QUALITY CONTROL OF JUTE GEOTEXTILES & DEVELOPMENT OF TESTING FACILITIES

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ABSTRACT

This study was undertaken to find out the feasibility of using Jute Geotextiles (JGT) as an alternative to man-made geotextiles in civil engineering applications. Four types of untreated JGT samples were selected from Bangladesh Jute Mills Corporation (BJMC) and Bangladesh Jute Research Institute (BJRI). Subsequently these were treated with bitumen. Physical, mechanical, hydraulic, short term and long term tensile tests were performed both on treated and untreated JGT samples. It is appreciated that, neither any standard test method nor any design approach related to JGT are currently available. The ASTM and DIN standard test methods for determining the properties and the design approach commonly employed for geotextiles were adopted.

The application areas for JGT were identified as the filtration in cross plane flow, separation of dissimilar materials, reinforcement of weak soils and in-plane flow. These applications, test methods and design approach have been discussed elaborately. The test procedures and results obtained are presented with graphs and charts. An attempt has been made to compare these test results with available geotextile data. Based on these test results some design examples have been presented using the procedures for geotextiles as outlined by Koerner (1997). An economic aspect related to geotextile and JGT is also presented in this study.

Key words : Jute geotextiles; synthetic geotextiles; biodegradability; index, mechanical and hydraulic properties; economic aspects.

INTRODUCTION

Jute geotextiles (JGT) has emerged as a strong alternative to synthetic geotextiles for many civil engineering applications. Synthetic geotextiles being made from non-biodegradable polymer based constituents such as polypropylene, polyester or polyethylene, have inherent advantage over natural fibre based biodegradable JGT for long-term applications. Due to their short life span, JGTs are used as separator, vegetation growing mesh on slopes or as vertical drains. Recently, Bangladesh Jute Research Institute **(BJRI)** and Bangladesh Jute Mills Corporation (BJMC) have developed some treatment techniques for JGTs which may enhance their life up to or even more than twenty years, Table 1. Development of such durable JGT materials is likely to allow them to be used in short-term to medium-term soil reinforcement applications, e.g. rural roads, construction access roads, flood and road embankments etc.

Besides, development of enhanced durability of JGT, it is equally important to set widely acceptable testing standards for these materials. Currently, in absence of any such recognized testing standard, the ASTM, BS, DIN or ISO methods of testing usually employed for synthetic geotextiles are most commonly adopted for the determination of the properties of JGT. Apparently there seems to be no reason why the standards used for synthetic geotextiles should not be applicable for JGTs. However, as the industry gains further momentum and use of JGT gets wider acceptance, the issue may be settled based on technical and construction experiences.

Table 1. Summary of jute blended with different materials at BJRI

Type	Compo-sition	Possible Durability	Bio degradibility	Moisture Content	Wt/Unit area	Tensile Strength (lb)
Woven Jute in different structure	Jute	2-6 month	Quick	12-14%	220-800	120-140
Woven Jute in different structure	Jute, Coir	5-12 month	Slow	7-10%	220-800	240-660
Woven Jute but treated composite	Jute Bitumen Carbon	6-48 month	Longrun	3-8%	Var.Wt.	140-700
Non woven	Jute blanket	6-18 month	Slow	8-12%	800	300-800
Non woven	Jute Blanket +Latex	5-20 year	Long run	5-7%	>800	>800
Woven with different construction	Jute latex	5-20 year	Long run	5-7%	>800	300-800

Source: Abdullah (1999) “A handbook on geotextiles particularly natural geotextiles from jute and other vegetable fibres”.

Test Results of some JGT Produced in Bangladesh

Untreated samples of Jute was obtained from BJRI and untreated Canvas, DWTwill and Hessian were selected from BJMC for the purpose of this study. It should be appreciated that Jute fabric is generally densely woven in which relatively flat type of yarn is used. It is manufactured in BJRI loom mainly for research purpose. However, if ordered, Jute fabrics can be produced in all the jute mills for commercial purpose as well. Canvas is a very densely woven fabric, woven by round twisted yarns. Canvas was used to be produced mainly in ABC Mill of Adamjee Jute Mills. After the layoff of Adamjee Jute Mills, all the machines were transferred to Latif Bawany Jute Mills situated at Demra of Dhaka. Canvas is the least porous out of the four and is now produced in Latif Bawany Jute Mills. DW Twill is also woven by using relatively flat type yarns like Jute. It is manufactured in many jute mills of Bangladesh. Hessian is the most porous amongst four and produced in all the jute mills of Bangladesh. Both DW Twill and Hessains are extensively used in the country mainly for packaging purpose.

Amongst the untreated JGT samples, Jute, Canvas and DW Twill samples were treated with bitumen by BJRI. The treatment procedure involved the following steps :

- i) preparation of carbon black with required quantity of volatile oil
- ii) addition of bitumen emulsion with paste followed by stirring
- iii) after mixing homogenously, the emulsion was laminated on the jute fabrics by brush and dried in sunlight or open area at normal temperature and pressure (NTP).

The salient properties of the samples are presented in Table 2.

Table 2. Salient properties of JGT samples

Trade Name	Source	Condition	Commercial Characteristics			
			Width (inch)	Wt. (oz/d^2)	Colour	Packing (yds/bale)
Jute	BJRI	Treated & Untreated	40-50	18-35	black & natural	500
Canvas	BJMC	Treated & Untreated	36-45	14-20	black & natural	1000
DW (Double Works) Twill	BJMC	Treated & Untreated	20-30	11-24	black & natural	500/1000
Hessian	BJMC	Treated	22-80	5-14	natural	700/2000

The tests were then performed on these treated and untreated JGT samples at the geotechnical laboratory of Bangladesh University of Engineering & Technology (BUET). The list of the tests carried out on these samples and the test methods employed for performing the tests are given in Table 3.

For the purpose of comparison of the test results of these JGT samples with the synthetic geotextiles commonly used in Bangladesh, test results of twenty different varieties of non-woven synthetic geotextiles were also obtained from BUET. The test results of JGT samples and non-woven synthetic geotextiles are summarized in Table 4. Some of the test results of JGT samples and non-woven synthetic geotextiles are also shown graphically in Figure 1 to Figure 5 for the purpose of comparison.

Table 3. Tests Performed on treated and untreated JGT samples

SL	ASTM/DIN	ASTM/DIN Test Name	Properties to be determined
1	D5261	Standard Test Method for Measuring Mass per Unit Area of Synthetic Geotextiles	Physical
2	D5199	Standard Test Method for Measuring the Nominal Thickness of Geosynthetics	Physical
3	D4595	Standard Test Method for Tensile Properties of Synthetic Geotextiles by the Wide-Width Strip Method	Mechanical
4	D4632	Standard Test Method for Grab Breaking Load and Elongation of Synthetic Geotextiles	Mechanical
5	DIN 54307	CBR Puncture Resistance	Mechanical
6	D 3786	Standard Test Method for Hydraulic Bursting Strength of Knitted Goods and Nonwoven Fabrics	Mechanical
7	D4751	Standard Test Method for Determining Apparent Opening Size (AOS) of a Geotextile	Hydraulic Properties
8	D4491	Standard Test Methods for Water Permeability of Synthetic Geotextiles by Permittivity	Hydraulic

Table 4. Test results of treated JGT, untreated JGT and synthetic geotextiles (Mohy 2005)

Product	Condition	Mass per unit area (g/m²)	Thickness (mm)	Wide width tensile strength (kN/m) MD/XMD	Grab tensile strength (N) MD/XMD	CBR puncture resistance (N)	Burst strength (kPa)	Permitivity (S^{-1})	AOS (mm)
Jute	Treated	1600	3.5	15/18	800/700	4000	1500	0.06	0.0 to <0.075
	Untreated	800	2.8	10/12	400/220	1500	1250	0.28	0.28
Canvas	Treated	1200	2.5	27/15	1100/700	1800	1600*	0.0	0.0 to >0.075
	Untreated	500	1.3	23/14	850/400	1700	2400	0.03	0.09
DW Twill	Treated	1400	3.1	25/32	1000/900	1700*	2600	0.21	<0.075
	Untreated	750	2.4	23/26	900/750	4500	2400	0.25	0.8
Hessian	Untreated	300	1.5	12/14	210/220	1500	1400	1.19	1.0
Synthetic	Non-Woven Geotextiles	240-640	2.0-4.5	[18-48] /[15-31]	[1160-2590] /[780-1900]	2660-5450	3800-4500	0.4-1.8	

Reduced after treatment

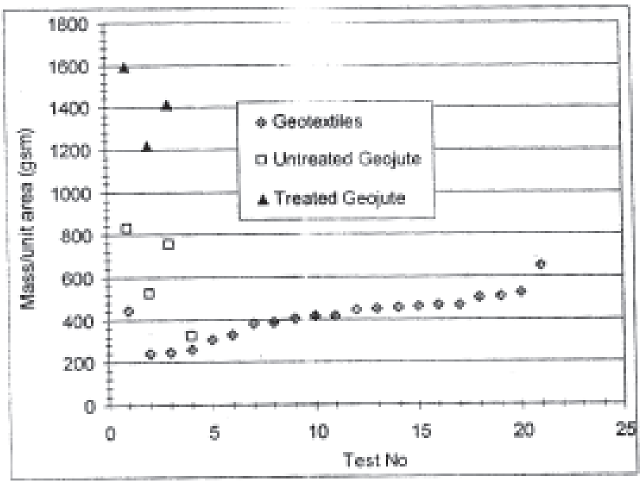

Figure 1. Mass per unit area of synthetic geotextiles, untreated JGT and treated JGT (Mohy, 2005)

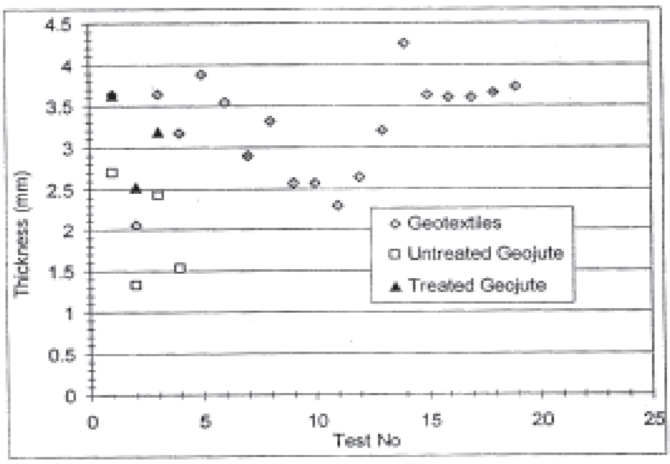

Figure 2. Thickness of synthetic geotextiles, untreated JGT and treated JGT (Mohy, 2005)

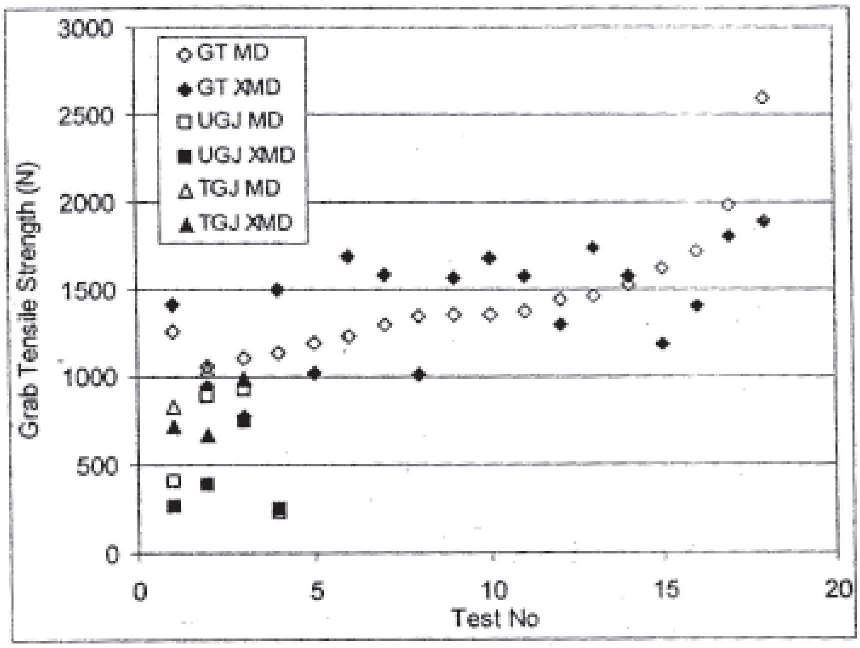

Figure 3 . Grab tensile strength of synthetic geotextiles, untreated JGT and treated JGT (Mohy, 2005)

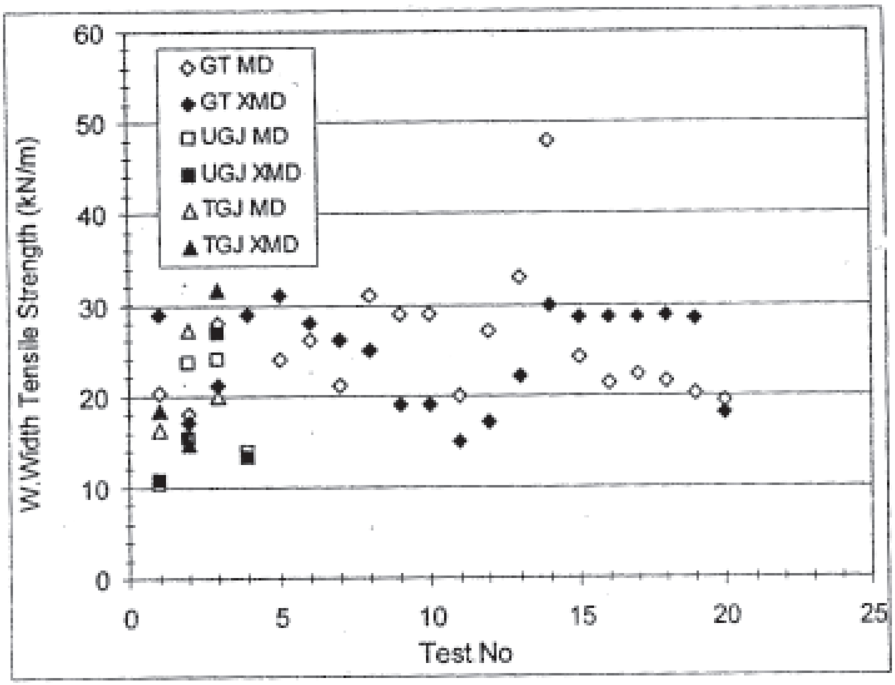

Figure 4. Wide-width tensile strength of synthetic geotextiles, untreated JGT and treated JGT (Mohy, 2005)

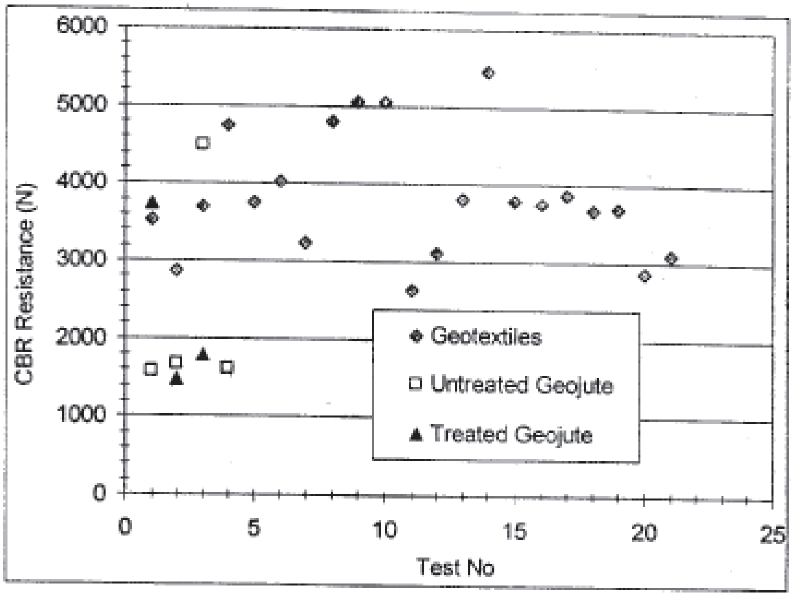

Figure 5. CBR strength of synthetic geotextiles, untreated JGT and treated JGT (Mohy, 2005)

It may be noted from these test results that the properties of JGT samples generally improve after treatment. However, AOS and cross-plane permeability of some of the samples (Jute and Canvas) literally reduces to zero due to blocking of the openings by application of bituminous agents for treatment. It should be further appreciated that synthetic geotextiles have better index, mechanical and hydraulic properties compared to JGT materials. This indicates that manufacturers and researchers should put more technical efforts to improve the properties of JGT materials so that they become obvious alternative to synthetic geotextiles.

REDUCTION FACTORS/PARTIAL FACTORS FOR JGT

Reinforced soil walls, embankments, slopes etc. are generally analysed and designed by Limit Equilibrium Method or Limit State Approach. Both of these design methods/approaches apply several reduction factors or partial factors to the ultimate values of synthetic geotextiles in order to obtain an allowable value of the mechanical and hydraulic properties.

Strength-Related Problems

In strength related problems the allowable value for synthetic geotextiles obtained as :

$$T_{allow} = T_{ult}\left[\frac{1}{RF_{ID} \times RF_{CR} \times RF_{CD} \times RF_{BD}}\right]$$

Where :

Tallow = allowable tensile strength of synthetic geotextile

Tuit = ultimate tensile strength of synthetic geotextile

RF_{ID} = reduction factor for installation damage

RF_{CR} = reduction factor for creep

RF_{CD} = reduction factor for chemical degradation

RF_{BD} = reduction factor for biological degradation

Typical values for strength reduction factors are given in Table 5. These values are usually tempered by the site-specific considerations.

Table 5. Recommended reduction factor values for strength-related problems (Koerner 1997)

Application Area	Range of Reduction Factors			
	Installation Damage	Creep	Chemical Degradation	Biological Degradation
Degradation Separation	1.1 to 2.5	1.5 to 2.5	1.0 to 1.5	1.0 to 1.2
Unpaved roads	1.1 to 2.0	1.5 to 2.5	1.0 to 1.5	1.0 to 1.2
Walls	1.1 to 2.0	2.0 to 4.0	1.0 to 1.5	1.0 to 1.3
Embankments	1.1 to 2.0	2.0 to 3.5	1.0 to 1.5	1.0 to 1.3
Bearing capacity	1.1 to 2.0	2.0 to 4.0	1.0 to 1.5	1.0 to 1.3
Slope stabilization	1.1 to 1.5	2.0 to 3.0	1.0 to 1.5	1.0 to 1.3
Pavement overlays	1.1 to 1.5	1,0 to 2.0	1.0 to 1.5	1.0 to 1.1

Flow-Related Problems

For filtration and drainage applications problems dealing with flow through or within a synthetic geotextile, the formulation of the allowable values takes the following form :

$$q_{allow} = q_{ult}\left[\frac{1}{RF_{SCB} \times RF_{CR} \times RF_{IN} \times RF_{CC} \times RF_{BC}}\right]$$

Where :

qallow = allowable flow rate of synthetic geotextile

qult = ultimate flow rate of synthetic geotextile

RF_{SCB} = reduction factor for soil clogging and blinding

RF_{CR} = reduction factor for creep reduction of void space

RF_{IN} = reduction factor for adjacent materials intruding into synthetic geotextile void

RF_{CC} = reduction factor for chemical clogging

RF_{bc} = reduction factor for biological clogging

Typical values for flow reduction factors are given in Table 6. It may be noted that these values are generally tempered by the site-specific conditions.

Table 6. Recommended reduction factor values for flow-related problems (Koerner 1997)

Application Area	Range of Reduction Factors				
	Soil Clogging and Blinding	Creep Reduction of Voids	Intrusion into Voids	Chemical Clogging	Biological Clogging
Retaining wall filters	2.0 to 4.0	1.5 to 2.0	1.0 to 1.2	1.0 to 1.2	1.0 to 1.3
Underdrain filters	5.0 to 10	1.0 to 1.5	1.0 to 1.2	1.2 to 1.5	2.0 to 4.0
Erosion-control filters	2.0 to 10	1.0 to 1.5	1.0 to 1.2	1.0 to 1.2	2.0 to 4.0
Landfill filters	5.0 to 10	1.5 to 2.0	1.0 to 1.2	1.2 to 1.5	5.0 to 10
Gravity drainage	2.0 to 4.0	2.0 to 3.0	1.0 to 1.2	1.2 to 1.5	1.2 to 1.5
Pressure drainage	2.0 to 3.0	2.0 to 3.0	1.0 to 1.2	1.1 to 1.3	1.1 to 1.3

It should be appreciated that, to date, no such reduction factors/partial factors have been identified for JGT materials. This is an area where researchers and industries should pay immediate attention for successful implementation of JGT projects. Meanwhile, the values recommended for synthetic geotextiles may be adopted.

DESIGN EXAMPLES

Anlysis and design for separation, filtration, drainage, reinforced wall and reinforced embankment using the properties of JGT samples have been carried out for the design examples given by Koerner (1997) for the purpose of comparison of outcome designs with those of synthetic geotextiles. By way of example, design of a JGT reinforced vertical wall and design of goejute filter behind a retaining wall are presented.

JGT reinforced vertical walls

A 6 m high wrap-around type of JGT wall is to carry a storage area of equivalent dead load of 10 kPa. The wall is to be backfilled with a granular soil (SP) having the properties of $\gamma = 18$ kN/ m^3, $\varphi = 36°$, and $c_a = 0$. A treated DW Twill with warp (machine) direction ultimate wide-width tensile strength of 25 kN/m (Table 4) and friction angle with granular soil of $\delta = 24°$ (since no test of DW Twill related to φ is carried out, the usual value applied for synthetic geotextile, i.e. 2/3 φ taken) is intended to be used in its construction. The orientation of the JGT is perpendicular to the wall face and the edges are to be overlapped or sewn to handle the weft (cross machine) direction. A factor of safety of 1.4 is to be used along with site-specific reduction factors. For the design of this JGT wall, the method outlined by Koener (1997) for synthetic geotextile reinforced walls is used. The outcome design is shown in Figure 6.

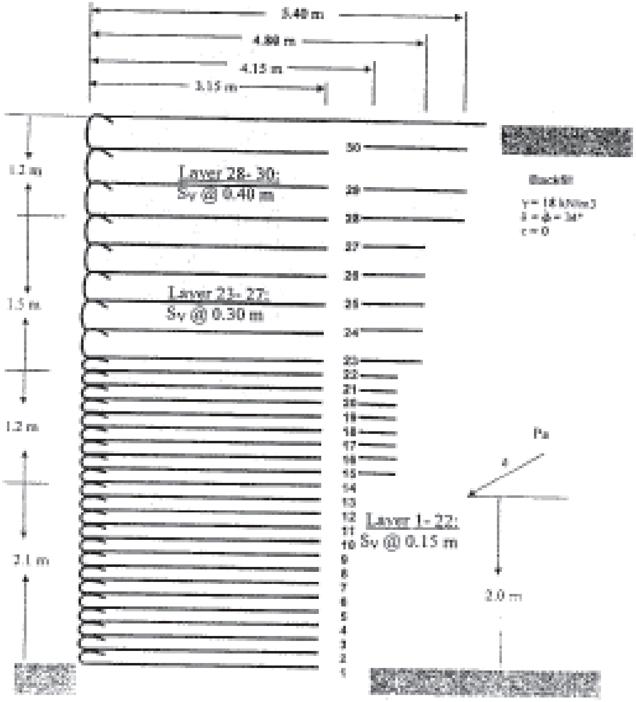

Figure 6. Outcome design of a 6.0 m high wall using treated DW Twill JGT filter behind a retaining wall

Given a 3.5 m high gabion wall consisting of three 1 x 1 x 3 m long baskets sitting on a 0.5 x 2 x 3 m long mattress as shown below, the backfill soil is a medium-dense silty sand ofd_{10} = 0.03 mm, C_u=2.5, k = 0.0075 m/s, and D_R = 70%. It is required to check the adequacy of four candidate untreated JGTs whose laboratory test properties are given below. The recommended reduction factors and design method outlined by Koemer (1997) are used.

No	JGT Type	Permittivity (s^{-1})	AOS(mm)
1	Jute	0.28	0.28
2	Canvas	0.03	0.075
3	DWTwill	0.25	0.8
4	Hessian	1.19	1.0

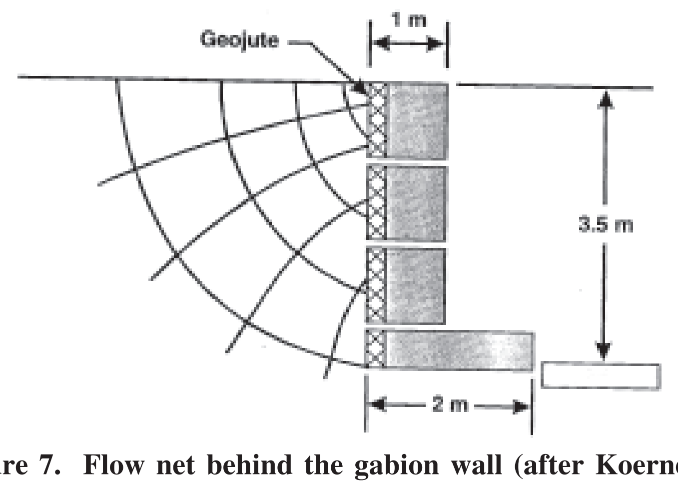

Figure 7. Flow net behind the gabion wall (after Koerner, 1997)

The design of filter is intended to ensure :

i) Adequate flow of water across the plane of JGT. This is achieved through a factor of safety of 2.0 against permittivity.

ii) No backfill soil loss through the JGT filter. This is achieved by satisfying the Carroll (1983) criteria $O_{95} < 2.5\ d_{85}$

On the basis of the and the procedure outlined by Koerner (1997) the outcome analysis is summarized in Table 7.

Table 7. Summary of the outcome analysis of the JGT filter design (Mohy, 2005)

Product	FoS against permittivity	FoS against AOS	Remarks
Untreated Jute	10.9 > 2.0	1.34 > 1.0	Acceptable
Untreated Canvas	1.17 < 2.0	5.0 > 1.0	Unacceptable
Untreated DWTwill	9.94 > 2.0	0.46 < 1.0	Unacceptable
Untreated Hessian	47.0 > 2.0	0.375 < 1	Unacceptable

Thus, it appears that for the given problem untreated Jute may be considered to be the only competent candidate.

COMPARATIVE COSTS OF JGT AND SYNTHETIC GEOTEXTILES

In making a proper economic assessment or evaluation, a number of inputs are required such as material cost, labour cost etc. Again, these inputs vary from place to place. In this study, an attempt has been made to analyse the comparative costs of untreated and treated JGT collected from BJRI, BJMC and local market. The comparative costs of the untreated JGT samples are shown in Figure 8.

A cost comparison between different types of locally available synthetic geotextiles is shown in Table 8. It appears that locally manufactured synthetic geotextiles are cheaper than the imported ones. No woven synthetic geotextiles are produced locally and prices of imported woven synthetic geotextiles are around 10% more than the nonwoven ones. The comparative costs of treated JGT with synthetic geotextiles are shown in Figure 9.

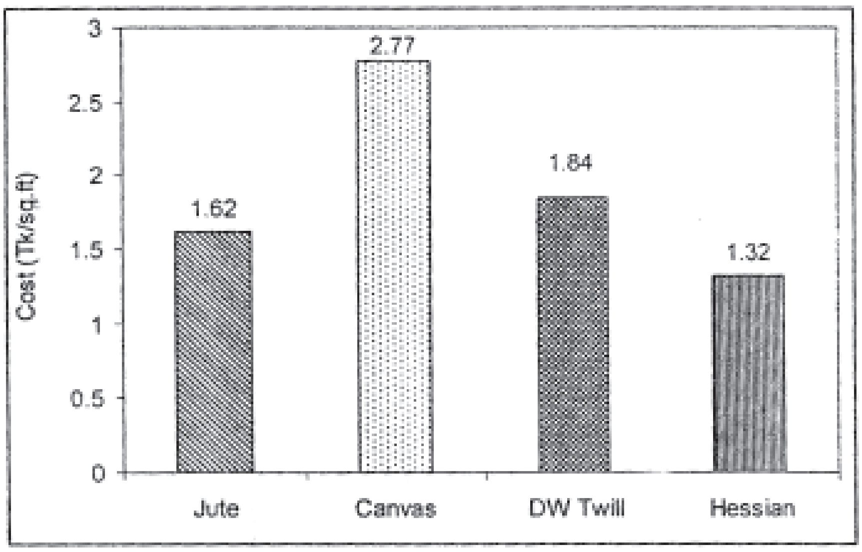

Figure 8. Comparative costs of the untreated JGT samples (Mohy, 2005)

Table 8. Cost of woven and nonwoven synthetic geotextile (Mohy, 2005)

Thickness (mm)	Cost / sft (Tk)		
	Woven (locally produced)	Nonwoven (Imported) (including tax)	Woven (Imported) (including tax)
1.5	4.65	5.55	6.11
2.0	5.11	7.09	7.80
2.5	5.40	8.31	9.14
3.0	6.50	11.19	12.30
3.5	7.43	13.25	14.58
4.03	8.36	17.36	19.10
Average	6.25	10.46	11.51

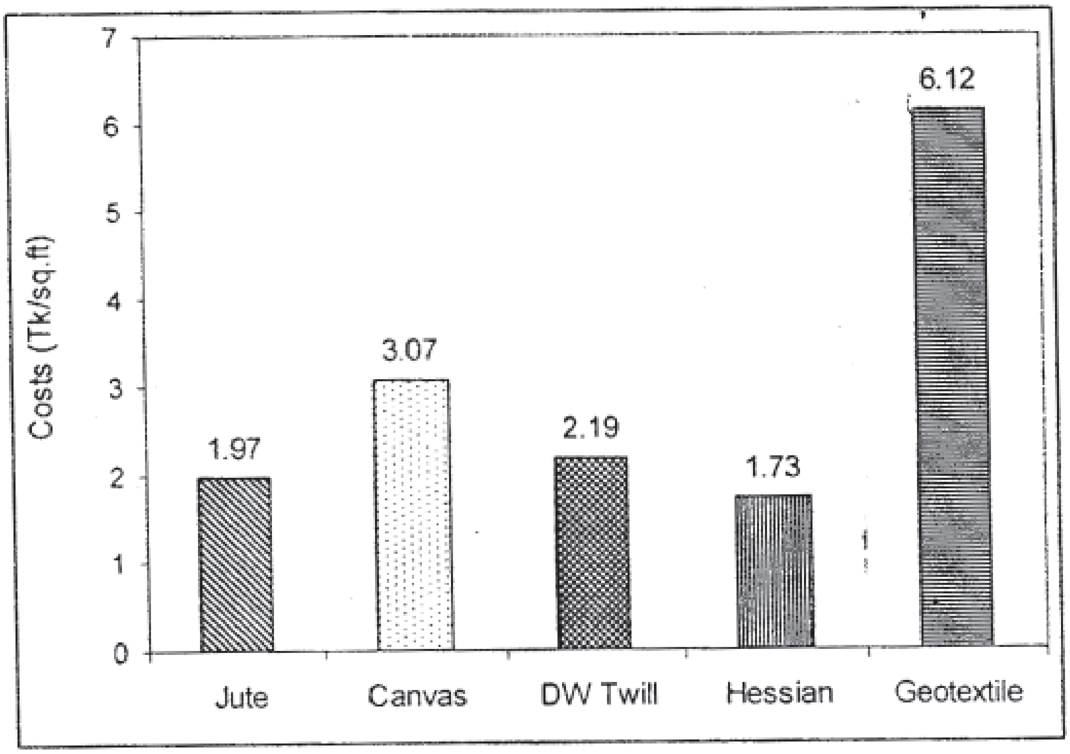

Figure 9. Comparative costs of treated JGT samples with synthetic geotextiles available in Bangladesh (Mohy. 2005)

The costing of different jute products developed by BJRI in 1997 by blending jute with hydrophobic fiber like coir or by modification with bitumen, latex and was resinous materials with the collaboration of BJMC and other governmental and nongovernmental organizations are listed in Table 9.

Table 9 : Summary of cost of jute blended with different materials at BJRI

Type	Composition	Possible Durability	Wt./Unit area	Cost Tk/yd^2
Woven Jute in different structure	Jute	2-6 month	220-800	8-18
Woven Jute in different structure	Jute, Coir	5-12 month	220-800	12-32
Woven Jute but treated composite Jute Bitumen Carbon	6-48 Month	Var.Wt.	12-35	
Non woven Jute blanket	6-18 month	800	65	
Non woven	Jute Blanket + Latex	5-20 year	≥ 800	80
Woven with different construction	Jute latex	5-20 year	≥ 800	20-40

(Source ."Directorate of Technology, BJRI)

ECONOMIC BENEFIT OF USING JGT IN DIFFERENT APPLICATIONS

On the basis of the analysis and design with JGT and synthetic geotextiles undertaken in this study for different applications and also on the basis of the costs of these materials mentioned above, it is suggested that by using JGT materials instead of synthetic geotextiles, a cost benefit of 35%-50% may be obtained. However, the technical shortcomings and durability restrictions of JGT materials must be appreciated prior to any application.

CONCLUDING REMARKS

It is appreciated that the inherent drawback of the untreated JGT materials is their short life span due to biodegradability. This restricts JGTs to be used as separator, vegetation-growing mesh on slopes or as vertical drains. Recently, BJRI has been able to develop some treatment techniques by means of which it is possible to ensure 'designed biodegradability' of these materials. Development of such durable JGT materials is likely to allow them to be used in short-term to medium-term soil reinforcement applications, e.g. rural roads, construction access roads, flood and road embankments etc. Although a lot requires to be done regarding determination and improvement of their index properties, mechanical properties, hydraulic properties, interaction behaviour and reduction factors, based on the current methods of designing with synthetic geotextiles, JGT materials seem to be a potential alternative. This is further accentuated by the significant cost benefit that may be accrued from using JGT materials instead of synthetic geotextiles.

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STANDARDISATION OF JUTE GEOTEXTILES : THEIR APPLICATIONS AND RELATED REGULATORY ISSUES

R. Jane Rickson

ABSTRACT

This paper will present the various types of geotextile currently available, in terms of physical format, composition and end use. There is evidence of increasing market demand for geotextiles (both in the traditional markets and in jute-producing countries) for diverse applications such as ground separation, earth reinforcement, slope stabilization, groundwater filtration, drainage, soil erosion control and vegetation management. Independent research in the laboratory and field has shown jute geotextiles to be technically "fit for purpose", especially in the fields of soil erosion control and vegetation management. There is also potential use of these products in the stabilization of rural earth roads.

The advantages of jute geotextiles over competitive products include :

- technical performance / effectiveness in the specified end uses
- cost per unit area
- sourcing from renewable raw materials
- utilization of high volumes of relatively low grade materials
- maintenance of rural livelihoods in jute-producing countries
- production based on existing, well-established manufacturing processes
- environmental friendliness (biodegradable, enhancement of natural resources)
- landscaping aesthetics.

However, these technical and socio-economic advantages of Jute Geotextiles are not reflected in the current market share. Reasons for this include :

- end-users' perceptions (e.g. quality of product and perceived impact this has on technical performance)
- real (and perceived) patterns of supply and demand, including reliability and timeliness of supply
- non-compliance of Jute Geotextile products with technical standards and specifications, such as those set in the US (ASTM, IECA and ECTC) and Europe (CEN).

The aim of this paper is to overcome the barriers to the adoption of Jute Geotextiles in the specified end-uses of erosion control, vegetation management and stabilization of rural earth roads. The paper will consider both traditional markets in developed countries as well as expanding novel markets in jute producing countries.

INTRODUCTION

Geotextiles are "permeable textiles used in conjunction with soil, foundation, rock, earth or any geotechnical engineering related material, as an integral part of a man made project" (John, 1987). The use of textiles in the construction industry is not new : there are examples of linen fabrics being incorporated into artificial slopes in ancient Egypt, and reinforcing cotton fibres have been found in centuries-old Chinese engineered slopes. In modern times, the use of textiles in civil engineering developed during the 1960s as a result of the expanding construction industry in North America and Europe, and the availability of cheap, surplus synthetic fabrics (such as nylon and polypropylene), in search of novel (i.e. non-clothing) markets. More recently, the emphasis on "environmentally friendly" products and "green" issues (such as the use of sustainable and renewable resources, and supply chains which minimise carbon footprints) has encouraged the expansion of the natural geotextile market, including the use of jute geotextiles. One potential new application of these products is in the construction and functioning of "ecotowns and cities", where green technologies are increasingly used.

At present there is a huge global demand for suitable textiles to be used in the civil engineering and construction industries. This market has grown from 250 - 400 million metre^2 per annum in 1996 (CFC/IJO, 1996), to 1,400 million metre^2 by 2003 (Pant, 2003). The annual growth rate has been estimated to be between 8.5% - 10% (Jagielski, 1990; Pant, 2003 respectively). Despite the significant market size and growth rate, jute geotextiles only comprise a very small fraction of these sales (estimated to be between 1 % - 7.5% (Pant, 2003; CFC/IJO, 1996 respectively).

The purpose of this paper is to evaluate the potential use of jute geotextiles, and to understand why this potential has not been fully realised to date. First, the benefits and advantages of jute geotextiles over competing products are highlighted, in terms of technical effectiveness (assessing whether jute geotextiles are "fit for purpose"). Second, the socio-economic and environmental impacts of sourcing jute geotextiles are discussed. Third, the disappointing market share of jute geotextiles is explained by identifying the barriers to the specification and adoption of these products by end users. Finally, the paper suggests ways in which these barriers can be overcome, so that the demand for jute geotextiles will increase, both in the traditional markets in developed countries, and in expanding novel markets in jute producing countries. In turn this will ensure environmental protection where these products are applied, and a sustainable livelihood for the thousands of people employed in the jute and allied industries throughout the world.

Types of Geotextile

Geotextiles are available in the form of mats, sheets, grids and webs made of woven, non-woven, knitted, or extruded fabrics. Geotextiles are made from natural or synthetic materials, or a combination of both. Synthetic geotextiles include polypropylene, nylon, polyester and polyethylene, which can be manufactured to very exacting technical specifications. Natural products include jute, coir, sisal, wood chips or shavings and paper. Giroud (1990) provides a full classification of geotextile products: the diverse range is highly dynamic, with new products frequently coming on the market.

Applications and Market demands

Geotextiles are used in a variety of applications, including ground separation, earth reinforcement, slope stabilisation, groundwater filtration, drainage, soil erosion control and vegetation management. Traditionally geotextiles have been used in developed countries, notably the USA, Japan and Europe. However, recently there has been increased interest in the potential use of these products in new markets, including those in jute-producing countries. Synthetic geotextiles dominate the applications of filtration, separation, slope stabilisation and drainage. This is because there are strict technical specifications required of these applications, which natural products cannot attain, such as porosity, tensile strength, durability, resistance to both weathering and microbiological attack, and hydraulic conductivity (see section 5 below referring to the constraints to the adoption of jute geotextiles). These are set in countries with high geotextile use, by international bodies such as the British Standards Institute (BSI), the American Society for Testing and Materials (ASTM), Standards Australia (SA), the European Committee for Standardisation (CEN) and the International Standards Organisation (ISO).

However, there are situations where these strict technical specifications may not be essential (and indeed are sometimes irrelevant) for effective product performance. It is in the applications of soil erosion control, vegetation management and stabilisation of rural earth roads, that jute based geotextiles have shown effectiveness in terms of technical performance, as well as accruing socio-economic and environmental benefits.

GEOTEXTILE PERFORMANCE

Technical performance of jute geotextiles

a) Soil erosion control

Whilst there are many case studies around the world where jute geotextiles have been used for soil erosion control (Rickson, 2000), there has been relatively little scientific, objective testing of these products. In 1994, the Common Fund for Commodities (CFC) and the International Jute Organisation (IJO) jointly funded a project entitled "Technical Specification and Market Study of Potentially Important Jute Geotextile Products". This project presented data that compared the effectiveness of various jute geotextile products with other competitor geotextiles available on the market (CFC/ IJO, 1996; CFC, 1998), including other natural and synthetic erosion control products. The tests were performed under numerous environmental conditions, with different rainfall intensities and soil types. In a significant majority of the experimental erosion control tests, woven jute products performed best (Figure 1).

Rickson (2000) went on to analyse why the jute products performed so well at controlling soil erosion. She correlated the physical characteristics of the geotextile products with erosion control performance and found that the following properties are extremely important:

a) Area of the geotextile (% cover)
b) Water holding capacity of the geotextile
c) Geotextile induced roughness to the flow
d) Weight of geotextile when wet
e) Depth of flow ponded by the geotextile.

Identifying these "salient" properties is vitally important for end users, manufacturers and specifiers of erosion control geotextiles. End users can apply this knowledge to evaluate both the products they currently use, and any alternative products available on the market. Specifiers and representatives on Standards Committees should ensure that these salient properties are quoted in any compliance standards used by the erosion control industry. Manufacturers can use the information on salient properties to improve existing products, and to design new, more effective erosion control geotextiles.

b) Vegetation management

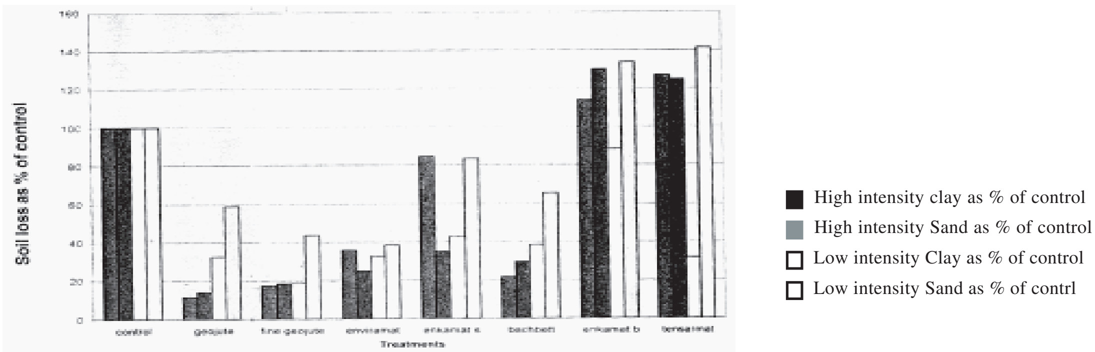
The establishment of vegetation following engineering works such as road construction, urban development or creation of new amenities is one of the greatest challenges in landscape management. Geotextiles may help to establish vegetation by creating more stable, non-eroding conditions by controlling erosion processes (see above). This will result in less washout of seeds and seedlings from slopes, and a reduction in damage to new plants through heavy rainfall and runoff. Geotextiles may also alter local microclimate and soil moisture on slopes, so enhancing vegetation establishment and growth (Fifield et al., 1987; Reynolds, 1976; Dudecketal., 1970).

At present, despite the widespread availability of geotextile products, there is a lack of scientific validation of their effectiveness and efficacy for vegetation establishment and growth. However, as part of the CFC/IJO project detailed above (CFC/IJO, 1996; CFC, 1998), an experiment was devised to test different geotextiles, including jute based products, in aiding vegetation establishment. All geotextile treatments had greater germination rates than the bare soil control plots. The high percentage cover, non-woven products produced the highest rates of seed germination. This is because they retained more soil moisture by restricting evaporation losses. They also insulated against heat losses from the soil trays at night, thereby maintaining optimum temperatures for germination. The jute woven products, with their relatively low percentage cover did not increase the germination rates to such an extent, but did increase rates compared to the control.

After Day 10, the vegetation was assessed visually on a percentage cover basis. The results for the natural geotextile products are shown in Figure 2. The figure shows that all the products had a relatively steady increase in vegetation cover over the course of the trial. All the woven jute products helped promote the growth of the seeded clover, which produced a much denser cover than the dicotyleous species found on the control plots.

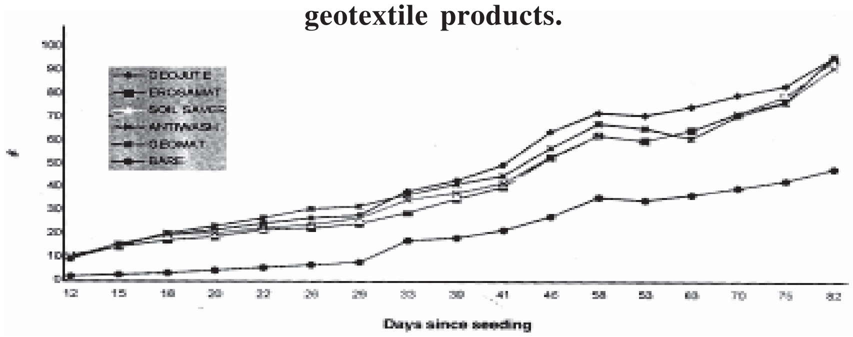
Figure 1. Relative performance of erosion control geotextiles

Mean Rainsplash Results



Although the Erosion Control Technology Council (ECTC) has drafted a standard relating to the “determination of temporary degradable rolled erosion control products performance in encouraging seed germination and plant growth”, no internationally recognised technical compliance standards exist for geotextiles used in vegetation management. It is important that the properties listed above are included in the criteria used in compliance or standards setting in the future.

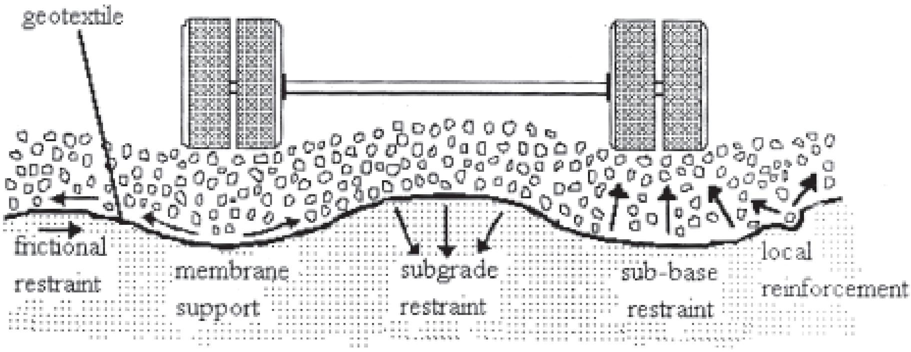
Figure 2. Vegetation establishment: Percentage cover for natural, woven geotextile products.



c) Stabilisation of rural earth roads

Geotextiles can be used to enhance the soil's bearing capacity. The geotextile is used to separate the various layers which comprise the structure of the road. The geotextile can prevent intermixing of the relatively stronger aggregate material (sub-base), and the relatively weaken in-situ soil (or sub-grade). Buried geotextiles will also provide local reinforcement and prevent lateral sliding of the aggregate (Figure 3). In this way, geotextiles may allow a reduction in the thickness of the pavement construction. This may represent savings as to the cost of road building.

Figure 3. Geotextile stabilisation of an **unpaved road (John, 1987).**



Little research or applied work has concentrated on the specific use of jute geotextiles for this end use. Woven jute geotextiles will have limited ability to provide a physical barrier to the intermixing of the aggregate and subgrade soil, but potentially these products could provide local reinforcement, restrain the aggregate sub-base from downward and lateral movement in the rut, restrain the subgrade soil from upward and lateral movement between the ruts, act as a support membrane and provide sufficient friction to limit lateral sliding of the aggregate.

Despite these potential functions, limited work has been carried out to test jute geotextiles in this application. The few studies that have been carried out (e.g. Ramaswarmy & Aziz, 1982; 1983; 1991; Rao et al., 1994; CFC/IJO, 1996) have recognised that jute geotextile products are able to impart tensile strength to soil and improve the ground bearing capacity, so improving trafficability of structures such as rural roads, compared to where no product is used at all. Some reduction in rut depths has also been reported. More research is needed in the physical performance of these products, bearing in mind their characteristics such as biodegradation over time. Also, despite the potential effectiveness of jute geotextiles in this application, the physical properties of jute geotextiles often fail to meet the strict technical compliance standards which dictate the specification of such products (Table 1).

Table 1. Compliance with European Standards for tensile strength (CFC/IJO, 1998)

Product	Tensile strength (Measured)	Belgium	France	Germany	Sweden
500 g/m^2 jute woven	3.4 kN/m	≥ 15 kN/m	12 kN/m	35 kN/m	20 kN/m

Socio-economic benefits of jute geotextiles

In addition to the technical advantages of jute geotextiles over competitive products, jute products remain competitively priced in terms of cost per unit area (including material and installation costs). This is partially explained by the utilisation of high volumes of relatively low grade materials in the manufacture of woven jute geotextiles. Also, the production of jute geotextiles does not require new technology or industrial infrastructure. Production of jute geotextiles is based on existing, well-established manufacturing processes. By expanding the markets for jute geotextiles, the income received will help maintain thousands of (mainly rural) livelihoods in jute-producing countries.

Environmental benefits of jute geotextiles

At a time when the sustainability of resources is being scrutinised, jute geotextiles have a significant advantage in that they are sourced from wholly renewable raw materials. They are perceived to be environmentally friendly as they are made from 100% natural materials, which have little environmental impact as they are completely biodegradable. It is claimed that the organic matter returned to the soil on fibre break down will enhance the soil's carbon and nutrient content. Finally, jute geotextiles are aesthetically pleasing in the landscape, as opposed to synthetics competing product, even when these are dyed green to "blend" into the surrounding environment.

Constraints to use

The technical, environmental and socio-economic advantages of jute geotextiles as outlined above clearly illustrate the potential of jute based products for use as geotextiles in the fields of soil erosion control, vegetation establishment and stabilisation of earth roads. The greatest market potential lies in the application of erosion control, and yet surprisingly, jute geotextiles only comprise 7.5% of this market. This anomaly between potential and actual use is discussed below.

End users' perceptions

There have been (largely unfounded) concerns about the quality of jute geotextiles from end users. Natural products show a variability in physical properties such as warp and weft density, roughness of the fibres etc. which may be taken as inconsistency of product quality. However, there is no evidence to show that these irregularities affect the overall performance of these products in controlling erosion or aiding the establishment of vegetation.

There have also been concerns about the use of mineral oil in the production of jute woven textiles, and the environmental fate of any residue left on the jute fibres after installation. Whilst studies have been carried out to allay these concerns, some end users are yet to be convinced of the true environmental credentials of jute products. Currently, IJIRA are conducting trials to assess the use of vegetable oils (e.g. rice bran oil) instead of the traditional mineral oil in the manufacture of jute geotextiles.

Real (and perceived) patterns of supply and demand

In the past there has been concern as to the reliability of supply of jute geotextiles. For example, in the UK, end users have been disappointed that they are unable to source adequate quantities of jute erosion control geotextiles. This is because high transport costs from jute producing countries mean it is only economically viable to import high volumes of jute geotextiles. Importers will only purchase high volumes of jute to minimise transport costs and overheads. This means the supply side of the market is not very responsive to demands. End users would rather specify competing products than wait for the next consignment of jute geotextiles to be imported.

Non-compliance of jute geotextile products

In many industrial sectors, quality assurance and compliance standards are given very high priority. The geotextile and geosynthetics industries are no exception, with increasing number of standards, specifications, reference properties and performance targets, ensuring the products are capable of doing the task they are designed to do. Products must comply with these standards, so giving confidence and assurance to potential end users. For geotextiles, most of this work has been undertaken for the end applications of separation, filtration, drainage and slope stabilisation (see for example, British Standards Institute, 1987; 1997a ; 1997b; 1997c).

However, for soil erosion control geotextiles, few standards have been formulated or set to date. Committees are being set up within various organisations specifically for this purpose. These include the European Committee for Standardisation (CEN) (Technical Committee 189), the AASHTO-AGC-ARTBA (American Association of State Highway Transportation Officers - American Geotextile Council - American Road and Transportation Builders Association) Joint Committee, the ECTC (Erosion Control Technology Council), the IECA (International Erosion Control Association) and the ASTM (American Society for Testing and Materials). The latter organisation's Subcommittee D18.25 on Sediment and Erosion Control currently has three proposed test methods for erosion control blankets in the ballot process (http://www.ieca.org).

Perversely, standards that do exist already concern geotextile properties that actually have no influence on erosion control performance, such as resistance to weathering and microbiological attack when buried (BSI, 1997b; 1997c). Another compliance standard, tensile strength, is often specified, for example BS 6906 Part 1 (BSI, 1987), with critical thresholds that must be met by products. However, tensile strength has no relation with erosion control effectiveness, as tested with correlation analysis (Rickson, 2000). Correlation of the tensile strengths of the various geotextiles with their ability to control erosion provides a correlation coefficient of $r = +0.0364$, which is not significant.

The American Society for Testing and Materials (ASTM) set a number of compliance standards for geotextiles (although no specific end use is quoted) (http://www.astm.org/search/ iatoc). These include thickness (ASTM D1777), mass/unit area (ASTM D3776-84) and tensile strength (ASTM D1682). Again, it appears that there is no relationship between these properties and geotextile erosion control performance, although there is a significant correlation ($p<0.05$) between soil loss and mass/unit area.

However, as listed above, other physical characteristics of geotextiles are correlated with erosion control performance, namely :

- percentage cover,
- geotextile induced roughness/Mannings 'n'
- dry geotextile weight,
- wet geotextile weight,
- ability to increase flow depth,
- water holding capacity.

To date, none of these properties has been considered by the compliance and standards committees. It is suggested that the mismatch between compliance criteria and salient properties of geotextiles for erosion control has two explanations. First, the new erosion control standards committees comprise experienced individuals who have sat on similar committees concerned with the other end uses of geotextiles (such as filtration, separation-and drainage). In these applications, properties such as tensile strength and durability are important. In contrast, the salient properties of geotextiles with respect to erosion control as listed above are largely unknown outside the erosion control industry. The standards committees will only set criteria with which they are familiar, and which have been defined as standards for the other geotextile end uses, inappropriate though these are to erosion control products.

The second explanation for the discrepancy between formulated standards and actual salient properties is of greater concern, especially for the natural fibre manufacturers and distributors. This point is voiced by CFC/IJO (1996): "Specifications and classifications for geotextiles are not formulated from purely altruistic, technical considerations, but contain a substantial commercial interest". There is concern in some quarters that the synthetics lobby on the Standards Committees is attempting to marginalise natural products, such as jute and coir. This is done by deliberately setting technical specifications that can never be met by the natural products, but that can be met easily by the synthetic products. This is why properties such as yarn thickness, mat density, tensile strength and durability are selected by the committees as the criteria for geotextile specification. The inherent, natural variability of natural products such as jute and coir woven products is one reason why these products can never meet such exacting standards, even though these products are the more effective at erosion control. Thus these geotextiles will never be selected as they consistently fail to attain the standards set by the synthetics-biased Standards Committees.

It is difficult to see how this situation will change, as individuals who are keen to promote the natural products are seriously under represented on the standards committees. CFC/IJO (1996) warns "It is unlikely that products which do not comply with future ASTM, IECA or ECTC standards will flourish in the US market". The commercial implication of this statement is that the natural products will be denied a share of at least 58% of the world consumption of erosion control geotextiles (=101 million m^2). Since the raw materials for natural products are often sourced from lesser developed countries (e.g. jute), this situation has implications for their economies and for world trade.

Thus there are considerable constraints to the use of jute erosion control geotextiles. However, none of these constraints is insurmountable, but overcoming them will depend on better education of the extensive benefits of erosion control geotextiles, better understanding of the salient properties of effective geotextiles and better promotion in all sectors of the erosion control industry of the most cost-effective products.

If compliance standards for erosion control geotextiles are to be used in the future by the industry, it is vital that the natural geotextile manufacturers and distributors are represented on the committees who set these standards. Failure to do this will mean the synthetics lobby will continue to dominate, and for whatever reason, the performance targets favouring synthetic products will be used, rather than instigation of novel criteria, which reflect soil erosion control effectiveness more realistically. There is a real danger that effective products will fail to comply with performance standards, and so will never be specified despite their cost and erosion control advantages.

CONCLUSION

The aim of this paper was to identify the advantages of jute geotextiles in the specified end uses of erosion control, vegetation establishment and stabilisation of earth roads. There is evidence that jute geotextiles have advantages in terms of technical, socio-economic and environmental aspects over competitive products. However, several barriers exist which have limited the specification and use of jute geotextiles in construction projects, and these have been identified in the paper. Knowing these barriers, and how they might be overcome will assist in the expansion of the jute geotextiles market both in the traditional markets in developed countries and in expanding novel markets in jute producing countries.

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CASE STUDIES ON FIELD APPLICATION

APPLICATION OF JUTE GEOTEXTILES IN HIGHWAY ENGINEERING

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N. K. Sharma, Kanwar Singh, S. R. Rao

SYNOPSIS

Over the last decade, the use of geotextiles of all types has recorded a tremendous increase, Geotextiles are being increasingly employed in various Civil Engineering activities and especially Geotechnical and Highway Engineering to facilitate construction, ensure better performance of the structure and reduce maintenance. The potential of geotextiles has caught the attention of Indian Engineering community as well and over the past few years, a number of laboratory studies and field experiments have been taken up. In view of this wide spread interest, the Central Road Research Institute has taken up a project for the development and promotion of jute based geotextiles for Highway Engineering applications. Accordingly, a number of field trials have been carried out using jute based geotextiles for various applications such as filtration, separation, drainage and reinforcement. The paper presents a summary of field experiments carried out to improve the soil behavior, the stability of roads and the filtration function in fills behind a retaining wall using jute geotextiles, thereby confirming the satisfactory results after monitoring the experimental stretches at various places.

1. INTRODUCTION

The Central Road Research Institute has been constantly working in the area of geotextiles since early 1980's. A number of laboratory studies on evaluation of geotextiles and their suitability for application, as well as, actual field trials have been carried out by the Institute. Jute is a low cost, renewable , biodegradable and eco-friendly natural product. With growing awareness about ecology around the world, it is worthwhile to develop jute geotextiles for specified end uses as these products have a large growth; potential in India. Keeping this in view, a number of field experiments using jute geotextiles were carried out in different parts of India for various application in highway engineering and monitoring at these experimental stretches are in progress. The details of some of these applications are given in **Table-1**. It is hoped that the outcome of these field experiments will provide reasonable solutions to some of the sustained problems in geotechnical engineering.

Table -1 Various Field Experiments using Jute geotextiles.

	Project Site	Application	Specification of Jute geotextiles	Quantity used
i)	Joshimath- Mallari Road (SH-45) in U.P.	Drainage	Non-woven, 750 gsm.	1000 sq.m
ii)	Hanuman -Setu Flyover, N. Delhi.	Drainage Filter	Non-woven, 750 gsm.	1000 sq.m
iii)	Okhla Flyover, New Delhi.	Drainage Filter	Non-woven, 750 gsm.	1000 sq.m

iv)	Kakinada Port Trust, Kakinada, (A.P.) 1	Reinforcement and separator	Woven, 750 gsm.	3010 sq.m
v)	Kandla Port Trust, Kandla, (Gujrat)	Separator in pavements.	Non-woven 750 gsm.	1000 sq.m

2. Jute Geotextile As Drainage Of Joshimath Mallari Road

The stretch of Joshimath-Mallari Road at km 5.6 on SH-45 in U.P., has been experiencing subsidences and sinking for the last many years. The stretch is located on debris slide area and consists of micacious sandy silt. A number of seepage points were observed on the uphill as well as oh downhill slopes. The road was experiencing subsidences during the monsoons every year, including damages to the restraining structures.

As a measure to arrest the sinking of road pavement, a systematic network of road side trench drains and cross trench drains were proposed. The layout plan and cross-section of the rubble trench drain is show in Fig.l. The trench drains were made of rubbles encapsulated in jute geotextiles to prevent the finer particle to enter into the voids of rubbles thereby clogging the trench drains, **Fig.2**. The properties of jute geotextiles used are given in **Table-2**.

Table-2 Properties of Jute Geotextiles used for Drainage, Filtration and separation applications

S. No.	Property	Total value
1.	Thickness	6.91 mm
2.	Weight	750 gsm
3.	Tensile strength	2.81 kN/m
4.	CBR Push through load	0.50 kN
5.	Failure strain	30%
6.	Index puncture resistance	0.077 kN
7.	Permittivity	3.36×10^{3}m/s
8.	Transmissivity	4.6×10^{-6}m/s
9.	Type of fabric	Non-woven
10.	Apparent Opening Size (AOS)	0.05 mm

About 1000 sq.m of non-woven jute fabric having 750 gsm has been used for drainage application on about 100 m length of road stretch on Joshimath-Mallari road during June, 1996, Fig.3. The monitoring of field experiments on this particular stretch of treated road was done in June, 1997 and has shown very encouraging and satisfactory results. There has been no further sinking and subsidences of the road at this location as shown in **Fig. 4 & 5**.

3. Jute Geotextile as Drainage Filter at Hanuman Setu

During the construction of road over bridge at Hanuman Setu, the filter criteria is critical during the construction as the water percolation into the backfill (of fly ash) is expected to be more during construction period in rainy or monsoon seasons. After the construction of road over bridge and approach road, the percolation of water is negligible as the road pavement

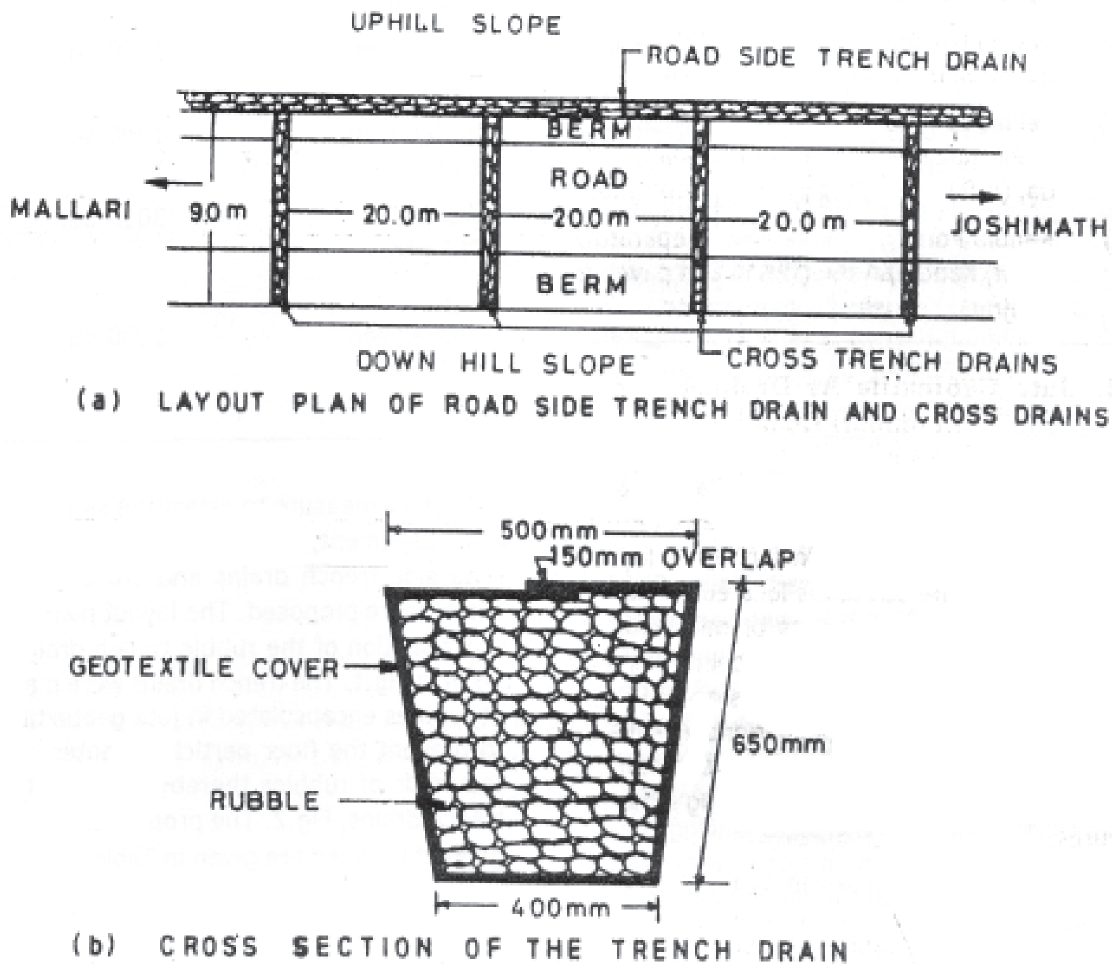

FIG. 1. LAYOUT PLAN AND CROSS SECTION OF TRENCH DRAIN

material is impermeable. Thus the drainage filter requirement is more during construction than after construction. In such cases, Jute geotextiles as drainage filter can be effectively and economically used along with reduced thickness of conventional filter. As non-woven jute geotextile satisfies the filter criteria and has shorter life, it can be economically used in structures such as Hanuman Setu flyover.

Fly ash was used as backfill material in this project. Because of lower specific gravity and finer gradation of the material, design requirement is more critical than the conventional backfill material. Non-woven Jute geotextiles with 750 gsm and properties as given in Table -2, was substituted for 30 cm thick conventional filter. The details of the drainage filter is given in **Fig. 6**. The installation and construction work has been completed in August, 1996. During the construction period, about 100 mm of rain fall occurred and it was found that jute geotextile retained the fine fly ash effectively and water drained through the jute geotextile.

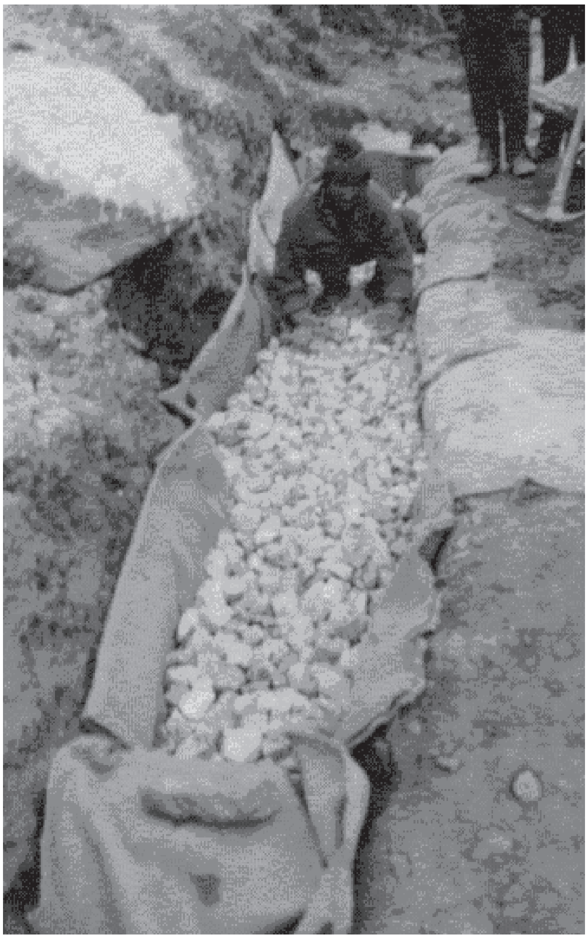

Fig. 2
The jute geotextiles were laid inside the road side trench and filled with rubbles.

Fig. 3 Rubbles encapsulated in jute geotextile.

4. Jute Geotextiles as Drainage Fil-ter at Okhla Flyover

The PWD, Delhi Administration has taken up construction of fountain in area adjoining newly constructed Okhla flyover involving the construction of retaining walls and about 4 m high backfill. Soil and flyash have been used as backfill in the area . Non-woven jute geotextile with 750 gsm was used as drainage filter behind the retaining walls constructed the area being developed for fountains. The work on the installation of jute geotextiles was carried out during February-March, 1997. Jute geotextiles was used as filter medium at the sand - soil or sand-flyash interface, as well as, around the weepholes. Graded stone aggregate of 20 mm nominal size has been used as conven-tional filter as per the details given in **Fig. 7**.

5. Jute Geotextiles to Improve Em-bankments at Kakinada

Reinforcement in an embankment of soft soil is very effective when placed at or close to the foundation surface. The primary role of reinforcement is to support the out-ward shear stress and relieve the foundation from lateral forces; thereby increasing the allowable height of the embankment that can be supported by the foundation soil. The subsoil at Kakinada Port area is soft plastic clay having moisture content ranging from 70% to 85% with bulk density varying from 1.3 g/cc to 1.45 g/cc. Undrained shear strength of the soil was found to be 4.6 kN /sq.m to 6.0 kN /sq.m. The water table is at 0.5 m below the ground level. However, whole area gets submerged during high tide.

The highway constructed earlier faced many problems during and after construction such as subsidence of the fill during construction, excessive post - construction settlements and lateral spreading of fill material etc. In order to mitigate the above problems,, various alternatives were examined, among which jute geotextile has shown itself to be promising one. Geotextiles may be used to improve (i) the embankment stability against bearing capacity failure, (ii) stability against slope failure through the foundation, (iii) allow a more controlled construction and ensure more uniform settlement of the embankment and (iv) also act as separator between the embankment material and soft sub-soil.

To some extent jute geotextiles also perform as drainage blanket for draining pore water during consolidation. Embankment stability usually needs to be improved only during the short period in which the foundation consolidates, and in such cases the long term durability of the geotextile reinforcement is of secondary concern.

Woven jute geotextiles with properties given in **Table-3**, was used at the experimental stretch at Port area for reinforcement and also as a separator between the embankment and the soft subsoil. The jute geotextile was laid with its warp direction (strong direction) parallel to the width of the embankment, **Fig. 8**. Ten pieces of geotextiles were stitched to make the width to 7.0 m and 26.0 m long geotextile and were carried to the site. Base width of embankment is 23.0 m and anchorage length at both grids is 3.0 m, **Fig. 9**, An overlap of 30 cm was given between two rolls of geotextiles. Sand filling on the spreaded geojute in the creek portion where water table is quite high is shown in **Fig. 10**. An overall view of the sand filled embankment is shown in **Fig.11**.

Monitoring of completed embankment i.e both treated and untreated control stretches were carried out by JNTU College of Engineering, Kakinada. The embankment treated by jute geotextiles is not damaged even by cyclone of 1996 as shown in **Fig. 12**. whereas the untreated stretch of embankment is completely damaged, is-shown in **Fig. 13**.

Fig. 4 Road sinking has stopped towards Joshimath side
(Monitored after one year)

Fig. 5 Road stretch towards Manali side has become stable
(monitored after one yer)

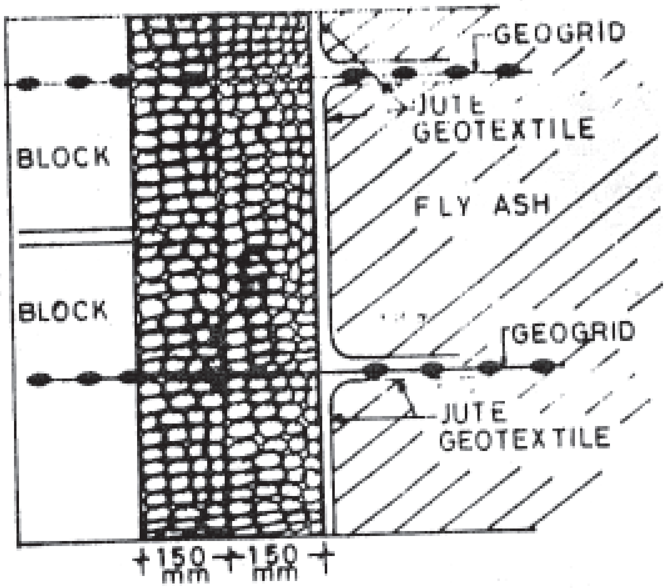

FIG.6. SKETCH SHOWING FILTER MEDIA AT HANUMAN SETU

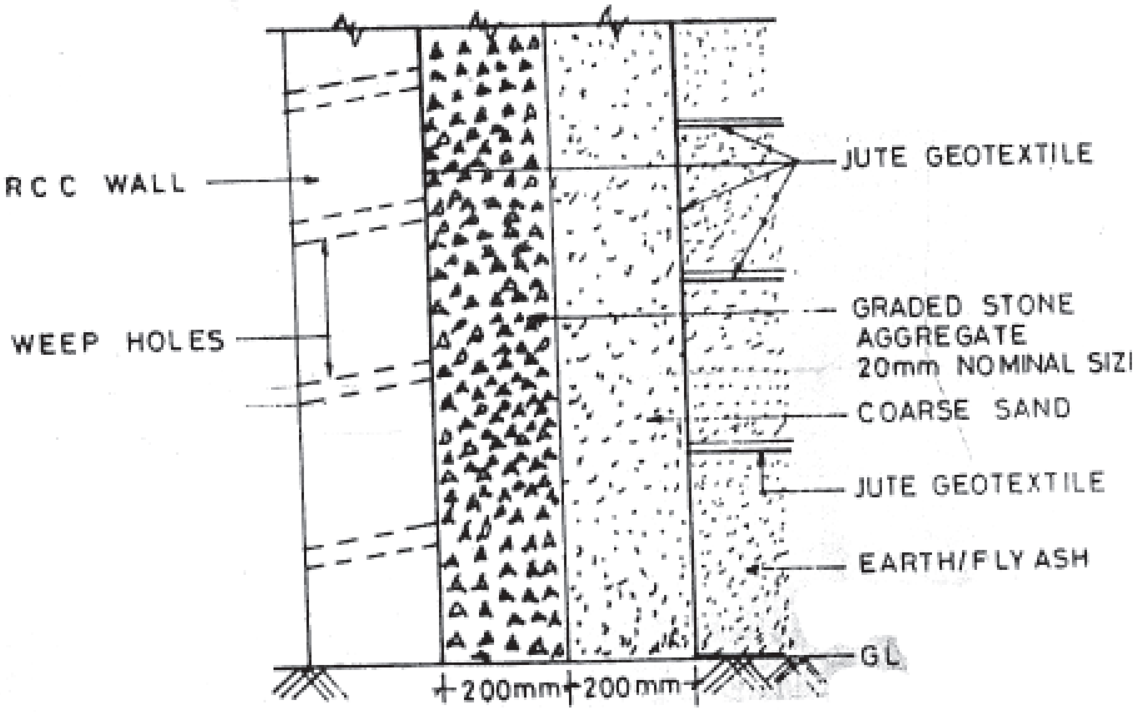

Fig. 7 Sketch Showing Filter Media at Okhla Flyover

6. Jute Geotextiles used as separator at Kandla Port

In Kandla Port area also, authorities are facing the problem of road construction on soft soil. The performance of pavements laid on soft soils can be improved using geotextiles. The fabric as separator enables the prevention of penetration of subgrade material into voids of granular base course. The permeability characteristics of the fabric also aid in faster dissipation of pore pressures and better drainage which result in better long term performance of the pavement.

The soil in the port area is very soft . The road network in Kandla Port Trust is required to be improved to facilitate better movement of vehicular traffic in the port area. To achieve this objective, a non-woven jute geotextile of the properties shown in Table-2, was used as a separator in the project. **Fig. 14** shows the design guide for separator function. The pressure at the stone-geotextile interface is related to the burst pressure for a given aggregate size (Koerner 1990). The subgrade was compacted to the optimum moisture content and dry density of the subgrade material. The jute geotextile was spread over the compacted subgrade. Base course consisting of 300 mm thick, 60-125 mm size stone aggregate followed by 40-60 mm size stone aggregate was provided, **Fig. 15**. A thin layer of 3.0 cm moorum was provided as cushion between the stone layers and helps in reducing the direct effect of large sized aggregate on geotextile.

The completed section is being monitored for its performance in terms of rut depth and other visible signs of distress by the engineers of Kandia Port Trust. Settlements of the test section in relation to conventional pavement section are being monitored by the engineers of the Kandia Port Trust. Settlement of the test section in rela-tion to conventional pavement section were recorded with the increase of pavement loads from 0.5 MT/m^2 to 2.0 MT/m^2. Loads were increased with increments of 0.5 MT/ m^2 each month from February, 1997 to May, 1997. Results of the sttlements recorded from February, 97, to May, 97 sent by Kandia Port Trust, shows almost negligible settlements and no signs of distress along the treated test section. This encouraging results has prompted the Kandia Port Trust to purchase another consignment of 15,000 sq.m of Jute-geotextiles from IJIRA recently.

Table-3 Properties of Jute geotextiles used at Kakinada Port

S. No.	Property	Test value
1.	Thickness	5 mm
2.	Weight	750. gsm
3.	Tensile Strength	15 kN/m
4.	Elongation	30%
5.	Puncture Resistance	350 N
6.	Overlap Length	300 mm
7.	Type of Fabric	Woven

7. CONCLUSIONS

Field experiments carried out at various places in India, has shown that the jute geotextiles play on effective role in various applications in highway engineering. The jute geotextiles can be more effective, eco-friendly and economical if used judiciously and jointly with other measures. The jute geotextiles in their present form are suitable for separation, filtration, drainage and reinforcement functions. However, there is need to design and develop specifications of fabrics to suit geotechnical applications in dif-ferent areas. To have better utilisation of the jute geotextiles, there is need to have closer interactions between the user Organisations and research Organisations such as CRRI, IIT's etc.

8. ACKNOWLEDGEMENTS

Authors are grateful to Indian Jute Mills Association (IJMA), Calcutta and UNDP for providing financial support for the project and other Organisations like Delhi PWD, Kandia Port Trust, Kakinada Port Trust and DGBR for their support in field experiments. The paper is published with the permission of Dr. A.K. Gupta, Director, Central Road Research Institute, New Delhi-110020.

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Fig. 8 Woven jute geotextiles were laid over the soft ground

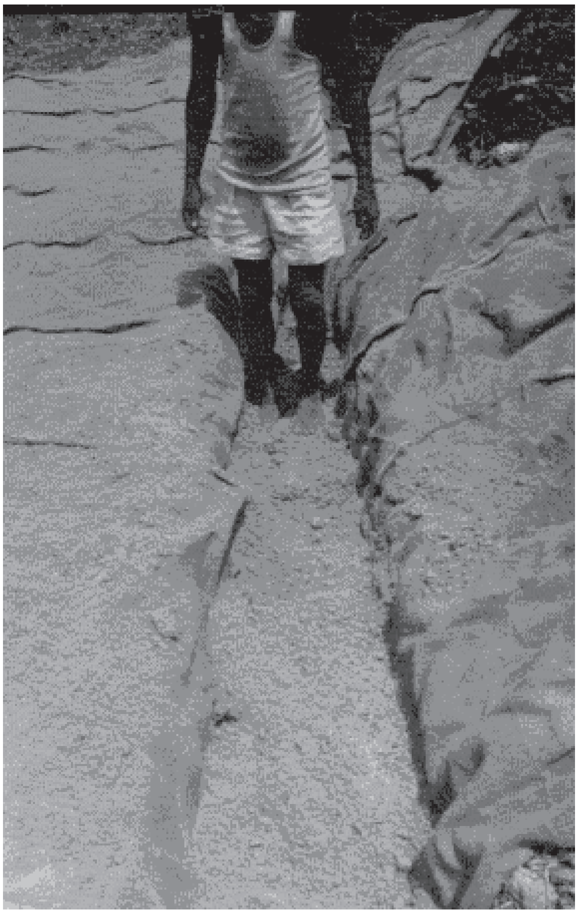

Fig. 9

Both ends of Jute geotextiles were properly anchored into trenches and back filled by sandy soil.

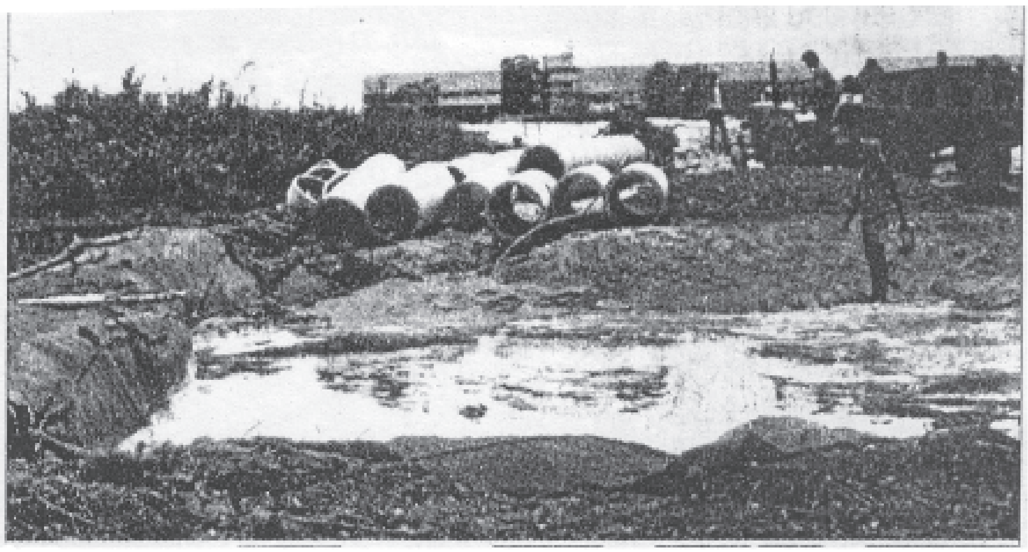

Fig. 10 Jute geotextiles were laid in the creek protion and sand filling in the process.

Fig. 11 Embankment construction nearing completion

Fig. 12 Monitoring after the cyclone of 1996 shows the embankment stretch treated by jute geotextiles is not damaged.

Fig. 13 The untreated stretch of embankment completely damaged by the cyclone of 1996.

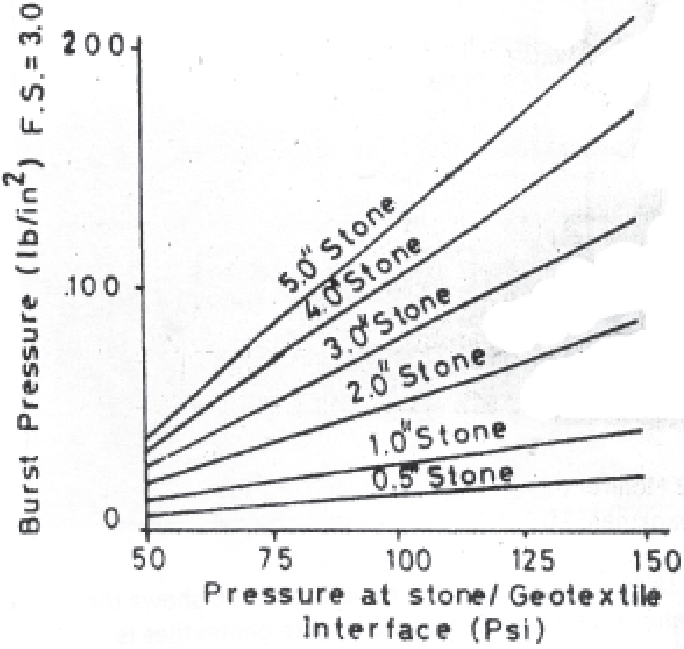

Fig. 14 Burst Resistance Design Guide

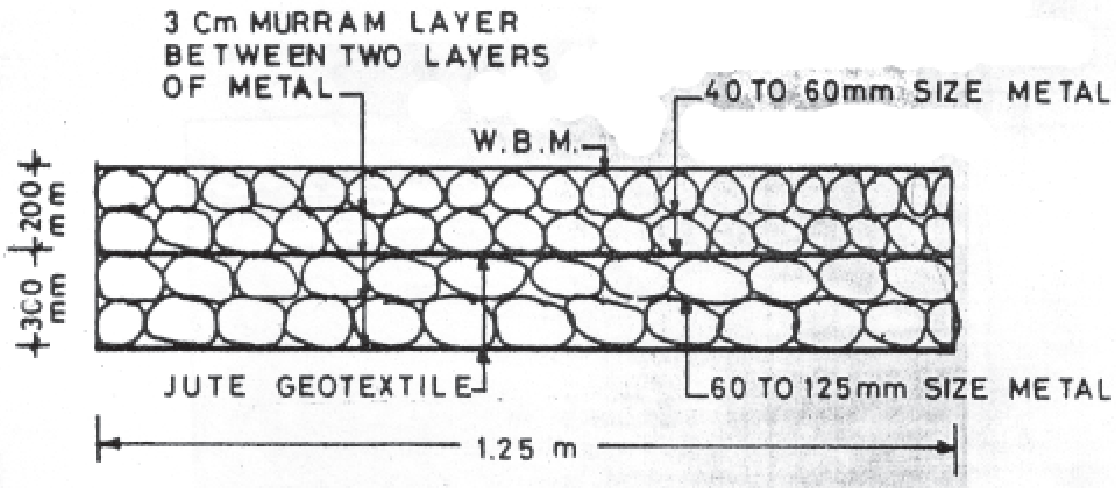

Fig. 15 Pavement Section at K. P.T.

CONSTRUCTION OF HIGHWAY EMBANKMENT ON SOFT MARINE SOIL USING JUTE GEOTEXTILES

P. Jagannath Rao, Bindumadhava, N. Venisiri

ABSTRACT

The paper presents case study of design and construction of 1.5m high embankment resting on 4m deep soft marine clay subsoil layer. In order to ensure adequate initial factor of safety, it was found necessary to provide a-reinforcing fabric at the base of the fill and jute geotextiie was successfully used for this purpose. Jute being biodegradable the natural fibre fabric suffers loss of strength with time. In the present case, it was found that the post construction gain in the undrained shear strength of the soft clay subsoil is adequate to compensate the loss in the strength of reinforcing fabric after it is placed in the soil. Thus, the factor of safety always remains at the design level. Construction of the embankment was completed in April 1996 and post construction monitoring showed the embankment performance to be satisfactory.

Keywords : Jute geotextiles, Reinforcement, Embankments.

1. INTRODUCTION

A major deepwater port was developed at Kakinada in Andhra Pradesh, India and within the port area, a highway network was under construction for transporting cargo from ships to godowns. At the proposed location, subsoil is soft clay upto 4m depth and water table is at about 0.5m below the ground level. The area gets submerged during high tide. Highways constructed earlier faced many problems during and after construction such as sub-sidence of the fill during construction, excessive post construciton settlements, lateral spreading of fill material, etc. It was observed that sometime as much as 30% of the fill sinks into the soft subsoil during spreading of the fill, thus necessitating use of large quantities of costly granular fill material, pushing up the cost of construction.

In order to mitigate the above problems, variour alternatives were examined among which jute geotextiie has shown it-self to be a promising one from performance as well as cost considerations. The use of geotextiles to improve the perfor-mance of embankments over soft subsoil is an effective and well tried form of reinforced soil construction. Geotextiles may be used to improve.

(i) embankment stability against bearing capacity failure.
(ii) stability against slope failure through the foundation.
(iii) allow controlled construction over very soft or difficult foundation soils and make possible more uniform settlement of the embankment
(iv) act as separator between the embankment material and soft subsoil.
(v) function as drainage blanket for draining of pore water during consolidation.

Reinforcement on soft soil is most effective when placed at or close to the foundation surface. Factor of safety of embankment is usually at its lowest during and immediately after construction and increases thereafter. The increase is a function of the gain in strength of the soft clay. Thus, re-inforcement has to be effective only of a short term, the duration depending on the consolidation characteristics of the soft clay layer. **In such cases, long term durability of the geotextile reinforcement is of secondary concern.**

The reinforcement is needed essen-tially to improve the stability during construction phase and in the period of consolidation during which the soil attains the required strength. The concept, shown in fig (1) is given by Jewell (1996) and forms the basis of design in the present instance.

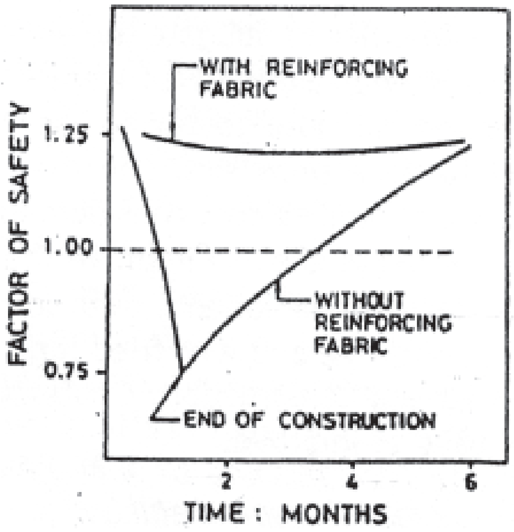

Figure 1 : Variation in factor of safety of fill on soft ground with and without reinforcing fabric Based on Jewell (1996).

The primary loading from an embankment is due to the self weight of the embankment fill, which causes horizontal stresses in the fill, which in turn produce lateral forces i.e., out ward shear stresses. The resulting outward shear stresses which act on the foundation surface reduce the bearing capacity of the foundation subsoil. Hence, the primary role of the reinforcement is to resist the outward shear stresses and relieve the foundation of the effect of lateral forces, thereby increasing the allowable height of theiembankment. A layer of reinforcement placed in the embankment would resist lateral displacement by exerting an inward shear stress on the foundation surface thus reduce the lateral spreading of the foundation soil. Since the geotextile is placed between the embankment fill and the subsoil, it also performs the function of separator thereby eliminating the possibility of the soft subsoil squeezing upward into the costly granular fill. This geotextile along with a sand cushion also acts as a drainage layer facilitating the escape of pore water during the consolidation Phase.

1.1 Properties of Subsoil

The subsoil upto a depth of 4m from the ground level is mainly clay with occasional mixture of silty sand. The. average liquid limit and plasticity index were 60 and 28 percent respectively. The soil in general was found to have a natural moisture content ranging from 70% to 80% with bulk density varying from 1.3 Mg/m^3 to 1.45 $Mg/\ m^3$. Average underained shear strength of the soil was found to be 6.0 kN/m^2 from in-situ vane shear tests, compression index (C_c) 0.225 and coefficient consolidation (C_γ) 2.0xl0^{-7}m^2/sec.

1.2 Design Aspects

Design of geotextile used for reinforcement is based on the methodology given by Jewell (1996) and is as follows :

Height of fill (H) = 1.5 m

Unit weight (γ) = 16.6 kN/m^2

Angle of internal friction $\phi = 30°$

Depth of foundation soil D = 4.0m Undrained cohesion C = 6kN/m^2

Thus vertical stress due to fill (α) = 16.6X1.5=24.9kN/m^2.

Factor of safety (FS) against bearing failure for the unreiriforced embankment.

$= N_c = 3.14$ in the unreinforced state.

Thus, the bearing capacity is not adequate without reinforcement at the base level. By providing a geotextile reinforcement, the bearing capacity factor, N_c increases to $\pi+2 = 5.14$ and the factor of safety works out to

$$\frac{6\times 5.14}{24.9} = 1.23$$

which is a satisfactory value.

$$\frac{CN_c}{\gamma H} = \frac{6\times 3.14}{24.9} = 0.75$$

The horizontal force to be resisted by tension in the fabric $P_a = K_{a\gamma} H^2/2$

$$= \frac{0.33\times 16.6\times 1.5\times 1.5}{2} = 6.16 \text{ kN / m}$$

Hence, required design tension in the fabric = 6.16 kN/m

For a fabric having a tensile strength of 20 kN/m, the factor of safety available is 3.2 and is thus adequate. Once the embankment is in place, the soft clay consolidates and improves in shear strength.

With an average $C_\gamma = 2 \times 10^{-7}$ m^2/ sec, the time required for 90% consolidation works out to 205 days or about seven months.

Settlement was estimated to be the order of 175 to 200 mm, by using standard calculations.

Strength gain at the end of consolidation is of the order of

$$\triangle Su = 0.18\times \triangle_{\alpha\gamma} = 0.18\times 24.9 = 4.48\,\text{kPa}$$

Average undrained cohesion at the consolidation would thus be of order of (6.0 + 4.48) say 10 kPa. Factor of safety of the embankment at the end of consolidation without any reinforcing fabric would thus be

$$FS = \frac{10\times 3.14}{16.6\times 1.5} = 1.26$$ which is satisfactory.

Thus the use of an even a relatively low strength geotextile helps to maintain the factor at an acceptable level of 1.26.

At the end of seven months when the strength gain due to consolidation has occurred, the increased shear strength of the subsoil ensures the minimum required factor of safety. The strength of fabric is no longer needed to provide reinforcing effect.

3.0 CHOICE OF FABRIC

In the preceding section, it was demonstrated that a fill can be built on the soft clay by placing a geotextile fabric and a low strength one is adequate. A variety of such geotextiles are manufactured from petroproducts. However, in certain areas of the world, natural fibers such as jute, coir, sisal, kenaf are being increasingly studied and evaluated for use in various geotechnical engineering applications. The objective of such efforts is to make use of desirable properties of above fibers, make a wider variety of fabric products available for geotechnical engineers where suitable use can be found and in some instances with cost advantages, provided performance criteria are met. The 5th International conference on geosynthetics held in September 1994 in Singapore developed a special session to Natural Fibre Fabrics. This session has clearly impressed the engineers with the potential of natural fibre fabrics for use in geotechnical engineering applications. These fabrics compliment the range of applications of petrobased fabrics.

Since jute is available in India in abundance, a United Nations Development Programme (UNDP) sponsored project on the "Development and Promotion of Jute Geotextile" is in progress in India covering the period 1992-1997. The Indian Jute Mills Association (IJMA) is. the coordinating agency for the project. Development of jute and jute based geotextiles, their evaluation and characterization and the use of such fabrics in full scale experimental constructions form objectives of the project. Efforts were concentrated on carrying out full scale field experiments to demonstrate and evaluate the capabilities of selected varieties of jute fabrics for use in surface erosion control of slopes, drainage, separation and to a limited extent, reinforcing function. The fact that jute fabric is biogradable, with a limited life and deteriorates in a short period of about two years was always kept in mind in the planning and operation of the project and choice of experimental installations. Full scale field experiments covering these applications have been implemented at different locations in India. Ramaswamy (1994) presents in detail the application of jute geotextiles in erosion control, drainage as well as reinforcement.

As explained in section 1 and shown in design in section 2, in the present instance, it is adequate if the reinforcing function of the fabric is available for a period of seven months. The use of fabric has essentially helped in overcoming problems in the placement of the fill and initial low factor of safely. Thus, fabric with a limited life can be tried in this project and its performance evaluated by the field trial. Accordingly, jute geotextile fabric having the basic properties given in **Table 1** was chosen for use in the project.

Table 1 : Properties of Jute Geotextile

S. No.	Property	Test Value
1.	Thickness	3 mm
2.	Weight.	750 gsm
3:	Tensile Strength	20kN/m
4.	Elongation	30%
5.	Puncture Resistence	350 N
6.	Overlap length	30 cm

The woven jute geotextile fabric was treated with cuproammonium sulphate to increase resistance of the fabric to biodegradability. Talukdar et al (1994) have studied the influence of various chemicals such as copper napthalate etc. with acrylic binder on the resistance to microbial attack when buried in soil. The results were very encouraging and showed that jute fabrics treated with selected chemicals have better resistance to microbial attact under conditions of burial in soil. Venkatappa Rao et al (1994) have shown on the basis of a careful study that the decrease in the narrow strip tensile strength of soil embedded in soil and remaining in submerged condition is only of the order of 35% after four months. Mohiuddin (1994) provides data to indicate that in jute fabrics treated with copper napthalate and such other chemicals, the loss of strength is retarded. Thus, it was reasonable to consider that jute fabric used would serve the reinforc-ing function in adequate measure, in the design life of 7 months.

4.0 INSTALLATION OF GEOTEXTILE

At present, jute geotextile being an experimental product is available in roll of 0.75m only. Hence, fabrics were stitched at site, using a portable stitching machine to obtain the requisite width. The stitching operation was easy, reliable and fast. Before spreading the geotextile, the site was cleared of any extraneous materials and tree/plant roots. A layer of sand 150 mm thick was spread to serve as a leveling course. The geotextile was laid with its warp direction (strong direction) parallel to the width of the embankment. Top width of the embankment was 7.0 m and side slope 1 vl to 2 h. A trench of size 0.5 x 0.5 m was dug in the soil at either toe line of the embankment and along its length. To provide an-chorage, the geotextile was placed in the trench. The trench was back filled with sand placed in layers and compacted. The fabric was streched manually after spreading on the ground so as to render it free of wrinkless and establish good contact with soil and fill. An overlap of 0.30 m was provided between two rolls of geotextiles. After spreading the geotextile and anchoring it along the edges, a sand cushion of 30 cm thick was placed to protect the geotextile from damage due to moving vehicles/Placing of fill upto the requisite height was done by rear dumping and spreading. The fill was then compacted by a 6 ton roller. Nearly 300 m of embankment was built under the programme. Construction of the embankment was completed in April 1996. Settlements were observed subsequent to the construciton. Simple standpipe type settlement gauge was installed for this purpose. It was found that the settlements conformed to the estimated value. The physical condition of the fill and its surface were moni-tored periodically and were found to be satisfactory.

‘The cost of jute geotextile used in the project is of the order of Rs. 18/- or US$ 0.50 and thus proved to be highly economical compared to products based on petrochemicals, which are costly in India.

5.0 CONCLUSION

An embankment was built on soft day subsoil using geotextile as a reinforcing layer at the base, the geotextile was required to serve as reinforcing fabric for a period of 7 months only. Subsequently the strength gain in the soft day was adequate to keep the embankment stable. The performance of the fill was found satisfactory. The project demonstrates that where site conditions enable the designer to rely on reinforcing properties of geotextiles for a limited time period, it is possible to use natural fibre geotextile in such applications. This has the effect of finding suitable range of conditions where natural fibre based geotextile can be used in geotechnical applications.

ACKNOWLEDGEMENT

The project was earned out as a part of the UNDP sponsored project "Development and Promotion of Jute Geotextiles'' The overall coordinating agency was the Indian Jute Mills Assodation, Calcutta. The work reported herein was earned out by the authors, while they were at the Central Road Research Institute, New Delhi and the senior author coordinating the project. The authors thank all concerned in the above organisations for their cooperation in successfully completing the project. The author also wish to thank officials of Kakinada Port and JNTU College of Engineering, Kakinada for help at site in various phases of the project.

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