water is totally expelled from soil. This conversion depends, besides the applied stress, on soil compressibility and the affected soil volume. Understandably soil consolidation may continue for several years and with the passage of time becomes gradually less dependent on geosynthetics. This phenomenon has been corroborated by case studies.

We present in this paper two field applications- one on erosion control and the other on strengthening of road sub-grade- done with Jute Geotextile, the natural variant of geosynthetics made of fibres of jute, that corroborate our perception as stated hereinbefore.

2. Mechanism of Erosion Control with Geosynthetics

Three types of erosion are controlled by application of geosynthetics in general. These are—

- soil erosion on ground surface
- soil erosion in slopes of embankments, granular heaps etc
- soil erosion on river banks.

The first type is not given the importance it deserves. It results in denudation of soil bereaving it of the vegetation that holds it. In fact this is more aptly soil conservation and is an integral part of watershed management. Detached soil particles after erosion are transported to drainage channels, mostly rivers, by overland flow. Incapacitated rivers fail to transport these soil particles that get deposited on the riverbeds. Rivers as a result lose their capacity if accretion continues unabated on bed. This happens to be one of the major reasons of flood. The remedy lies in creating a vegetative cover on ground. Geosynthetics made of natural fibres like jute can immensely help not only in creation of greens but at the same time can control detachment of soil particles on bare ground caused due to impact of precipitation and confine them within the fabric grids. The worth of Jute Geotextile (JGT) in creation of vegetation is well established. On bio-degradation open weave JGT adds nutrients to the soil, though at micro-levels, exerts mulching effects on the denuded ground, attenuates extremes of temperature and reduces the velocity of surface run-off acting as micro-barriers due its three dimensional structure.

One feature of open weave JGT deserves special mention. JGT has the unique property to absorb water up to nearly five times its dry weight. This characteristic of jute helps in effecting storage. When soil is less permeable and precipitation is heavy, soil erosion, especially in slopes, can somewhat be controlled by overland storage and prevention of detachment of soil only. The situation calls for proper selection of the JGT-type as well as species of vegetation.

The mechanism of control of soil erosion in slopes is no different from what was indicated above. The mechanism will be better understood through the following mathematical representation.

The figure represents a cross-section of an embankment slope inclined at an angle β^o to the horizontal. 'd' is the diameter of the weft yarns of the open weave JGT while 'l' represents the base of the storage triangle on the slope. It is assumed that surface run-off will get hindered by the weft yarns and will take the shape of a triangle.

$$\text{Storage 'S'} = \tfrac{1}{2} \times l \times d - \tfrac{1}{2} \times \pi \times d^2 \times \tfrac{1}{4}$$

$$= \frac{4 \times l \times d - \pi \times d^2}{8}$$

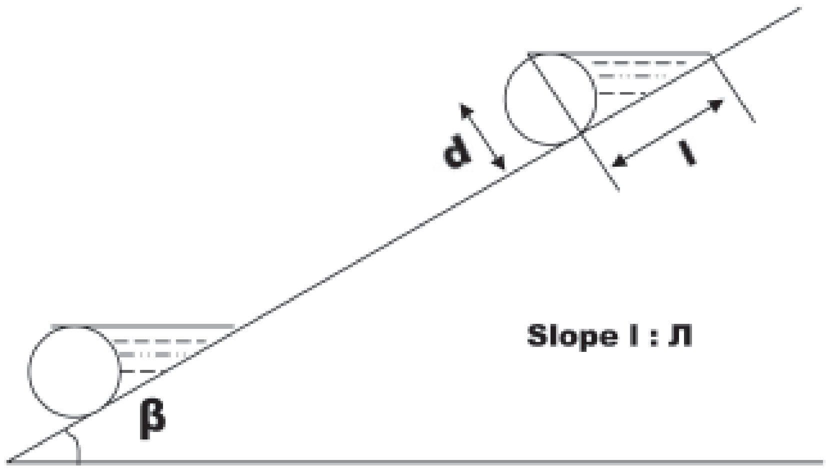


Fig : I. Storage by OW JGT on slope

For N wefts/meter,

$$S = \frac{N \times (4 \times l \times d - \pi \times d^2)}{8}$$

Substituting l = d x cot β

$$S = \frac{N \times (4 \times d^2 \cot \beta - \pi \times d^2)}{8}$$

or, $$\frac{N \times d^2 (4 \cot \beta - \pi)\ 10^3\ mm^3 / m^2}{8}$$

Taking cot β as 'n' i.e. with slope as 1: n (1 vertical to 'n' horizontal units)

$$S = \frac{N \times d^2\ (4n - \pi)\ 10^3\ mm^3 / m^2}{8}$$

With a slope of 1:2, d= 4 mm & N=45, it can be deduced that **storage S is 0.437 litres/m².**

The pre-condition of the theoretical deduction is that JGT should be perfectly drapable. This is possible as JGT is the most drapable of all geosynthetics especially when it is wet (Report of Thomson & Ingold –1986- prepared for International Trade Centre).

The storage capacity of JGT is further enhanced due to jute's inherent capability to absorb water even to the extent of 485% of its dry weight. It is assumed that 450% is the capacity of dry JGT to absorb water. When an open weave JGT of 500 gsm is installed, this would mean an additional storage of 4.50 times 500 i.e. 2250 gms / sqm of water or 2.25 litres / sqm. In other words, the total volume of water that can be stored overland by JGT stands theoretically at (0.437 +2.25) litres per sqm or 2.687 litres per sqm when slope is 1:2, diameter of weft yarns is 4 mm and there are 45 yarns per sqm in the weft direction. JGT therefore can claim to possess the highest capacity of water storage leading all other geosynthetics. And when storage of water on overland is high, there are less chances of soil erosion for understandable reasons.

Erosion of riverbanks has much to do with the type of the bank soil as well as fluctuation in water level. Bank erosion is caused as a result of :

- penetration of water into the bank soil and generation of pore water pressure therein and
- outward thrust exerted by the pore-water after the water level recedes.

When the bank is full to the brim, pore water does not have any chance to come out due to the counter pressure exerted by the river water striking a balance. Only when the level of water drops in the river, the balance is disquieted giving the entrapped pore water to force its way out. The remedy lies in allowing the pore water to come out without dislocation of the bank soil. This is essentially the filtration function that geosynthetics are supposed to perform. It is necessary to decide on the right pore size of the fabric that is capable of preventing migration of the most of the soil particles on the one hand and allowing water to penetrate along and across them. The two functions being of contrasting nature, porometry of the fabric requires to be decided judiciously. Empirical relations do exist for this purpose for man-made geosynthetics, but for jute-based geosynthetics there is need to consider absence of smoothness of its yarns along with the hygroscopic character of jute.

Bank soil is eroded also as a result of waves induced by ships and high wind. Current hugging a bank and vortices developed at the toe of a bank are also responsible for bank erosion. The magnitude of bank erosion depends, apart from severity of extraneous factors, on the vulnerability of the bank soil. When more than one factor co-exist, regulation of flow by construction of guide wall, repelling spurs and the like may be necessary concurrently with bank protective measures with geosynthetics.

The pre-requisite for use of treated JGT in control of bank erosion is to enhance its durability against continuous exposure to water. Bitumen has been in use for quite some time with success for this purpose. Bitumen however affects drapability of JGT. We are looking for a better alternative that would ensure water immiscibility and the desired drapability without loss of strength and porometry. The study is in an advanced stage of development.

3. Case Study with JGT for Erosion Control

3.1 Location of the Site

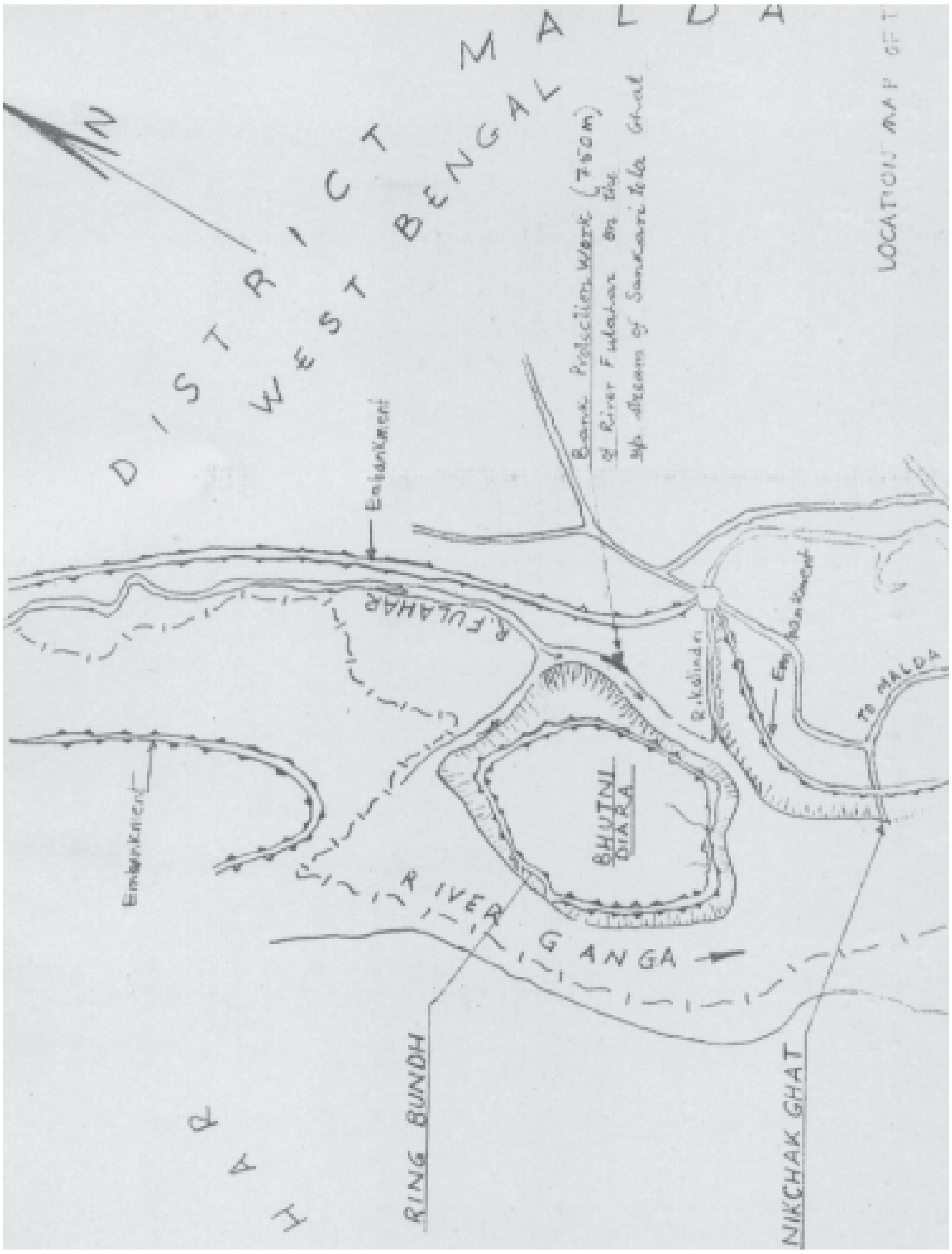
Left bank of the river Phulahar in the district of Malda, West Bengal, up stream of Sankharitala Ghat near Mathurapur (35 km from Malda town).

3.2 Problem

Flood during the monsoon as a result of high precipitation caused rise in water level both in the Ganga and the Phulahar connected with it. There was a heave-up of the excess water at the mouth of the narrower Phulahar that takes a bend at a distance of one and a half kilometers from its outfall in the Ganga. The concave bank was understandably subjected to heavy erosion that was accentuated due to strong protective measures undertaken on the opposite end for the stability of a big land-form (Bhutni Diara) that has emerged within the Ganga.

On earlier occasions of flood also, the same stretch was subjected to similar erosion. Irrigation & Waterways Department, Govt. of West Bengal constructed earlier an apron of loose boulders to control of the bank. The apron could not stand the erosive forces and gave in.

The problem is unabated erosion at the eastern stretch during the flood, engulfing chunks of land every year.



3.3 Object

The object is to control erosion in the vulnerable stretch of 750 meters (approximately) of the river Phulahar by use of Jute Geotextile and/or other measures.

3.4 Remedial concept

Erosion at the toe of the bank can be controlled by construction of submerged repelling spurs or by construction of a toe wall. Irrigation & Waterways Department adopted the second option, presumably for avoiding flow repulsion to the opposite end that could destabilize the protective work around Bhutni Diara. The bank slope measuring 12 meters in length was given a 'break' after 5 meters from the bank top, forming a berm of a 1 meter.

3.5 Some features of relevance

The bank soil was made up of fine sand (average particle size – 0.175 mm). Co-efficient of soil permeability was of the order of 10^{-4} per sec. The monsoon discharge veers around 9330 cumec while the maximum velocity of the current was of the order of 2 meters per second.

3.6 Implementation

Implementation of the remedial concept was done in 2004 after the monsoon. A toe wall with crated boulders (900 X 1200 in size) was constructed. The bank slope behind the toe wall was prepared and dressed to 2 : 1 slope and bitumen-treated woven Jute Geotextile was laid over it. An armour layer of loose granite boulders (Rajmahal trap) having a thickness of 450 mm was placed over the fabric.

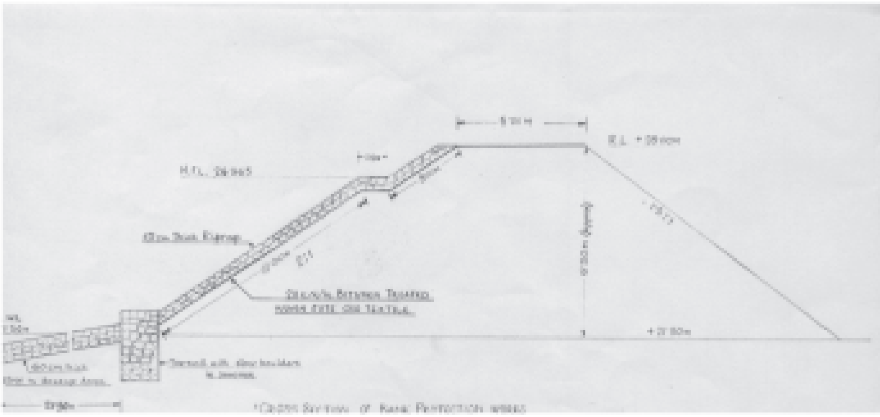


Fig. 3: Cross-section of bank protection works in the river Phulahar, Malda, W.B.

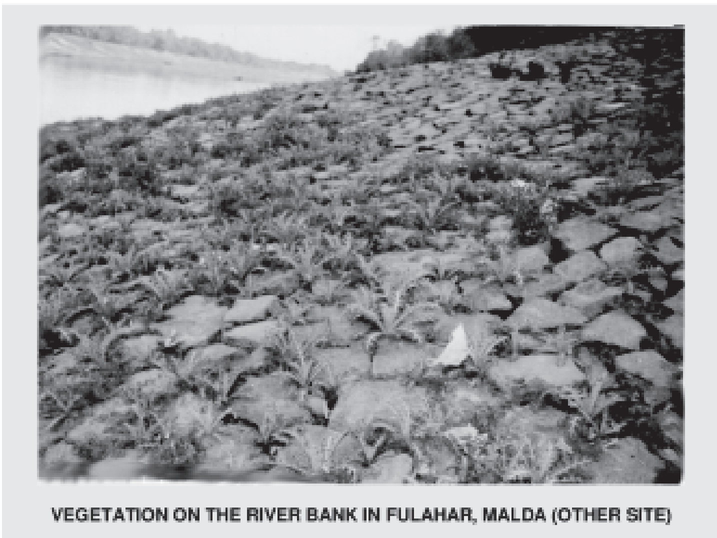


Fig. 4: Vegetation on the river bank Phulahar, Malda (other side)

3.7 Feature of Jute Geotextile used

The JGT used had the following features—

- Weight per unit area —760 gsm (1200 gsm after treatment with bitumen)
- Tensile Strength (MDXCD) —minm. 20 kN/m x 20 kN/m when grey

21 kN/m X 21 kN/m after treatment

- Elongation at break (MDX CD) —maxm.10% X 10%
- Porometry —150 micron ± 10%
- Flow Rate at 50 mm constant water head—14 litres/m^2/second
- Permittivity at 50 mm constant water head—350 x 10 $^{-5}$ per sec.
- Puncture Resistance —400 kN

3.8 Performance evaluation

The treated stretch of the affected bank is in a fine shape two years after remedial measured were taken with Jute Geotextile. The letter of the Executive Engineer, Malda Irrigation Division dated is confirmatory. The toe wall also played its desired role in controlling erosion at the toe.

4. Mechanism of Strengthening of Road Sub-grade

One of the underlying principles for separation and reinforcement function to be effective by use of geosynthetics is not only to ensure segregation and withstanding dynamic stresses respectively, but also to help generate membrane effect that exerts an upward thrust against the imposed loads. Initial tensile strength of JGT and its low extensibility certainly helps in this respect. But more important are the functions of filtration and drainage of geosynthetics that ensure natural consolidation of a road sub-grade. Permittivity (flow across the geosynthetics) and transmittivity (flow along the plane of geosynthetics) are two critical parameters that help maximize soil consolidation only when soil in the sub-grade is not allowed to migrate. Roadside drainage and lateral restraint of the pavement are two other technical necessities. All the requirements as indicated could be achieved if the fabric porometry is rightly decided. Decision on pore size of JGT or, for that matter, any geosynthetic is critical.

Consolidation of soil, as already mentioned, is a time-dependent process and may continue for a protracted period. In one of the field applications on roads done in Kakinada Port in Andhra Pradesh, an increase of CBR by about 3 times were observed after a lapse of 6 years of laying of woven JGT on a severely damaged road! (Rao et al 1993, Sreerama Rao 2003) This is again a pointer that long term durability of JGT is not a technical indispensability in all cases.

One of the difficulties faced in placement of JGT under granular base/sub-base is the probability of puncturing. The fabric may be punctured by the sharp edges of coarse aggregates. The difficulty can be obviated by spread of a thin cushion of sand above or under the fabric as necessary. In one of the field studies, JGT was overlain by WBM comprising sharp-edged brick metals ( ). Thickness of WBM was reduced and part of it was replaced by brick flat soling for prevention of puncturing. Admittedly there were chances of inhibition of permittivity in such arrangement. The difficulty was overcome by keeping a gap of 10 mm in each joint. In reality the extent of transmittivity exceeds the magnitude of permittivity, the arrangement worked and the performance of the treated pavement was satisfactory.

5. Case Study in Road Construction

5.1 Location of the Site

Andulia-Boyratola Road is a 3.5 km long rural road located under Haroa block of the North

24 Parganas, West Bengal. It passes through three unconnected habitations and is close to agricultural fields, fishing ponds and small scale industries. The area in future is expected to show up due to developmental programmes being envisaged in the area. The proposed road is likely to take on a larger traffic in future. It rests on a ground higher than the ambient ground level by 725 mm.

The average annual rainfall in the area is 1500 mm.(Figs. 6 to 7)

5.2 Soil

The soil is basically organic silty clay (IS Soil classification OL), Average L.L. is 46% while average P.L. is 27.5% (PI is 18.5%). OMC was found to be 23.5% while MDD was observed to be 1.72 gm/cc. The average soaked CBR value of the sub-grade was found to be 3.22 % (4 days).

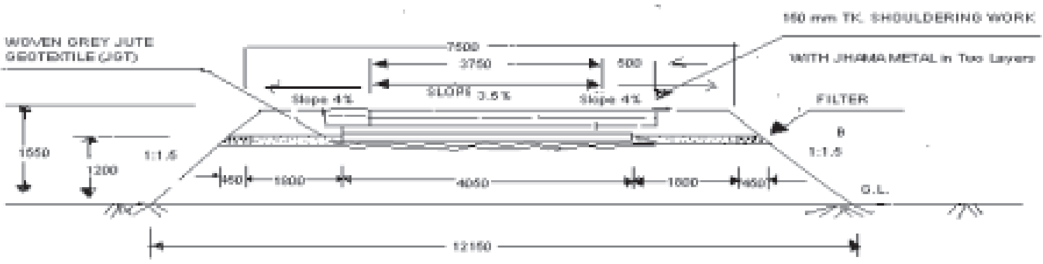


Fig. 6 : Typical cross-section of the road

ANDULIA – BOYRATALA ROAD BEFORE LAYING JGT

Fig. 7: Andulia-Boyratala road before laying of JGT

5.3 Traffic

Traffic census was carried out at the nearest all weather road (AWR) for the purpose of design , CVPD (Commercial Vehicles per day) has been taken as 22, considering 10% of the traffic in the nearest all-weather road (AWR).

5.4 Salient Features of the Project

The DPR was drawn up in accordance with IRC SP 20:2002. Woven Jute Geotextile (JGT) was laid on the sub-grade to improve its CBR. Pavement was designed with an enhanced CBR value of 4.93% (1.5 times the exiting CBR of the subgrade -rounded off to 5%). The total cost of the project worked out to Rs. 1.48 crores. The financial component of JGT was 4.34% of the total project cost. The thickness of the sub base, the base and the wearing coarse was 200 mm, 150 mm and 26 mm respectively. (as per the relevant curve corresponding to the assumed CBR, CVPD & average annual rainfall).

5.5 Installation of Woven JGT

Woven untreated JGT (specifications given below) was laid on the sub-grade after raising the road level to 1200 mm from G.L. (the level of the sub-grade). The top width of the road was finished to 7500 mm with 1:1.5 side slope while the actual carriage way measured 3750 mm.

After the sub-grade was rolled to OMC, the specified JGT was laid in taut condition on the prepared sub-grade, taking care to ensure that there was no gap between the sub-grade and the fabric. Overlaps at sides (150 mm) and ends (300 mm) were provided duly stapled at an interval of 300 mm with broad- headed nails. A cushion of a thin layer of local sand was provided on JGT to avoid puncturing during rolling the sub-base and the base of the pavement.

On laying the fabric, the pavement was finished as per specifications stated in the approved DPR which was vetted by the Civil engineering Department, Bengal Engineering & Science University, Sibpur,West Bengal.

JGT LAID ON THE SUB GRADE

5.6 Specifications of Woven JGT

The specifications adopted for the woven untreated JGT were as under—

• Weight—— 810 gsm (untreated)

• Thickness—2 mm

• Width ——— 76 cm

- Tensile Strength—minm.   30 kN/meter (both in machine & cross directions)
- Elongation at break—max. 10 % (both in MD & CD)
- Porometry—   150 micron ± 10%
- Permittivity at 50 mm constant water head—350 x 10^{-5} per second
- Puncture Resistance —0.600 kN

5.7 Inference

Field CBR was ascertained by the Civil Engineering Department of Bengal Engineering & Science University (also the accredited State Technical Agency for the PMGSY Programme). CBR was found to be –

** The case study is a pointer that i) with promotion of JGT, the CBR could be improved to % of the value, higher than what was estimated. Ii) the thickness of the pavement and returned by 45 mm, this will almost off set the cost on JGT.

6. CONCLUSION

In the present realm of growing global emphasis on adoption of bio-technical measures, Jute Geotextile deserves encouragement due to its several striking attributes. Of all the ingredients of natural geosynthetics, jute happens to be the best spinnable fibre that ensures making of customized fabric to meet site-specific requirements. JGT is also the most drapable of all geosynthetics—a property essential for control of surficial soil erosion. Its low extensibility and high initial strength helps in enhancing the bearing capacity of soil. Woven JGT can now be made to a tensile strength of 40 kN / meter with a porometry as low as 100 micron. Its environmental concordance is by far its most attractive feature along with its cost-competitiveness. When we consider the environmental price of JGT, it matches with its man-made counterpart both in respect of price and technical suitability in most of the geotechnical applications. This is because long durability of geosynthetics is not a technical necessity in majority of applications.

PREVENTION OF RAILWAY TRACK SUBSIDENCE WITH JUTE GEOTEXTILE
- A Case Study under Eastern Railway

Tapobrata Sanyal & P.K. Choudhury

1, INTRODUCTION

Road & railway tracks built on earthen embankments undergo subsidence mostly as a result of inadequate bearing capacity of the fills. Railway tracks are more vulnerable to subsidence than road tracks *due* to more sustained repetitive dynamic loads imposed on them. The majority of railway embankments in India was built when Geotechnical Engineering did not take its roots in constructional spheres related to soil There was hardly any room for choice of fill materials - not to speak of the punctiliousness required in proper soil compaction with the OMC. This has led to use of fills from borrow pits irrespective of their quality and character. Use of fills with high clay content i.e. with high P.I. leads to entrapment of water within the body of embankments, causing differential volume changes with the variation of water/moisture content within. Railway track subsidence along with "mud pumping" is a common phenomenon. Short term measures to remedy the inherent deficiency do not help.

In this article, a case study for prevention of railway track subsidence is presented in which Jute Geotextile (JGT) in various forms were put to use. The affected railway tracks are located at a distance of 36 kms and 46 kms respectively from Howrah under Chandanpur - Gurap Section of Howrah-Bardhaman Chord line. The Railway Engineers, for the last several years, took pains to restore the subsided track to the desired level by adopting conventional measures without permanent effects.

2. PRE-REMEDIAL SITUATION AT SITE

The railway embankment in question at both the locations is fairly old, having been built with cohesive fills of varying composition - silty clay to silty loam. There are three tracks. The central track interposed between two outer ones has not faced any subsidence problem. The southern track is more affected than the northern. **(Fig.1)**

The height of the embankment is not uniform and varies between 1.0 meter to 6.0 meters from G.L. Side slopes of the embankment were also disuniform ranging between 1:2.5 to 1:5. The cess at the side of the southern track was almost non-existent due to unabated erosion of the surficial soil. Borrow pits almost touch the toe of the embankment at most places with water within. When the subgrade was exposed for inspection, no sand cushion was seen under the ballast layer.

The nature of problems encountered in the affected stretch were not one but several. The track alignment was seen to be disturbed, side slopes were steeper in places than what the angle of internal friction of this fill could permit, cross-level was not in order, there was creep in formation with erosion of cess along with settlement and surface-soil erosion in slopes. Annex-l presents the details of the types of problems at different stretches.

Howrah Division of Eastern Railway carried out a number of studies for finding out the reasons for the perennial track subsidence in the section, incidentally, the section is one of the busiest in the Indian Railways. Important passenger trains like Rajdhani Express, Poorba Express etc. run on this line, apart from a series of heavily loaded goods train and frequent EMU locals.

The first study was done in 1968. The subgrade was reported to be made of shrinkable soil, but not of black cotton type. Shear Strength of the fill was found to be poor (1.47 T/sq.m to 1.96 T/sq.m) while natural dry density was in the range of 70% to 80%. Driving of Sal-ballahas in series (75 cm apart, 30 cm away from the edge) was suggested.

In the second study done in 1977 it was advised to provide sand drains at critical locations with slopes flattened to 1:2.5 and lime - piles provided at critical stretches.

In the third study done in 1987, providing of sand-blanket and sand-drains was suggested.

The Railway engineers reportedly implemented the recommendations, but the track could not be stabilised to the desired degree. The main area of concern was about the disturbance of the cross-level and the alignment of the outer tracks. The matter was reportedly referred to R.D.S.O., Lucknow which recommended provisions of sub-bank and salballah piling at the trouble-stretches.

3. REASONS OF TRACK SUBSIDENCE AND REMEDIAL PRINCIPLE

Poor quality of the fill (clayey composition), entrapment of water within the embankment due to drainage deficiency and inadequate compaction at O.M.C. during construction could be the probable reasons of subsidence of the two outer tracks laid over the embankment. Ballasts were seen to have penetrated into the subgrade as a result due to absence of a separating layer between the subgrade and the ballast-base. The Railway engineers desired to try out the remedial package with JGT in the southern track which was more severely affected.

Remedial principles were based on the following -

a) drainage of rain water before it couid reach the subgrade
b) providing a separating layer between the subgrade and the ballast-base
c) improving bearing capacity of the subgrade
d) prevention of lateral dispersion of the embankment-toe
e) cess-and-slope reclamation

The remedial package based on the above was proposed by Sanyal (2000) by use of Jute Geotextile in several forms as a trial in the stretches at 36/13-21km and 48/3-9 km. commencing from Madhusudanpur Station and Belmuri Station respectively.

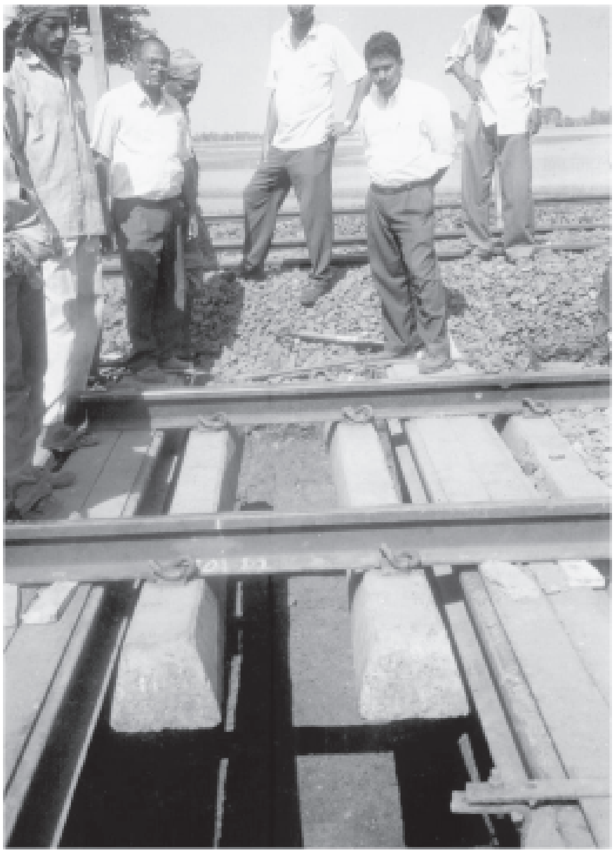
4. IMPLEMENTATION OF THE REMEDIAL PACKAGE

The following stage-wise implementation programme was framed.

- **Recommendations - (first set)**

✔ to scoop out the ballast layer completely exposing the subgrade in the space between

two sleepers manually. The hanging lines are to be rested on rail-clusters and wooden blocks on both sides **(Fig. 2)**.



✔ to spread a thin sand-layer on the subgrade after taking out the penetrated ballast pieces to prevent puncturing of JGT

✔ to lay woven JGT (specifications given in Annex-II) on the sand cushion overlain by non-woven JGT (specifications given in Annex-II). The woven JGT was provided to act as "filter" implying that it would check movement of subgrade particles and at the same time will allow pore-water to seep through the fabric pores. The purpose of "placing" non-woven JGT was to make it act as shock-absorber and as drainage medium

✔ to place a layer of sand over JGT (22.5 cm to 30 cm). The purpose was two fold. The layer would act as a cushion against dynamic stresses induced by moving trains and also as an additional drainage medium along with JGT. Sand was mechanically vibrated with portable vibrator for ensuring its compaction **(Fig. 3)**.

✔ to replace the scooped out ballasts after washing.

It may be mentioned in this connection that woven and non-woven JGT were in conjunction to take advantage of better drainage capability of the non-woven fabric and better filtration properties of the woven one. Woven JGT posseses higher tensile strength than non-woven JGT and can withstand induced stresses better. Permittivity and transmittivity are better with the combination.

- **Recommendations (second set)**

✔ to lay JGT-encapsulated rubble (brick ballast) drains at a suitable gradient, by removal of earth, reaching the bottom end of the subgrade with the open end of the JGT-capsulated drain finished on the exposed embankment slope.

The purpose was to facilitate drainage of water from the subgrade level. Saucer surface drains on the slopes were advised to prevent rain-gully formation. **(Fig. 4)**.

- **Recommendations (third set)**

✔ to build the cess (cess width at least 900 mm) and berms at the toe of the embankment

✔ to provide lateral restraint by building sausages (boulders encapsulated in wire nets) at the toe of the embankment where water-fitted borrow-pits were perilously close.

- **Recommendations (fourth set)**

✔ to restore the embankment profile (slope 1:2.5) with borrowed carted fill materials ensuring adequate compaction

✔ to lay open-weave JGT (specifications in Annex-ii) **(Fig.5)**

✔ to place grass-sods/spread seeds on slopes for quick vegetation growth.

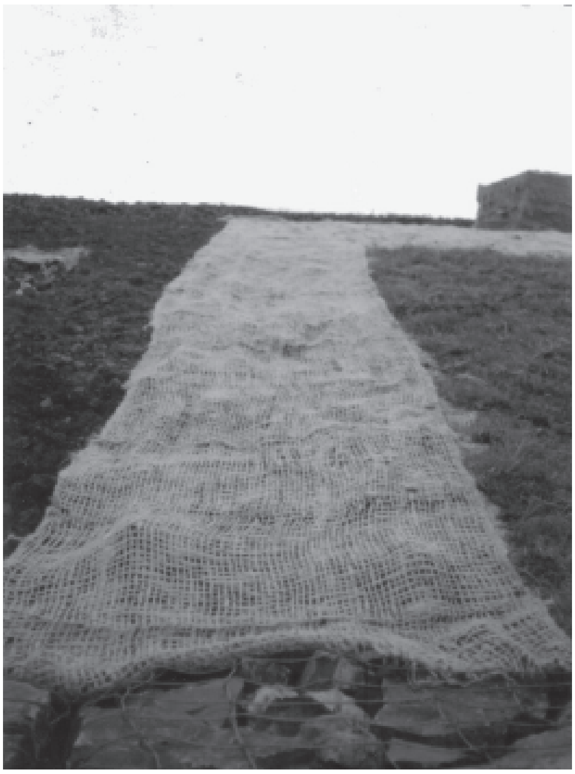
5. PROBLEMS IN IMPLEMENTATION AND WORK METHODOLOGY

The Railway engineers were insistent, not without reason, that there could be no disturbance of the train-timings during execution. Speed restriction would certainly be imposed. As a result, the work was so programmed as to complete resectioning and restoration of the subgrade between two sleepers within a day.

The contractors (Engineering Projects India Ltd - a Central Govt. Concern along with their sub-contractors) divided the workmen into 7 groups, each group comprising six men for carrying out recommendations simultaneously. The critical job of re-sectioning and restoration of the affected sub-grade between two sleepers consisted of –

– scooping out ballasts and exposing the subgrade after excavation
– placing of supports made of rail-clusters (fabricated separately)
– dressing the subgrade after picking up penetrated ballast pieces

- placing a thin cushion of sand over the subgrade
- laying of woven JGT overlain by non-woven JGT over the sand-cushion
- placing of sand on the non-woven JGT, compacting the sand with mechanical portable vibrator
- re-placing ballasts followed by removal of rail clusters



The work area measured 1.30 m (length) x 4.00 m (wide) x 0.80 m (depth) which had to be completed in one day in all respects. It was noticed that excavation itself took at least 4 hours.

The length of the trial stretch initially allotted measured 250 metres followed by another contiguous stretch measuring 200 metres.

It needs mention here that the site had no direct road access worth the name.

6. CONCLUSION

The entire work was completed within 83 working days covering a stretch of 450 metrers. The notable feature was that train services were not allowed to be disturbed during the entire period of execution. The work methodology was so planned as to ensure completion of the job in time. Similar methodology may be adopted in other areas also.

The restored stretch remains undisturbed after two seasons, withstanding two full monsoons. According to the Railway engineers, the vulnerable stretch where remedial measures were undertaken did not require any intervention for the first time. This substantiates the effectiveness of the measures done by use of Jute Geotextile in several forms, It may be stated here incidentally that where mud-pumping is noticed, additionally insertion of Jute prefabricated vertical drains, atleast upto the depth of the subgrade, will be helpful. This intervention was not necessary in view of absence of mud-pumping in the stretch chosen for trial.

7. ACKNOWLEDGEMENT

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REFERENCE: -

Sanyal T - Track Subsidence in Railway Embankments - A case for Jute Geotextile as a solution (2000).

(Published in the proc. of the Indian Geotechnicai Conference held at IIT, Mumbai in Dec, 2000).

Annex – 1

DETAILS OF THE FORMATION AND PROBLEMS ON BAD BANKS ON UP HBC OF HWH DIVISION

KM	General problem	Loc of severe problem	Nature of problem	Bank Ht & Slope	Toe Condition	Cess Condition
36-37	Alignment disturbed			2-4 mt 3:1		
		36/15-19	(Creep in formation causing) alignment defect	— 3 mt 2.4 mt 3:1	Normal ground	2 mt wide
37-38	Low Cess causing Gross level disturbance			2.3 mt, 3.5:1		
		37/ 5-9	Low cess, settlement of cess & creep in formation causing XL & alignment defect		Normal ground	
	-	37/21-23	Low cess, settlement of cess & creep in formation causing XL & alignment defect		Pond	
38-39	Long alignment defect with low cess and steep slope			3-2.4 mt 3.5:1	Normal *ground*	
39-40	Low Cess causing Cross level disturbance			2.4 mt, 3.5:1	Normal ground	
40-41	Chandanpur station limit and no formation problem					
41-42	Cross level get disturbed			2,17 mt 3.47:1		
		41/3-23	Cross level gets frequently disturbed	proper	Deep pond	low
42-43	Cross level get disturbed			1.59 mt 4.16:1		
		42/3-5	Cross level gets frequently disturbed	1.835 mt 3.32:1	Normal ground	
		42/21-23	Cross level gets frequently disturbed	1.00 mt 6:1	Deep pond	
43-44	Cross level disturbed due to low cess and water pond at toe			1.13 mt 4.96:1		
		43/15-17	Cross level gets frequently disturbed	1.06 mt 3.9:1		Cess non existant
		43/21-23	Cross level gets frequently disturbed	1.48 mt 3.72:1	Deep pond	
44-45	Creep in formation causing alignment and cross level problem			1.36 mt 5.23:1		
		44/21-29	Creep in formation causing alignment and cross level defect	1.8 mt 1.75:1 to 5.35:1	Deep pond	

KM	General problem	Loc of severe problem	Nature of problem	Bank Ht & Slope	Toe Condition	Cess Condition
45-46	Creep in formation causing alignment and Cross level problem			1.34 mt 4.3:1	Deep pond	Cess non existant
46-47	Alignment disturbed					
		46/15 47/0	Alignment gets disturbed; no cross-level problem		Shallow pit	
47-48	Alignment disturbed due to creep in formation					
		47/0-7	Alignment gets disturbed; no cross-level problem		Shallow pit	
48-49	Alignment disturbed due to creep in formation and low cess			3.6 mt, 2.3:1		
		48/3-9	Cross level gets frequently disturbed		Deep pond	Cess non existant
		48/15-21	Cross level gets frequently disturbed	3.6 mt, 2.3:1	Shallow pit	Cess non existant
49-50	High bank, Low Cess, deep pit at toe causing Cross level and alignment disturbance			5-6 mt 2:1		
50-51	High bank, Low Cess, deep pit at toe causing Cross level and alignment disturbance			5-6 mt 2.2:1		
		50/1-5	Alignment and Cross level gets frequently disturbed due to creep in formation	6 mt. 2.2:1	Deep pond	Low and sinking cess
51-52	High bank, low cess, deep pit at toe causing cross level and alignment disturbance			6-3 mt, 1.5:1 to 2.5:1		
		51/19-23	Long level, Alignment and Cross level get frequently disturbed due vertical settlement in formation and creep in formation	3 mt 5:1	Deep pond	
52-53	High bank, low cess, deep pit at toe causing cross level and alignment disturbance			3 mt, 2.5:1		
53-54	No major problem except minor cross level and alignment defect			2mt 3.7:1		
54-55	No major problem except minor cross level and alignment defect					
55-56						
		55/25 56/1	Settlement in cess causing cross level variation			

KM	General problem	Loc of severe problem	Nature of problem	Bank Ht & Slope	Toe Condition	Cess Condition
61-62						
		61/17-19	Frequent cross level and alignment defect			
		61/19-21	Frequent cross level and alignment defect			
62-63						
		62/17-23	Frequent cross level defect			
		62/25-29	Frequent cross level and alignment defect	Steep slope	Shallow pit	

ANNEXURE - II

WOVEN JUTE GEOTEXTTLE (BITUMSENISED) SPECIFICATIONS

PROPERTIES	
Weight (g/m^2) at 20% M.R.	1200
Threads/dm (MD x CD)	102x39
Thickness (mm)	2
Width (cm)	76
Strength (kN/m) (MD x CD)	21x21
Elongation at break (%) (MD X CD)	10x10
Pore size (O_{90}) Micron	150
Water permeability at 10 cm water head (I/m^2/S)	20
Puncture resistance (N/cm^2)	400
Durability (yrs.) Max.	4

NON-WOVEN GEOTEXTELES SPECIFICATIONS

PROPERTIES	
Weight (g/m^2) at 20% M.R.	1000
Thickness-(mm)	8
Width (cm)	150
Strength (kN/m) (MD x CD)	6x7
Elongation at break (%) (MD x CD)	20x25
Pore size (O_{90}) Micron	300
Co-eff. of water permittivity (m/s)	3.4×10^{-4}
Durability (yrs.) Max.	1

OPEN MESH WOVEN JUTE GEO-TEXTILE SPECIFICATIONS

PROPERTIES	
Weight (g/m^2) at 20% M.R.	500
Threads/dm (MD x CD)	6.5x4.5
Thickness (mm)	4
Width (cm)	122
Open area(%)	50
Strength (kN/m) (MD x CD)	10x7.5
Water holding capacity (%) on dry weight	500
Durability (yrs.) Max.	2

PROSPECTIVE APPLICATIONS

THE ROLE OF NATURAL FIBRES IN GEOTEXTILE ENGINEERING

James C Thomson

ABSTRACT

The paper describes the current and potential role of natural fibres for geotechnical application. The applications are considered under:

1. Separation, filtration and reinforcement
2. Erosion control

INTRODUCTION

At the 3rd. International Conference on Geotextiles held in Vienna in 1986, Dr. Jean-Pierre Giroud, President of the Inter-national Geotextile Society, in his opening address to the conference, acknowledged the historical role of geotextiles made from natural fibres.

Examples going back several thousand years can be found of the use of fascines and mats in construction made from natural fibres such as wool, jute and cotton.

Some early examples are the use of cotton fabrics in the strengthening of road pavements in the USA around 1930 and in the UK the use of jute fabrics in road con-struction in Dundee in the 1920s come to mind. To assist in the 1944 invasion of Normandy, the British Army developed a machine to lay canvas or fascine rolls to provide roads across beaches and dunes.

The rise of synthetic fabrics

The advent of synthetic fibres and the development of production methods revolutionized the textile industry after the Second World War and the subsequent availability of cheap, strong and durable fabrics formed the basis from which the present day geotextile industry grew.

The very rapid establishment of the geotextile industry has encompassed a vast range of products, some of which bear little similarity to the original concepts of a fabric. Today there are meshes, mats, grids, straps and composites and the original term geotextile has become less appropriate and such terms as geosynthetics, geofabrics and geomaterials have all been suggested. Dr. Giroudin in his address to the Vienna Conference acknowledged the need to broaden the definitions and particularly he acknowledged and recognized the role of natural fibre products.

With the better understanding of the properties and functions of these materials and their application to geotechnical problems, this has led to an appreciation of the characteristics and qualities of natural materials and to recognize that their biodegradability and formation from natural fibres provide positive advantages.

Natural fibre geotextile applications

Broadly, there are two areas of application for natural fibre geoproducts.

Firstly, in applications such as separation, filtration and reinforcement where the required lifespan is short; secondly, in erosion control.

Separation, filtration and reinforcement

An example of separation was on a pipeline scheme across environmentally sensitive countryside where a cheap jute sacking cloth was used as a separator between the turf and the stored top soil. Jute being a natural fibre was environmentally acceptable.

On contractors' haul roads where the required life may only be in terms of months, natural fibre fabrics can act in a similar way to synthetic materials.

In areas of the world such as India there could be a much more extensive use of natural materials such as coir and jute, both of which are indigenous to the region. They could play a most useful engineering role in road construction. Laid over the subgrade before placing of the sub-base, they will act in a similar way to a synthetic geotextile, contamination, assisting in the drainage by removing excess water and providing improvement in the bearing capacity by virtue of their reinforcement value. Laboratory and field tests conducted by the National University of Singapore using jute cloth showed the substantial improvements that can be gained.

For embankments and cut slopes where there is a need for some form of earth reinforcement during the initial period of consolidation of remedial measures to local instabilities, then according to availability a number of natural materials could be utilized. Again, they would have the advantage of being environmentally acceptable.

Although jute could be very economic for short-life situations, the relatively rapid biodegradation and loss of strength limits the reinforcement role. An alternative natu-ral material which has excellent strength characteristics and biodegrades over a long period is coir.

After formation into strands it can be formed into heavy cloths and strips suitable for reinforced soil applications. Vertical drains are commonly used to accelerate the consolidation process of thick deposits of soft compressable and clayey soils. One such type of drain developed by the University of Singapore is the Fibre Drain and is made of organic fibres extracted from jute and coir.

Erosion control

The most important application for natural fibre geotextiles is in erosion control. This is forecast to be one of the major growth areas for geoproducts over the next ten years.

The mechanics of water erosion are the detachment of soil particles by rainsplash or by the surface flow. In wind erosion, detachment and transportation are part of the same process. In water erosion, the most destructive processes which have to be countered are the detachment by rainsplash and the transport by surface flow. These factors become increasingly destructive as the landslope increases.

Detachment by raindrop splash is a function of the erodibility of the soil and the kinetic energy of the rain drops. The larger the drops and the heavier the rain-fall, the more particles are detached.

Transport by surface flows occurs when the capacity of the soil to absorb water is exceeded by the rate of rainfall and then water unable to filter into the soil flows over the surface. This surface flow trans-ports soil particles and if a certain value depending on the particular soil type is exceeded, then extended erosion takes place.

Erosion is a function of erosivity, which is natural energy from the rainfall or wind and the erodibility factors which are the soil characteristics, land topography and vegetation.

There are a number of forms of erosion control materials which have been developed with the use of natural fibres. The products now on the market are all laid on the surface of the soil after normal seeding and are described usually as blankets.

Enviromat is a blanket material from Australia. A very similar product used in the United States goes under the name of Excelsior mat. Enviromat consists of an inner filling of poplar or pine woodwool contained within a lightweight polypropylene mesh. Exposure to climatic conditions causes the woodwool to expand and become more bulky. The material is claimed to be biodegradable : the plastic mesh photodegrades when exposed to ultraviolet light.

Other blanket products use natural fibres in a non-woven form and include coir fibre and cotton waste often mixed with straw. An erosion control product widely used in Hong Kong is made form spunbonded cotton and forms a light pro-tective blanket.

Coir mats and strips have found acceptance as erosion control materials. Originally developed and used in Germany, they are being introduced into the other European countries and the USA.

The strength, longer life and environmentally acceptable natural material has found particular use in river works. For erosion control on cut slopes in road works, 20cm strips are pegged out in a diamond configuration and act as a containment to the soil.

Very frequently, natural fibre geotextiles are used in conjunction with other natural materials such as fascines, live staking, vegetation and trees to play an engineering role. The techniques, known as Soil Bio-Engineering, can offer environmentally acceptable cost effective solutions in a number of erosion, instabilty and revegetation situations. An example of such work comes from Rotbach in Switzerland where a landscape architect restored *a* river valley using such methods, including an erosion control fabric manufactured from cotton.

Jute meshes or nets are one of the best known and most widely used biodegradable blankets. These materials, which vary in appearance and quality depending on the origin, are marketed under a number of names. The fibre is spun and woven into a heavy woven jute matting made from 100 per cent jute yarn and having an open mesh structure. Regular grades are available at 500 g/m^2 and a heavier grade at 800 g/m^2. The fabric can be treated to render it smoulder-free for areas of high fire hazard. Geojute is biodegradable and rots in about two years. Since slope protection in the long term is provided by the grass, jute affords acceptable protection in the short term so that the seed is not washed off the slope before it germinates and takes root.

One of the major attractions of jute is that it decomposes within the ecological cycle. Acting rather like a straw or peat mulch, the decomposing fibres assist in the retention of moisture and the improvement of the soil permeability. Their presence on the surface of the soil creates an increased roughness, which reduces water flow velocity and also traps soil particles.

The destructive forces of overland flow can be mitigated by storing or absorbing the maximum amount of water. Jute makes a useful contribution both in storing and in reducing flow velocity. The storage is achieved by the form of the jute which makes a series of dams with the weft yarns that run along the contour of the slope. To achieve this capacity to dam the down slope flow, the fabric must have the ability to follow the contour of the slope, so staying in intimate contact with the soil. Jute is very efficient in this manner. Furthermore, jute has the ability to absorb a significant amount of precipitation by absorbing up to five times its own weight of water.

A benefit that has to be quantified is that blankets of natural material provide a very beneficial micro-climate for the germination and growth of plant life and offer a moderating influence of temperature and dessication. The ability of jute to store water is important and particularly in hotter, dry periods this storage and releasing of moisture over extended periods will main-Jain a much extended period of humidity and thus mere favourable germinating conditions. The blankets have an additional benefit in that they provide protection against seed deprivation by birds and general protection to newly-sown slopes from both animals and man.

Conclusions

Depending on price and technical performance, there would appear to be considerable potential for use of natural fibre materials, including many not specifically mentioned in the text, in India and Asia on civil engineering works which require modification of the soil.

Key applications would include :

(i) Erosion control of highway embankment and cutting slopes, railway embankments and cuts, river bank pro-tection, mine tips and, to a lesser ex-tent, waste tips.

(ii) Separation applications, such as roads (permanent and temporary), storage areas, rail roads and car parks. In-deed, ground separation in general.

(iii) Reinforcement applications such as unpaved roads, temporary walls and steep sided slopes and possibly embankments on soft ground combined with wick drains.

(iv) Filtration in road drains, trench drains and land reclamation.

(v) In-plane drainage, in wick drains and construction of embankments using wet fill.

(vi) Containment such as concrete of earth-filled jute bags used for the construction of variety of structure.

To date, the use of natural fibres has been limited. This is partially due to the natural characteristics of these fibres but probably due even more to the failure of the natural fibre industry to understand the needs of the geotechnial engineer and to develop products to meet these needs.

PROSPECTIVE INNOVATIVE APPLICATIONS OF JUTE GEOTEXTILE

A. B. M. Abdullah

ABSTRACT

Geotextiles particularly Jute Geotextiles (JGT) are emerging technical textiles in geotechnical and bio-engineering fields.These are fabricated by both man-made and natural fibres with different designs, shapes, sizes and compositions according to functional needs. These are a group of commodities which are used for solving problems related to geotechnical, bio-engineering, agronomic and horticultural requirements by way of consolidation, filtration, separation and management of soil along with agricultural mulching.

JGT are sometimes used on the surface to prevent surficial soil erosion and sometimes inside a construction under the surface as separator and reinforcer of soil. In fact geotextiles are multi-functional and location-specific in nature. Bioengineering / agro-mulching of natural fibrous materials are most effective due to their biodegradability, eco-compatibility and improvement of soil fertility and texture. In addition to erosion control they also facilitate vegetative growth, de-weeding and canopy of the land.

The application area of geotextiles is increasing continuously with the development of modern scientific and technological innovation. In respect to their physical, mechanical, hydrological properties, natural geotextiles particularly JGT are getting increasing acceptability due to their environmental complementary support.

Moreover, increasing scientific and technological information and knowledge about earth, soil, water, environment and ecological sustainability as a whole, are facilitating emergence / development of new kind of natural geotextiles as per specific location / functional needs. Different kinds of design with biodegradable geotechnical applications are being developed and increasingly used.

INTRODUCTION

Jute is a seasonal agricultural crop. Widely grown in this part of the world, particularly Bangladesh, India, Nepal, Myanmar, Thailand and Vietnam. Commercial jute fibers are extracted from two spices Chorchorus Capsularis (white), Chorchorus Olitorious (tossa), through complex microbial process of retting. It is a photo reactive plant, only 120 days are needed for its harvesting. Temperate, wet and humid climate of Bangladesh are very conducive to the growth of jute.

Jute is a ligno-cellulosic, composite natural bast fiber. Cellulose, hemi-cellulose and lignin are its major constituent components & its three dimensional structure is formed by different inter and intra-molecular forces resulting from various physical, chemical, and hydrogen bonds between them. The commercial fiber consists of hairy strands of cylindrical networks of ultimate jute fiber. Properly retted and washed jute fibers are fairly lustrous with moderate strength but rough to touch. The color of the fiber also varies from creamy white to brown.

Jute is one of the important fiber crops being exceeded in production and use only by cotton. It is a coarse textile fiber being used as a raw material for the production of packaging materials like twines, hessian, carpet backing, gunny back, tarpaulin, woolpack, cotton bagging etc. It is one of the versatile natural fibers. Its intrinsic and extrinsic properties are the accumulated properties of individual component and various groups and bonds attested to them. Jute and jute products are biodegradable, photo-degradable, thermal degradable, nontoxic, non-plastic, acidic, anionic, hydrophilic, drapable, less extensible, with higher moisture and UV absorbing capacity and higher tenacity. Most of the cellulose are present in crystalline part of it. Amorphous parts are mostly non-cellulosic in nature due to the presence of hemi-cellulose and lignin. It has similarity with soft and hard fiber and cotton and wood simultaneously. A vast range of diversified jute products can be manufactured through vertical and horizontal modification. These are textiles, home textiles, technical textiles, medicare textiles, geotextile, agrotextiles, woven and nonwoven, composite and non-composite, decorative, toys and handicrafts, pulp/paper and their products and cellulose and cellulose derivates etc, which can be used as a substitute of cotton, wood, synthetic, plastic etc.

There are numbers of traditional products as mentioned above which are manufactured in spinning and composite mills through existing conventional jute spinning and looms. A wide range of fabrics can be produced with the variation of drafts, twists, dollop weight, design such as plain, twill, basket, satin/sateen with closed, dense and open structure with definite strength, tenacity, porosity, permeability according to need. Moreover, nonwoven, knitted and netted jute fabrics can also be manufactured-by needle punching, stitching and chemical bonding, with different strength, thickness, porosity and permeability according to need. Furthermore composite types of fabrics can also be manufactured by the combination of knitted, netted jute fabric, with the specific need and functions.

Geotextiles particularly jute geotextiles are emerging technologies in geotechnical and bio-engineering fields. Geotextles are not a single commodity. These can fabricated by both synthetic and natural fiber with different design, shape, size, composition according to functional needs. These applications are generally categorized as; soil stabilizer, application at the interface of the formation of soil and the track back to minimize pumping of fine soil into granular materials; to lay beneath asphalt surface to delay crack development; consolidation of soil through filtration and drainage by filter cake formation; application as erosion control; reinforcement of civil construction; moisturization, protection from rain, wind, light and cold etc. In fact geotextiles are multi-functional and location-specific in nature. Bioengineering/agromulching of natural fibrous materials are most effective due to their biodegradability, eco-compatibility and improvement of soil fertility and texture. In addition to erosion control they also facilitate vegetative growth, de weeding and canopy of the land.

Divergent and prospective applications of jute and modified jute products can be used as a solutions of various problems related to geotechnical/erosion control/mulching/environment related activities are narrated briefly in this paper.

IMPORTANT CHARACTERISTIC PROPERTIES OF GEOTEXTILES

These are broadly classified as;

1) **Physical properties** :

   a) specific gravity, b) weight, c) thickness, d) stiffness, e) density etc.

2) **Mechanical properties** :

   a) tenacity b) tensile strength c) busting strength d) drapability e) compatibility f) flexibility g) puncture strength h) tearing strength i) frictional resistance etc.

3) **Hydraulic properties** :

a) porosity b) permeability c) permittivity d) transmissivity e) soil retention f) filtration etc.

4) **Degradation properties** :

a) biodegradation b) hydrolytic degradation c) photo degradation d) chemical degradation e) mechanical degradation f) other degradation occurs due to attack of rodent, mite, termite etc.

5) **Endurance properties**:

a) Crip/ elongation under texture b) abrasion resistance c) clogging length and flow etc.

All jute products as mentioned above can be used as geotextiles. But one of the most important weakness of the jute products is their quick biodegradability. But their life span can be extended even up to 20 years through different treatments and blendings. Thus it is possible to manufacture designed biodegradable jute geotextile, having specific tenacity, porosity, permeability, transmissivity according to need and location specificity soil, its type and composition, water its quality of flow, landscape etc. Physical situation determines the application and choice of what kind of jute geotextiles should be used. In contrast to synthetic geotextiles, though jute geotextiles are less durable they also have some advantages in certain areas to be used particularly in agro-mulching and similar areas where quick consolidation are to take place. Again for erosion control and rural roads where soil protection from natural and seasonal degradation caused by rain, water, monsoon, wind and cold weather are required jute geotextiles as separator, reinforcing and drainage activities along with topsoil erosion in shoulder and cracking are used quite satisfactorily. Furthermore after degradation of jute geotextiles lignomass are formed which increases soil organic content, fertility, texture and increases vegetative growth with further consolidation and stability of soil.

In fact in mulching and top soil erosion control, jute geotextiles of open weave construction (300-1000 gm/sq.m) create micro-climate for easy passage of water, retaining soil particles. Further application of grasses on it helps to harness stabilization and protection.

APPLICATIONS AND USES

Geotextiles are used in wide range of areas. Following are some important application areas where treated-untreated, blended-nonblended, natural and synthetic, geotextiles are used. They may be woven-nonwoven, knitted-netted, corded, composites and sandwiched etc. But application of geotextiles being location-specific, in addition to the characteristics of geotextiles, identification and application of geotextiles depend on soil type, soil composition, moisture content, liquid limits, plasticity index, bulk density, soil pH, iron/calcium content, clay/silt and sand composition, land sloping & hydraulic action etc. Moreover, climatic condition of the application site is also to be considered.

A. As a Separator

These are aggregates used to form some layer which prevent contamination of one kind of material from another kind of material, called separator. They[1] are used in all classes of roads and civil foundation as the base of construction on contaminated layer is the single-most cause of premature failure. The use of separator prevents pumping effect created by dynamic load and also help the passage of water while retaining soil particles. In these types of geotextiie, thickness and permeability are most important characteristic properties.

B. Reinforcement of Weak Soil And Other Materials

Reinforcement with geotextiles is intended to reduce the level of stress in the soil. For example it could be used for building of a road/any civil construction over soft soils like marshes, swamps, wetland, peat of similar difficult areas. Similarly stability of dams and embankment can be increased with their property of reinforcement. Strength and durability are the major characteristic properties needed for this type of geotextiie. Geotextiles can reduce the thickness of the pavement and increase the life span of the road along with cost reduction.

C. Filtration (Cross-Plane Flow)

In filtration fabrics can be either woven or non-woven, to permit the passage of water while retaining soil particles. Porosity and permeability are the major properties of geotextiles which act in filtration. This applications are also suitable for both horizontal and vertical drains.

D. Drainage (In-Plane Flow)

1. Fiber drains/prefabricated drains :

In foundation engineering, consolidation settlement of clayey, silty and muddy soil create serious problems for construction engineers. The application of various types of drains is to allow accelerated dissipation of pore water pressure by lateral drainage provided by geotextiles.There are various kinds of drains having their own characteristic properties.,These are ; sand drain, cardboard drain, wick drain, prefabricated drain and latest innovated banana drain. Ideal drains would have following characteristics :

1) High permeability to enable rapid dissipation. Its permeability must be much higher than that of the ground to be treated.
2) Good flexibility to enable large ground movement and not act as a pile and so prevent consolidation. Similar stiffness to soil mass is preferred
3) A good hydraulic connection with a natural or placed permeable blanket layer which act as a hydraulic sink and have continuity over its length.
4) Introduction into the soil should be without any harm/disturbance as to modify its beneficial action as drain
5) Remain useful as a drain over the required period in most cases a few months and rarely over a year for consolidation processes as opposed to permanent drains.
6) It should be preferably biodegradable
7) The properties should be kept over various states of stress usually increasing stress.
8) Porosity / permeability / textures of the drain body should not be clogged by the surroundings fine soils.
9) To reduce consolidation time it is obviously necessary to shorten the length of the flow paths. Installation of vertical drains of high permeability capacity are needed for quick and specific path direction.

Jute Geotextiles can be conveniently used for separation reinforcement, filtration and drainage.

In fact though geotechnical appliances are function-oriented, yet the same contrivance can serve for more than one functions simultaneously.

E. Geotextiles in Rural Road Construction

The use of geotextile products in temporary and rural unpaved road construction is one of their most common uses, and work on them is well established. The basis behind their use is that by placing a geotextile between the weak subgrade soil and the aggregate fill the unpaved road construction get strengthenes.

Considering above factors, treated and untreated, composite and blended, jute geotextiles can be used in stabilizing rural roads and protecting them from natural and seasonal devastation with increasing life span.

F. Erosion Control

Erosion control products are designed to control erosion and cover a diverse range of products which includes; nets, meshes, mats, blankets, both synthetic and natural biodegradable and non-biodegradable are used to mitigate erosion under different conditions for short, medium and long terms.

Jute geotextiles particularly geojute of open, porous and knitted structure (500-1000gm sqm) are generally used for its effective and advantage over synthetic geotextiles. Such use helps to create microclimate to protect top soil erosion by rain, water, wind flow etc. Recently hessian of 270-300 g/m^2 have also shown to be effective in erosion control in certain cases.

G. Mulching

In agricultural practices, particularly in agronomic/horticultural activities, various fibrous materials are being used from time immemorial for better and effective benefits in producing better crops. Mulches are used to suppress the growth of certain plant species, whilst enhancing the growth of others. Agro-mulching is a general term applied to mulches used for agricultural applications and includes traditional loose mulches such as straw. Most application require suppression of weed growth to reduce competition with the selected or designed vegetation for vital resources such as moisture, light and nutrients. End users have included horticultural and land escaping operations. To ensure success, jute geotextifes must have following characteristics.

- suppress weed growth
- enhance growth of the selected vegetation species by reducing competition and enhancing soil/plant/water relationship.
- protect from heat and cold and from drying & wilting etc.

Jute geotextiles are biodegradable and have only a lifespan of one season. In horticultural applications this may correspond with a crop season, and the products is simply removed and disposed of at harvesting. Where an agro plant mulch is required for a longer time (as in land scaping applications) then careful selection of site and species is important, or specialized treatments may have to be used to increase the longevity of the mulch product.

These mulches are used in the cropland where conditions are less favourable and there is a need to protect them. A natural mulch is most commonly straw, hay, although nearly any organic materials (leaves, peat, wood chips, barks, banana leaves etc. that are non-toxic can be used) There are also synthetic mulches such as polypropylene, plastics, bitumins/latexes, treated fibrous material etc. Mulch provides some protection from rainsplash, erosion retards runoff, traps sediment and creates a better environment for plant germination and development.

Some times treated and untreated light jute fabrics in the form of taps are used for covering plants from natural injury from cold and wilting. These are nursery pot, nursery sheet, nursery tapes, nursery fabrics etc.

H. Moisturizers

Moisturizers are generally from natural fibers. They are fabricated and designed so that they have high water holding capacity. High capiliraties and hydrogen bonding properties are special properties for this types of geotextile, so that they can provide water to the plants / crops/land/structure when needed.

There are woven, non-woven, composites, treated and untreated fabrics like nursery sheet/ pot, nursery tapes etc. some time with special treatment for higher water absorption capacity, anti-microbial protection etc. Some application areas are;

1) Seasoning newly constructed RCC/civil structure during building
2) Protect land from desertification by planting special type of grass/ herbs/plants and providing water for initial growth propagation.
3) Protection of forest plant from drought/dehydration by supplying soil moisture and preventing evaporation.
4) Anti-forest fire retardant/stopping fire propagation by the application of specially treated geotextile in forest area.
5) Land reclamation from sea/desert

Jute is a versatile fiber having composite nature of high chelate forming groups along with high water absorbing capacity, can easily form complexes with silts passing through the big rivers and settle down quickly as sedimentation at the confluence to sea/river. By setting them land reclamation can be undertaken and further with the formation of lignomass quicker vegetative growth occurs.

On the other hand desert area can be transformed in to a cropland with the transformation of sand into soil by gradual supply of water and plantation on it.

I. Cropland / Hydroponics / Roof-Top Planting / Orchid Production / Floriculture etc.

These are special type of fabrication made by sandwiching nonwoven with open structure netting where nonwoven part contains seed, fertilizer and soil in specific ratio according to crop need. Water is occasionally sprinkled to the fabrics. Generally these are used as seed beds during emergency and devastating flood. This seed bed can be placed anywhere like roof of the building. Again similar type of fibrous fabrics are also used for hydrophonic agriculture, generally placed on raft made of banana stem or similar structure.

Rooftop planting /orchid production/floriculture became very popular and modern approach of gardening/floriculture in top roof of buildings and similar places. These types of jute geotextiles are similar to that of cropland but they are modified with specific needs in respect of water content, soil content, fertilizer content and canopy needs. These types of geotextiles are getting popular in city and urban areas as these not only harness economic benefits but also protect environment by Carbon dioxide-Oxygen balance in the atmosphere.

J. Irrigation liner

Irrigation liners are non-permeable fabrics, generally synthetics or natural modified with resin/ rubber/polymers etc. so that water can not pass through it.

Some times these irrigation liners are made with differently treated jute ribbons.

K. Seismic protection

Jute and other fibrous materials were used as a reinforcing material in the construction of mud houses of this part of the world from time immemorial. Recently jute and other fiber materials have been identified as an effective raw materials for stabilizing various buildings made mud in Asia and African countries from protection of earthquake.

L. As Temporary Irrigation Dam

These are specially treated /modified jute fabrics which are hydrophobic, non-permeable and easily movable so that water can be channelised to a short usable area.

M. Protection of Tea Garden

Jute having high moisture and UV protecting character have a definite capability to protect soft tea leaves giving appropriate moisture and protection from UV radiation reflected from sun by giving canopy.

CONCLUSIONS

There is a wide scope for innovative and prospective uses of jute geotextiles as it is not only environment friendly but application of jute products particularly jute geotextiles are effective for protecting environmental degradation. So application of jute geotextiles can play an important role for sustainable economic development and planning where jute is easily available. Though scientific and technological innovation related to the uses of jute geotextiles are available, yet it could not be popularized for commercial uses due to non-availability of user application parameters needed for putting them in design of working plan.

REFERENCES

1. An Introduction to Jute /Allied Fibers Properties and Processing , Abdullah, Latifa and Matin, International Jute Organization, Dhaka, 1992
2. Fiber and Yarn Quality in Jute Spinning, H,P Stout The Textile Institute (Manchester)
3. Jute Diversification Study, Common Wealth Secretariat, December, 1999
4. Proceedings of the fifth International Conference of Geotextiles . Vol-1-5 Singapore 1994
5. Geotextile and Related Products as Filter and Drain in Dams Construction, Madras, India, 1987
6. Environmental Aspects of Geojute for Soil Bio Engineering , International conference on Jute and the Environment, The Hague, 1993
7. Jute Geotextiles Techno economical Manual CFC and IJO 1998
8. Production of Jute/Coir Blended Yarn From Low Grade Jute And Coir Fibers, Abdullah, Kabir, Latifa, Rahman etal BJRI 1987
9. Possible Uses Of Presently Available Jute Materials As Geotextiles, Kamal, Abdullah, Rahman, Books Of Papers, International Seminar On Jute And Allied Fibers Technology, Indian Council Of Agriculture Research, Calcutta I998
10. An Approach to Photo-Stabilization of Jute Abdullah's PhD Thesis, 1983
11. Use of jute fabrics in erosion control. International Jute Organization, Thomson and Ingold 1986
12. Consolidation of Clay by Band Shaped Prefabricated Drains, Hansbo, Ground Engineering, 1979.
13. As Referances-4
14. Performance Evolution of Jute Geotextiles, JMDC, Kolkata 2003.
15. A Manual on use of Jute Geotextiles in Civil Engineering, JMDC, Kolkata 2007.

PROSPECTIVE APPLICATIONS OF JUTE GEOTEXTILES

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ABSTRACT

Versatility and distinctive physical characteristics of jute fibres coupled with its high spinnability, make it an ideal material for new technical applications beyond the existing conventional end-uses. The conventional end-uses of Jute Geotextiles (JGT) in the areas of slope stabilization, surficial soil erosion control, strengthening of road sub-grades and protection of river and canal banks have yielded satisfactory results in quite a few field trials carried out in India. Standardization in use of different varieties of JGT in the aforesaid end-uses is under way.

Application of the appropriate JGT in other geo-environmental and geotechnical end-uses should be concurrently thought of considering the distinctive features of jute fibres to widen its market base.

The author feels that standardization of the prospective applications of JGT will pave the way for larger acceptability of JGT. At the same time there should be no relenting of efforts to continue study and research in the field for improvement of production and ensuring quality of products for a sustainable customer-base.

INTRODUCTION

Versatility and distinctive physical characteristics of jute fibres coupled with its high spinnability make it an ideal material for new technical applications beyond the existing conventional end-uses. Tailor-made technical textiles can be made out of its fibres/yarns a feature that can hardly be matched by any other natural fibre. Principal application of Jute Geotextiles (JGT) is in the sector of erosion control where its efficacy stands established. Bio-degradability of jute and, for that matter, of other natural fibres such as coir is a distinct advantage from environmental considerations. But coir is deficient to jute in so far as spinnability is concerned. In view of the renewed global emphasis on adoption of bio-engineering measures especially to address geotechnical problems, jute-made technical textiles have seemingly bright prospects. At the same time there is need to explore avenues for their use in geo-environmental sector. These are areas where man-made geotextiles have inherent limitations.

In this paper, an attempt has been made to present before the readers the prospective applications of JGT other than its conventional uses.

EXISTING APPLICATIONS OF JGT

So long JGT has been used in the following areas with success :

- slope stabilization
- surficial soil erosion control
- strengthening of road sub-grades and drainage
- protection of river & canal banks

Slope stabilization envisages strengthening a soil body threatened with distress. JGT, when inserted within an embankment in appropriate layers, can prevent rotational slides. As a basal reinforcement, JGT curbs the settlement of an embankment or any fill. The principal cause of lateral dispersion of any fill, besides its low shear strength, is intrusion of water into the fill-body. Drainage of water can be facilitated by insertion of the right type of JGT at appropriate levels within the fill.

Erosion of top soil either on a flat ground or on a slope can be effectively prevented by open weave JGT. Three-dimensional construction of open weave JGT helps reduce the velocity of surface run-off by interposing successive micro-barriers to the direction of flow and entrap the soil particles dissociated by the kinetic energy of rain drops. Bio-degradarjility of JGT facilitates growth of vegetation because of conditioning of the ambient temperature and regulation of humidity to a congenial level effected by it. It has also been reported that JGT may add micronutrients to the soil on which it is laid and do not draw upon nitrogenous reserves on bio-degradation. Moreover JGT-residue is beneficial as it helps enhance the hydraulic conductivity of soil. The efficacy of JGT in control of surficial soil erosion for all these reasons is now well established.

Appropriately designed woven JGT when placed on a *road sub-grade* enhances its bearing capacity (expressed as CBR %).The phenomenon is the result of the functions of separation and filtration performed by an appropriately designed woven JGT laid on the sub-grade. Consolidation of soil is a protracted process. It is for this reason CBR of a sub-grade keeps on increasing over a period even after degradation of the jute fabric. This is a pointer to the fact that JGT and, for that matter, all geotextiles act as a change agent to the soil helping it to consolidate to its maximum. Normally the range of enhancement of CBR of a sub-grade treated with JGT is 150% to 300% of the control value.

Bitumen-treated woven JGT has performed satisfactorily in *controlling erosion of river and canal banks.* Woven JGT can serve as a better and cost-effective substitute of the conventional granular filter. Availability of granular aggregates often poses difficulty, apart from the difficulties encountered in exercising quality control. A layer of woven JGT treated with a suitable water-repellant additive may replace the layers of granular aggregates. An armour layer over the fabric prevent the fabric displacement and its direct exposure to weather alongwith its other main functions.

Bitumen, however, is not the ideal material for coating JGT as bitumen makes the fabric rigid and less drapable. Search is on for a better additive that can retard degradation of JGT even after its continuous exposure to water; but we may have to rely on bitumen as a water-repellant additive till such time a more suitable alternative is found and successfully tried. Incidentally bitumen and jute have excellent thermal compatibility. IIT Kharagpur has been entrusted with this project by JMDC under Jute Technology Mission, India. We may have to wait for a period of three years for the result.

PROSPECTIVE APPLICATIONS OF JGT

Considering the physical attributes of jute, it is worth trying JGT in some form or the other in areas other than what was indicated above. Geo-environmental applications of JGT should demand priority considering its eco-concordance. In developing countries the progress so far in this area has been sluggish. Developed countries are likely to encourage use of natural bio-degradable products that decompose within its short ecological cycle. Man-made geotextiles have obvious limitations in this respect.

a) Prospective geo-environmental applications

Prospective application of JGT may be categorized into two groups—geo-*environmental and geo-technical.* JGT holds commercial promise under the *first group* in the following sectors.

- stabilization of mine-spoils and over-burden dumps (OB dumps)
- management of fly ash (PFA) heaps
- management of solid municipal waste (MSW)
- water-shed management.

Open cast mines are saddled with the problem of <u>over-burden in stability</u>. Mine safety is jeopardized as a result of unplanned heaping of O B dumps that may rise up to a height of 50 meters and above with apprehension of sliding/slipping. Mine Safety Regulations are often not followed in private open cast mines. Besides, such unplanned heaping contravenes the national mineral policy of the government that emphasizes adherence to mine safety rules and stabilization of vulnerable bare dumps.

Mine spoils usually consist of coarse aggregates varying in size from 0.2 mm to 50 mm. Hydraulic conductivity being very high, water retention on surface can be ensured by use of thick open weave JGT. Entrapment of particles detached as a result of precipitation can also be effectively achieved due to 3-D structure of thick open weave JGT. Conjunctive use of open weave JGT and vegetation is recommended in stabilizing such dumps. The method was successfully tried in O B dumps under Northern Coalfields at Singrauli and Western Coalfields at Nagpur in India with the advice of the World Bank consultants, l.l.T, Kanpur.

Thermal power plants face persistent problems with <u>PFA heaps</u> Only about 15% of PFA out of 100 million tonnes generated in thermal power plants in India are used for diverse applications such as land filling, brick manufacture. Accumulation of PFA in the precincts of thermal power plants not only poses environmental threats (air and sub-surface pollution), but also intrudes upon the essential free space within the plant along with uncertainties on their stability. A few years back a fly ash bund failed at Kolaghat thermal power plant in West Bengal.

PFA is usually alkaline and therefore should not stand in the way of land-filling and brick-making. It has a lower specific gravity than soil (between 2.15 and 2.18). If no other avenues are found, there remains hardly any option but to use the heaps for landscaping at least to prevent pollution. What is needed is proper planning considering the normal life of a thermal power plant to be 30 years. The quantity of PFA likely to be generated during the period is to be estimated vis-a-vis the extent of its utilization and open area availability for disposal.

Any way, PFA heaps can be similarly treated with open weave JGT and vegetation as in the case of O B dumps. Additionally a cover of non-woven JGT will prevent air pollution. Both O B dumps and PFA heaps can be developed into pleasing greeneries with the support of JGT. It is however needed to be selective about the species of vegetation. Expert advice in the matter should be sought.

<u>Management of solid municipal waste (MSW)</u> is a neglected sector in developing countries. MSW is a veritable source of pollution. It may contaminate ground water, pollute air and spread diseases. In developed countries daily covers are used over MSW. Non-woven JGT can be conveniently used as daily covers to help dissipation of foul gases and entrapped polluted liquids and to keep air pollution on check. Unfortunately the concept of providing daily cover over MSW heaps has not gained ground in developing countries.

Watershed management has not received the importance it deserves in developing countries. Denudation of ground makes it vulnerable to erosive forces of precipitation and overland flow. Detached soil particles are carried away to the nearest waterway with the run-off and either deposited over the bed of the waterway or transported further to a distance by the flowing stream depending on velocity of flow, weight and plasticity of particles. Any way deposition of sediment is instrumental in reduction of cubature of waterways and consequently their capacity to hold water. This is the main reason of occurrence of floods in this part of the globe. If vegetation can be grown on bare ground, the probability of soil erosion will get substantially reduced. Open weave JGT may be especially effective for growth of vegetation in arid and semi-arid regions because of high water absorbing capacity of jute and its mulching properties.

b) Prospective geotechnical applications

Under the *geotechnical category,* the following prospective applications are worth trying.

- turf-reinforced mat (TRM) with JGT- backing
- jute-reinforced asphaltic overlays
- jute-reinforced temporary haul roads
- fabriforms jute fibre-reinforced concrete

Ready-to-use *turf mat* with JGT backing can be conveniently used on vulnerable slopes and denuded ground. TRMs are in good demand in the overseas. Cost aspects however deserve consideration.

Bitumen-soaked jute-overlays may be used as riding surface of roads. Presently in India mastic asphalt is being extensively used. Jute-based asphaltic overlays will be cheaper though less durable. Jute and hot bitumen have excellent thermal compatibility. Moreover non-woven JGT is a very good receptor of bitumen. A combination of woven and non-woven JGT smeared with bitumen is expected to work as a resilient, water-proof and abrasion-resistant paving sheet on roads. Such sheets will have wide application especially for resurfacing the distressed riding surfaces of flexible pavements. A project to design and develop jute-based asphaltic overlay is included in the on-going Jute Technology Mission in India.

Jute possessing a higher modulus than its competitive man-made counterpart, has lower elongation at break and is proportionately stiffer. For *temporary haul roads* as in the case of approaches to construction sites, internal roads in mines, woven JGT hold both technical and commercial advantage over its man-made counterpart. New roads can be built over such temporary roads without the hazard of lifting the used JGT. This is an unexplored area in developing countries though JGT should have a good market in developed countries for such use.

Fabriform is a kind of fabric that can hold wet concrete in a desired shape. Once the concrete hardens, the utility of the fabric ceases. It can be used as revetment mattresses, for restoration of concrete elements and as lining and armour. The advantage is its degradability.

Concrete reinforced with jute fibres should be stronger and is expected to be resistant against minor distresses in concrete. Recently man-made fibres have been tried to reinforce concrete with reported success. Jute fibres should add to the both tensile and compressive strength of concrete. A project for this purpose has been included in the ongoing Jute Technology Mission under “Design & Development of JDPs”. Jute fibre-reinforced concrete may also reduce the extent of steel reinforcement in RCC.

Jute geogrids may serve as a substitute of polymer-based geogrids if proved cost-effective. Geogrids can be used for control of slips and slides in hilly slopes and to check the sustained migration of debris along the slopes. Such geogrids may be used with advantage in shallow surficial slides in areas with temperate rainfall and moderately cohesive soil cover. Central Road Research Institute (CRRI) used such geogrids in Himachal Pradesh, India. Till date, jute geogrids have been used sparingly.

Prefabricated Vertical Jute Drains (PVJD) should have a good market for ground improvement. A wide range of such drains with man-made yarns are being marketed commercially. PVJD are equally effective as substantiated by studies and trials. PVJD has been patented in the U K and Singapore and has also been registered as a utility model in Japan (Ramaswamy 1997). PVJD, according to reports, are being used in south-east Asian countries, especially in Indonesia for hastening consolidation of soft deep-seated clay. I.I.T, Delhi has devised a similar drain with a braided sheath. In India use of PVJD has been insignificant so far. PVJD needs special rigs for insertion into the ground. This could be a reason why the product has not found encouragement from the consultants.

Woven JGT has been experimented successfully as separator and fiiter *in reclamation of land from tne sea* (Tan et al 1994). But for some reasons use of woven JGT in land reclamation has not gained ground. It is felt that problems of reclamation of water-logged areas can be effectively obviated by use of JGT as separator and filter.

In hill slopes, fall of fine debris, especially during the monsoon, is common. This is precursor to heavier slips and slides. Arresting the detached aggregates within the slope itself is a way that can reduce or delay the chances of heavier damages as a result. Ranklor (1994) suggested erection of *silt fences* for this purpose. Silt fences can be constructed by erecting locally available timber/ bamboo/tree branches down the slope at suitable intervals and filling the interspaces between the posts with woven JGT. Understandably woven JGT screens will need replacement when it loses strength or worn out.

Prof Ramaswamy indicated in a paper (1990) that he had developed *jute geomembranes* while working in a UNDP project at Indian Jute Industries' Research Association, Kolkata. This was a blend of two layers of woven JGT impregnated with bitumen emulsion and a high density HDPE sheet sandwiched in between. It is however felt this exercise will not provide any commercial advantage. Moreover use of HDPE sheet sandwiched between JGT layers is apt to raise questions on the suitability of bitumen-smeared woven JGT as a water-proof barrier.

CONCLUSIONS

In order that prospective applications of JGT may find larger acceptability, it is imperative that technical requirements of the end-users should be precisely ascertained and appropriate JGT developed with an eye to the comparative commercial advantage over its man-made counterpart. It is to be accepted that JGT cannot match man-made GT in terms of durability. However in the majority of geotechnical applications, geotextile acts as a change agent to the soil on and in which it is laid. Durability therefore is a matter of secondary concern in such cases. JGT scores over its man-made counterpart if environmental aspects are considered. Measures to protect environment with eco-friendly materials should fetch a special discount.

Harding (1994) suggested an Erosion Control Benefit Matrix (ECBM) for comparative assessment of environmental management practices. The matrix takes into account six salient characteristics viz acceptance, cost, effectiveness, installation, vegetation establishment and maintenance with several sub-variables under each. JGT has distinct advantages in respect of each variable determinant. What is perhaps needed is to standardize each existing and prospective application of JGT, to exercise quality control over the product to meet the desired specification and to adopt a pro-active marketing strategy by the manufacturers. At the same time there should be no relenting of efforts to improve the products on the basis of scientific studies and research in the field. The deficiencies need be continually addressed through relentless research.

REFERENCES

1. Jute Geotextiles-A Survey of Marketing & Distribution Systems in Selectea European Countries—prepared by International Trade Centre UNCTAD/GATT for IJO (1991J

2 The Past, Present & Future for Geosynthetics in Indonesia : Ranklor P R

Geotextiles & Geomembranes-Vol 13, Nos 6-7-Elsevier applied Sciences, Oxford (1994)

3. Use of Jute Geotextiles in Layered Clay-sand Reclamation Schemes: Tan S A, Muhammed N, Karunaratne G P & Lee S L

Proc 5th International Confon Geotextiles, Geomembranes and Related Products-Volll-Singapore (1994)

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