APPLICATION OF GEOJUTES IN CIVIL ENGINEERING-A NEW ERA IN JUTE SECTOR

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ABSTRACT

This study is undertaken to find out the feasibility of using geojute materials produced in Bangladesh as an alternative to geotextiles in civil engineering applications. Four types of untreated and three types of treated geojute samples were selected from Bangladesh Jute Mills Corporation (BJMC) and Bangladesh Jute Research Institute (BJRI). Laboratory tests were performed on these treated and untreated geojute samples to determine their physical, mechanical and hydraulic properties. An attempt has been made to compare these test results with the available geotextile data in Bangladesh. Based on these test results some design examples have been presented using the design methods developed for geotextiles applications. An economic aspect related to geotextiles and geojute materials is also presented. It is appreciated that if geotextiles are replaced with geojute in civil engineering applications as exemplified, significant economic benefit can be obtained.

KEY WORDS: Geojute; geotextiles; biodegradability; index, mechanical and hydraulic properties; economic aspects.

1.0 INTRODUCTION

The addition of materials to improve the properties of soils was possibly done long before our first historical records. Examples may be the use of tree trunks, small bushes, and the like to stabilize swamps and marshy soils. Such stabilization attempts were undoubtedly continued with the development of a more systematic approach in which timbers of nearly uniform size and length were lashed together to make a mattress surface. The concept of reinforcing poor soils has continued until the present day. Geotextiles were the first to use in erosion control applications and were intended to be an alternative to granular soil filters. Synthetic Geotextiles are now being widely used for a number of different geotechnical applications. The functions are mainly filtration in cross plane flow, separation of dissimilar materials, reinforcement of weak soils, drainage in in-plane flow etc (Koerner, 1997). Synthetic materials dominated the field because of its special characteristics like high strength, high thermal insulation, low specific gravity, good resilience, chemical inertness and resistance to moth and bacterial attack (Talukder, et al, 1988).

As mankind seeks to reduce the conflict between the expanding world population and the limited natural resources available to it on the one hand, and between the daily deterioration of the environment and the exploitation of natural resources for industrialization on the other, it is now realized that the promotion of a fiber other than natural cotton and synthetic cellulose has become very important. In view of these developments, jute, a natural fibre has come up to supplement and/or replace synthetics, has been receiving increasing attention from the industry. The past success of jute is due largely to its environment friendly characteristics.

Jute fibre is comparable or superior to synthetic fibre in physical and chemical characteristics. Jute is an annually renewable energy source with a high biomass production per unit land area. It is biodegradable and its products can be easily disposed without causing environmental hazards. The abundant availability of jute in Bangladesh renders Jute fabrics cost effective for various applications such as temporary roads and yards, repair of permanent roads, drainage application, reclamation works, stabilization of temporary bunds and erosion control. In tropical, humid, rain fed and frequently flood-affected countries like Bangladesh quick biodegradability of jute is a disadvantage for its use in geotechnical applications. Recently a wide range of geojute has been developed in the laboratory of Bangladesh Jute Research Institute (BJRI) by blending jute with hydrophobic fibre like coir or by modification with bitumen, latex and wax resinous materials with the collaboration of Bangladesh Jute Mills Corporation (BJMC). This has enabled to produce geojute having designed biodegradability and increased hydrophobicity (Prodhan, 1996).

Though different researchers, organizations and institutions, have performed many study/research works, a systematic study related to the index & mechanical properties of geojute and their short/long term applicability could not be performed for identifying design parameters of these materials for geotechnical applications. A study was undertaken on four untreated and three treated samples produced in Bangladesh to determine various physical, structural, mechanical and hydraulic properties at the geotechnical laboratory of BUET by standard testing method (ASTM/DIN) to compare different properties of the Geojutes with those of geotextiles, present an economic aspects of untreated and treated geojute with synthetic geotextile, to assess the efficiency of geojute for long and short term geotechnical application and present some procedures on designing with geojute.

2.0 GEOJUTE SELECTED FOR STUDY

For collecting geojute samples for the research, International Jute Study Group (IJSG), Jute Diversification Promotion Centre (JDPC), Bangladesh Jute Mills Corporation (BJMC) and Bangladesh Jute Research Institute (BJRI) were contacted. The IJSG is an intergovernmental body set up under the aegis of UNCTAD to function as the International Commodity Body (ICB) for Jute, Kenaf and other Allied Fibers. The IJSG is the legal successor to the erstwhile International Jute Organization (IJO), was established on 27 April 2002, to administer the provisions and supervise the operations of the Agreement establishing the Terms of Reference of the International Jute Study Group, 2001. The head office of this organization is situated in Manipuripara, Dhaka. JDPC was set up by the Ministry of Textile & Jute, Government of Bangladesh through an Office Memorandum on 31 October 2002. The JDPC has been created with the vision of reviving the past glory of jute as ''Golden Fibre'' through extension of uses of jute by vertical and horizontal diversification and thereby improving the socio-economic conditions of the all section of people involved directly and indirectly with the Jute Sector. The BJMC was established on 1972 in order to overall operation, management, maintenance and future development agenda of all the jute mills of Bangladesh, considered as the world’s largest state owned manufacturer and exporter of jute products. BJRI is regarded as the country’s oldest and only jute research organization, established on 1951 in order to regulate, control and promote agricultural, technological and economic research on jute and allied fibres and their manufactures and dissemination of results thereof. Considering the climatic condition, BJRI has developed as many as fifty types of jute products by blending jute with hydrophobic fiber like coir or by modification with bitumen, latex, wax resinous materials with the collaboration of BJMC and other governmental and non-governmental organizations since its inception of technological research on jute in 1963 which may enhance their life up to or even more than twenty years.

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

Type	Compo-sition	Durability (month)	Biodeg-radibility	Moisture Content	Wt./Unit (gm)	Tensile Strength (lb)
Woven Jute in different structure	Jute	2-6	Quick	12-14%	220-800	120-140
Woven Jute in different structure	Jute, Coir	5-12	Slow	7-10%	220-800	240-660
Woven Jute but treated composite	Jute Bitumen Carbon	6-48	Long run	3-8%	Var. Wt.	140-700
Woven with different	Jute latex	60-240	Long run	5-7%	≥ 800	300-800
Non woven	Jute blanket	6-18	Slow	8-12%	800	300-800
Non woven	Jute Blanket +Latex	60-240	Long run	5-7%	≥ 800	≥ 800

Source: Abdullah (1999) "A hand book on geotextiles particularly natural geotextiles from jute and other vegetable fibres".

Four untreated samples, namely Jute, Canvas, Double Works (DW) Twill and Hessian were selected from BJRI and BJMC. The Jute is a densely woven fabric by using relatively flat type of yarn. It is manufactured in BJRI sample producing factory mainly for research purpose. The Canvas is a very densely woven fabric, woven by round twisted yarns. Canvas is mainly used to produce 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. The Canvas is the least porous out of the four and is now produced in Latif Bawany Jute Mills. The Twill is also woven by using relatively flat type yarns like Jute. It is manufactured in many jute mills of Bangladesh. The Hessian is the most porous amongst four and produced in all the jute mills of Bangladesh. It is used extensively in different works.

Amongst the untreated samples, Jute, Canvas and DW Twill samples were treated with bitumen by BJRI. The treated samples selected so that the test results can be compared with untreated one. The salient properties of the samples are presented in Table 2.

Table 2: Salient properties of samples

Trade Name	Source	Condition	Commercial Characteristics			
			Width (inch)	Wt. (oz/yd^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
Double Works (DW) Twill	BJMC	Treated & Untreated	20-30	11-24	black & natural	500/1000
Hessian	BJMC	Treated	22-80	5-14	natural	700/2000

Source: Bangladesh Jute Mills Corporation Handout, 2003

3.0 TESTS CONDUCTED FOR STUDY

It may be mentioned that since there are no specific standard test methods for determining or evaluating physical, mechanical and hydraulic properties of geojute to date, the methods commonly employed for geotextiles are adopted. To determine the physical properties of geojute three tests have been performed. Six tests were performed to determine the mechanical properties. To determine the hydraulic properties three tests were performed. Creep test has been performed to determine long term tensile strength. As a whole total thirteen tests were performed. Twelve tests have been performed as per ASTM test standards and one test has been performed as per DIN (Germany) standard. An overview of tests performed is shown in Table 3.

Table 3: Tests Performed in the Research Work

Ser	ASTM/DIN		Properties determined
1	D 5261	Standard Test Method for Measuring Mass per Unit Area of Geotextiles	Physical Properties
2	D 5199	Standard Test Method for Measuring the Nominal Thickness of Geosynthetics	
3	D 1117	Standard Test Method for Determining Absorbency Time and Absorptive Capacity of Non-oven Fabrics	
4	D 4595	Standard Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method	Mechanical Properties
5	D 4632	Standard Test Method for Grab Breaking Load and Elongation of Geotextiles	Mechanical Properties
6	D4533	Standard Test Method for Trapezoid Tearing Strength of Geotextiles	
7	D 4833	Standard Test Method for Index Puncture Resistance of Geotextiles	
8	DIN 54307	CBR Puncture Resistance	
9	D 3786	Standard Test Method for Hydraulic Bursting Strength of Knitted Goods and Nonwoven Fabrics	
10	D 4751	Standard Test Method for Determining Apparent Opening Size of a Geotextile	Hydraulic Properties
11	D 4491	Standard Test Methods for Water Permeability of Geotextiles by Permittivity	
12	D 4716	Test Method for Determining the (In-plane) Flow Rate per Unit Width and Hydraulic Transmissivity	
13	D 5262	Standard Test Method for Evaluating Unconfined Tension Creep Behavior of Geosynthetics	Long term tensile strength

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

Table 4: Test results of treated geojute, untreated geojute and geotextiles

Product	Condition	Mass per unit area (g/m^2)	Thickness (mm)	Wide width tensile strength (kN/m) MD/XMD	Grab tensile strength (N) MD/XMD	CBR puncture resistance (N)	Burst strength (kPa)
Jute	Treated	1600	3.5	15/18	800/700	4000	1500
	Untreated	800	2.8	10/12	400/220	1500	1250
Canvas	Treated	1200	2.5	27/15	1100/700	1800	1600*
	Untreated	500	1.3	23/14	850/400	1700	2400
DW Twill	Treated	1400	3.1	25/32	1000/900	1700*	2600
	Untreated	750	2.4	23/26	900/750	4500	2400
Hessian	Untreated	300	1.5	12/14	210/220	1500	1400
Geotextile	Non-woven	240-640	2.0-4.5	[18-48] /[15-31]	[1160-2590] /[780-1900]	2660-5450	3800-4500

**Reduced after treatment*

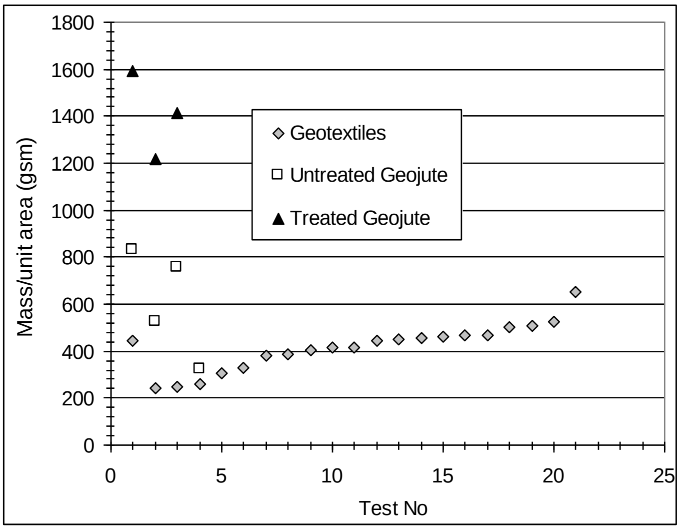


Figure 1: Mass per unit area of geotextiles, untreated geojute and treated geojute

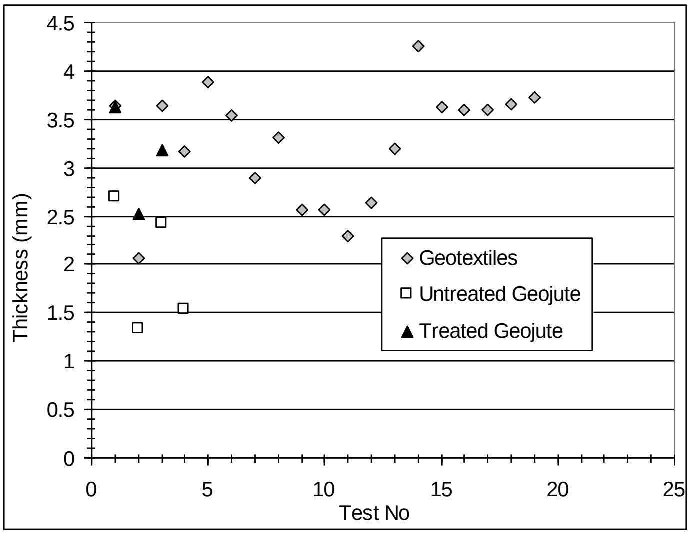


Figure 2: Thickness of geotextiles, untreated geojute and treated geojute

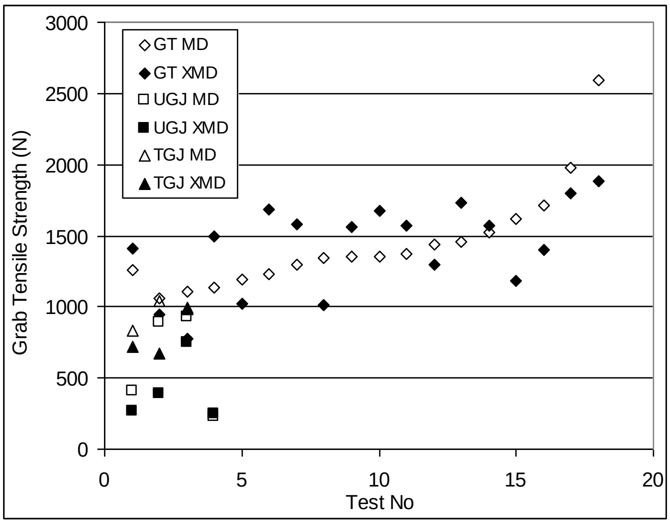


Figure 3: Grab tensile strength of geotextiles, untreated geojute and treated geojute

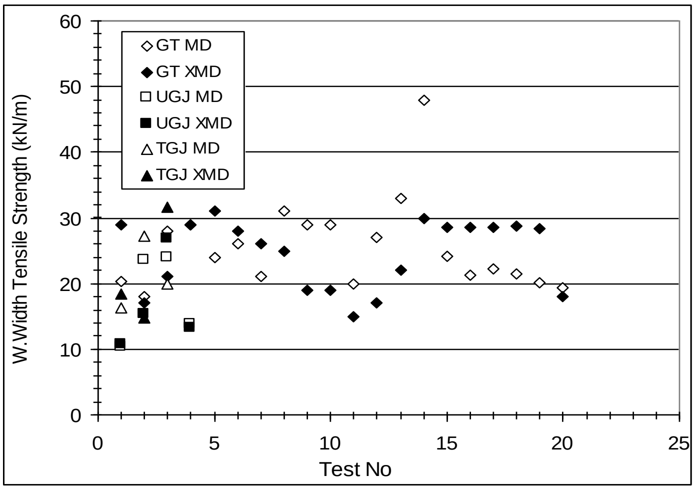


Figure 4: Wide-width tensile strength of geotextiles, untreated geojute and treated geojute

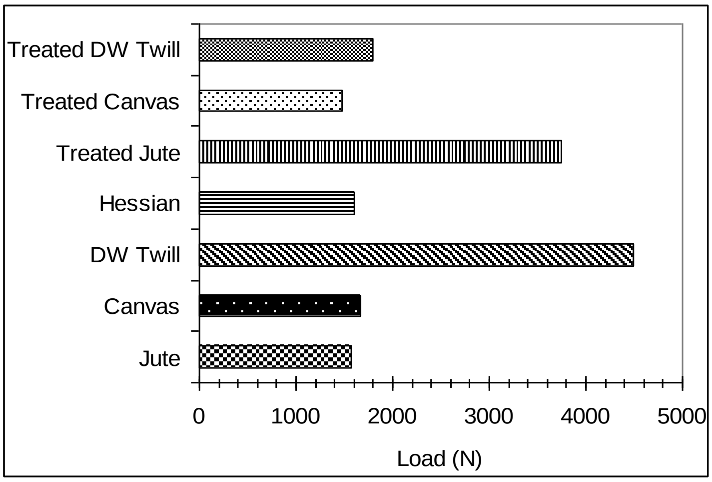


Figure 5: CBR strength of geotextiles, untreated geojute and treated geojute

It may be noted from these test results that the properties of geojute samples generally improve after treatment. However, 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 geotextiles have better index, mechanical and hydraulic properties compared to geojute materials. This indicates that manufacturers and researchers should put more technical efforts to improve the properties of geojute materials so that they become obvious alternative to geotextiles.

4.0 DESIGN METHODS

To a designer many possible design methods or combinations of methods are available. However, as Koerner (1997) describes the ultimate decision for a particular application usually takes one of three directions: design-by-cost-and-availability, design-by-specification, and design-by-function.

Design-by-Cost-and-Availability

This method is quite simple. Available funds are divided by the area to be covered and a maximum available unit price that can be allocated for the geojute is calculated. The geojute with the best properties is then selected within this unit price limit and according to its availability. Intuition plays a critical role in the selection process. The method is obviously weak technically but is one that is still sometimes practiced.

Design-by-Specification

This method is very common and is used almost exclusively when dealing with public agencies. In this method, several application categories are listed in association with various physical, mechanical and/or hydraulic properties. Different agencies have very different perspectives as to what properties are important and as to their method of obtaining the numeric values.

Design by Function

This method consists of assessing the primary function that the geojute will serve and then calculating the required numerical value of a particular property for that function. Dividing this value into the candidate geojute's allowable property value gives a factor of safety (FS).

$$FS = \frac{\text{allowable (test) property}}{\text{required (design) property}}$$

where,

Allowable property = a numeric value based on a laboratory test that models the actual situation

Required property = a numeric value obtained from a design method that models the actual situation, and

FS = factor of safety against unknown loads and/or uncertainties in the analytic or testing process; sometimes called a global factor of safety

If the factor of safety is sufficiently greater than 1.0, the candidate geojute is acceptable. The above process can be repeated for a number of available geojute, and if others are acceptable then the final choice becomes one of availability and least cost.

5.0 REDUCTION FACTORS/PARTIAL FACTORS FOR GEOJUTE MATERIALS

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 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 geotextiles is obtained as:

$$T_{allow} = T_{ult} \left(\frac{1}{RF_{ID} \ X \ RF_{CR} \ X \ RF_{CD} \ X \ RF_{BD}} \right)$$

Where:

T_{allow} = allowable tensile strength of getextile
T_{ult} = ultimate tensile strength of 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 Use in Strength-Related Problems

Application Area	Range of Reduction Factors			
	Installation Damage	Creep*	Chemical Degradation	Biological Degradation
Separation	1.1 to 2.5	1.5 to 2.5	1.0 to 1.5	1.0 to 1.2
Cushioning	1.1 to 2.0	1.2 to 1.5	1.0 to 2.0	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
Railroads (filter/sep.)	1.1 to 3.0	1.0 to 1.5	1.5 to 2.0	1.0 to 1.2
Flexible forms	1.1 to 1.5	1.5 to 3.0	1.0 to 1.5	1.0 to 1.1
Silt fences	1.1 to 1.5	1.5 to 2.5	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 geojute, such as, the formulation of the allowable values takes the following form. Typical values for reduction factors are given in Table 6. It may be noted that these values must be tempered by the site-specific conditions.

$$q_{allow} = q_{ult} \left(\frac{1}{RF_{SCB} \ X \ RF_{CR} \ X \ RF_{IN} \ X \ RF_{CC} \ X \ RF_{BC}} \right)$$

$$q_{allow} = T_{ult} \left(\frac{1}{\text{II RF}} \right)$$

where
q_{allow} = allowable flow rate,
q_{ult} = ultimate flow rate,
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 geojute's void space,
RF_{CC} = reduction factor for chemical clogging,
RF_{BC} = reduction factor for biological clogging, and
IIRF = value of cumulative reduction factors.

Table 6: Recommended Reduction Factor Values for Use in Flow-Related Problems

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
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
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

6.0 DESIGN EXAMPLES

Anlysis and design for separation, filtration, drainage, reinforced wall and reinforced embankment using the properties of geojute samples have been carried out for the design examples provided by Koerner (1997) for the purpose of comparison of outcome designs with those of synthetic geotextiles. As example, few designs have been presented.

Geojute Reinforced Walls

A 6-m-high wrap-around type of geojute wall that 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 γ = 18 kN/m^3, ϕ = 36°, and Ca = 0. A DW Twill with warp (machine) direction ultimate wide-width tensile strength of 25 kN/m and friction angle with granular soil of δ = 24° (since no test of DW Twill related to δ is carried out, the usual value applied for geotextile, i.e. 2/3 ϕ is taken) is intended to be used in its construction. The orientation of the geojute 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 geojute wall, the method outlined by Koerner (1997) for geotextile reinforced walls is used. The outcome design is shown in Figure 6.

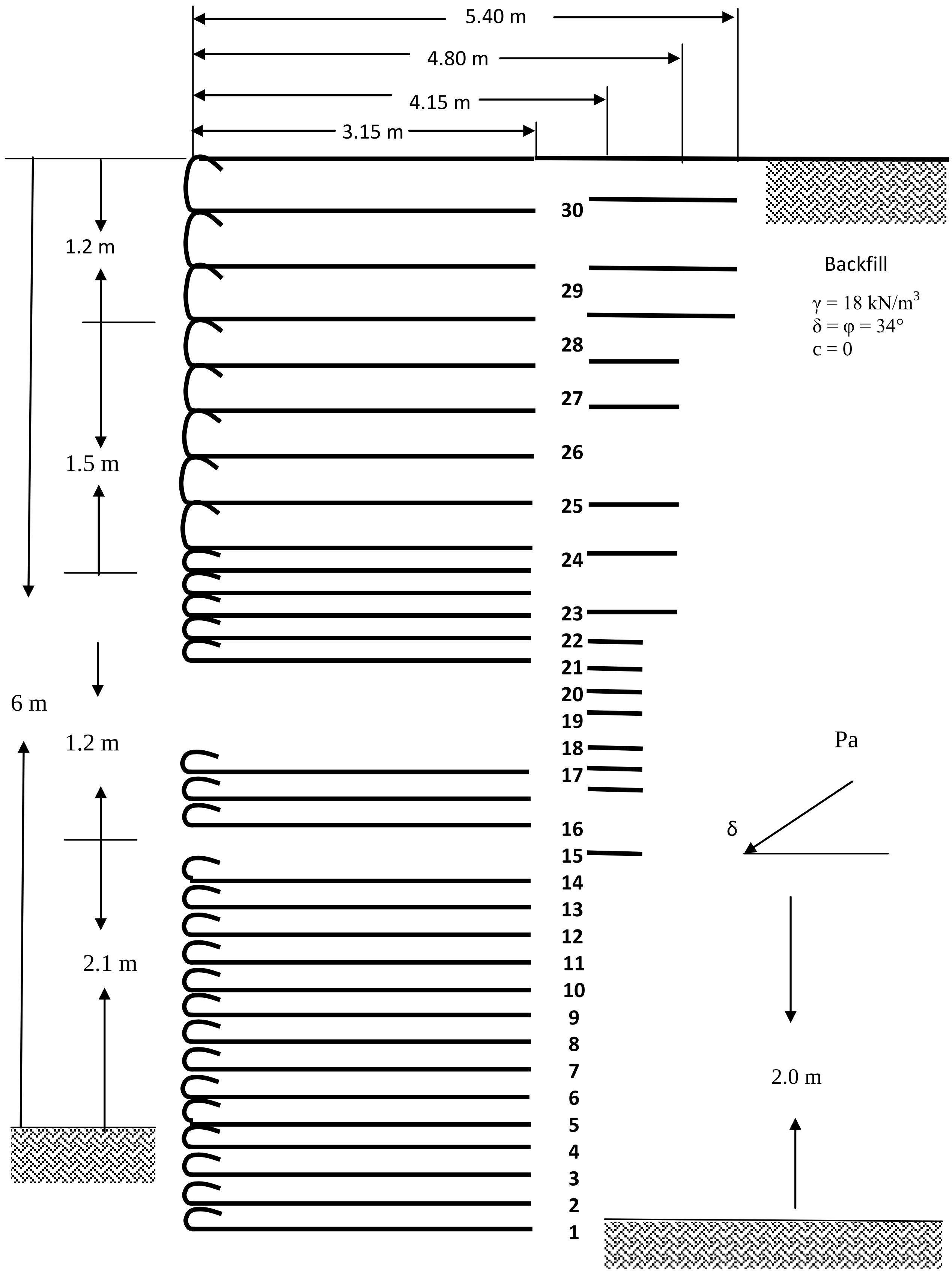
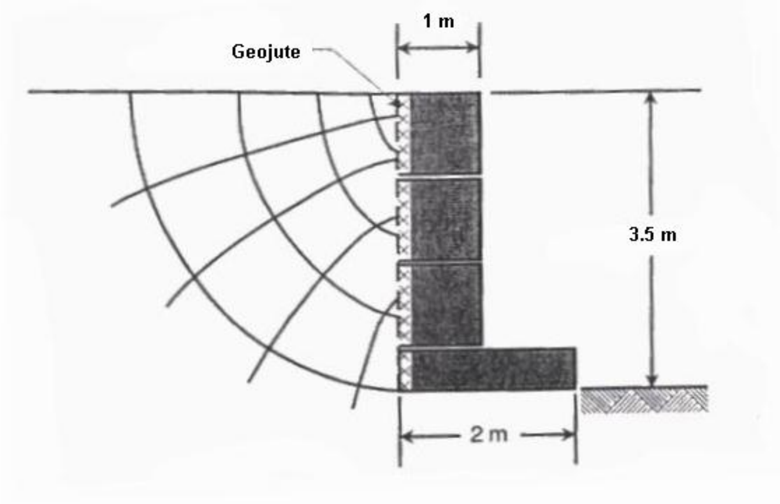


Figure 6: Outcome design of a 6.0m high wall using treated DW Twill geojute

Geojute 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 of d_{10} = 0.03 mm, C_u = 2.5, k = 0.0075 m/s, and D_R = 70%. Check the adequacy of four candidate geojutes whose laboratory test properties are given below. Use the cumulative reduction factors as 15.0, in order to adjust the ultimate laboratory-obtained permittivity value to an allowable field-oriented value.

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



The design of filter is intended to ensure:

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

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

On the basis of the above and the procedure outlined by Koerner (1997) the outcome analysis is summarized Table below:

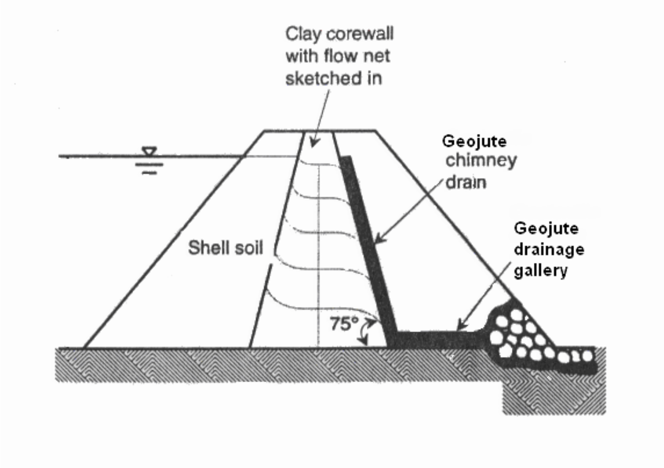
Table 7: Summary of the outcome analysis of the geojute filter design

Product	FS permittivity	FS 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 DW Twill	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.

Designing for Gravity Drainage

Given a 5 m high-zoned earth dam for use as an irrigation reservoir, the dam has a cross section as shown below. A geojute is being considered as a chimney drain and drainage gallery. The geojute under consideration is Jute (manufactured in BJRI) having $\theta = 3.68 \times 10^{-4}$ m^2/min at 10 kPa. Use cumulative reduction factors of 3.0 to convert this to θ_{allow}. What factor of safety does this geojute have for flow seeping through the core wall, which is a clayey silt of permeability 1 X 10^{-7} m/s?



In stages, the solution is as follows:

(a) Calculate the maximum seepage coming through the clay core wall that the geojute must carry. The use of a flow net (as shown in the sketch) gives

$q = kh\ (F/N)$

$= (1 \times 10^{-7})\ (5)\ (5/2)$

$= 1.25 \times 10^{-6}\ m^2/s$

$= 7.5 \times 10^{-5}\ m^2/min$

(b) Calculate the gradient of flow in the geojute

$i = \sin 75°$

$= 0.97$

(c) Calculate the required transmissivity θ_{reqd} using Darcy's Formula

$q = kiA$

$= ki\ (t \times W)$

$= (kt)\ (i \times W)$

$kt = q/(i \times W)$

$\theta_{reqd} = (7.5 \times 10^{-5}) / (0.97 \times 1.00)$

$= 7.73 \times 10^{-5}\ m^2/min$

(d) Determine the global factor of safety:

$FS = \theta_{allow} / \theta_{reqd}$

$= (\theta_{ult} / \Pi\ RF_p) / \theta_{reqd}$

$= \{(3.68 \times 10^{-4}) / 3.0\} / (7.73 \times 10^{-5}) = 1.6$

Due to the critical nature of this application, this FS value is too low and a minimum value of 5.0 is recommended. Two options present themselves: one is to use multiple layers of Jute (to increase θ_{allow}) in the lower part of the chimney drain and in the drainage gallery (the upper part of the chimney drain could still use one layer); the other is to use the FS = 5.0 and back-calculate the necessary Jute's transmissivity. This latter suggestion is illustrated as follows.

$\theta_{allow} = \theta_{reqd} X FS$

$= (7.73 \times 10^{-5}) \times 5.0$

$\theta_{allow} = 3.87 \times 10^{-4} m^2/min$

This, in turn, requires a Jute to have an ultimate (or as-manufactured) transmissivity considerably in excess of θ_{allow}. If the cumulative reduction factor is 3.0

$\theta_{allow} = (3.87 \times 10^{-4}) X 3.0$

$= 11.6 X 10^{-4} m^2/min$

This is possible only by selecting an extremely thick nonwoven needle-punched geotextile. Alternatively, geonets or geocomposites can be considered.

7.0 COST ANALYSIS BETWEEN GEOJUTE AND SYNTHETIC GEOTEXTILE

In making a proper economic assessment or evaluation, a number of inputs are required such as, material cost, labor cost etc. Again, these inputs vary place to place. In this study, an attempt has been made to analyze the comparative costs of untreated and treated geojute collected from BJRI, BJMC and local market. The comparative costs of the untreated geojute samples are shown in Figure 7.

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

Table 8: Cost of Woven and Nonwoven Geotextiles

Thickness (mm)	Cost/sft (Tk)		
	Nonwoven (local)	Nonwoven (Foreign)	Woven (Foreign)
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
4.0	8.36	17.36	19.10
Average	6.25	10.46	11.51

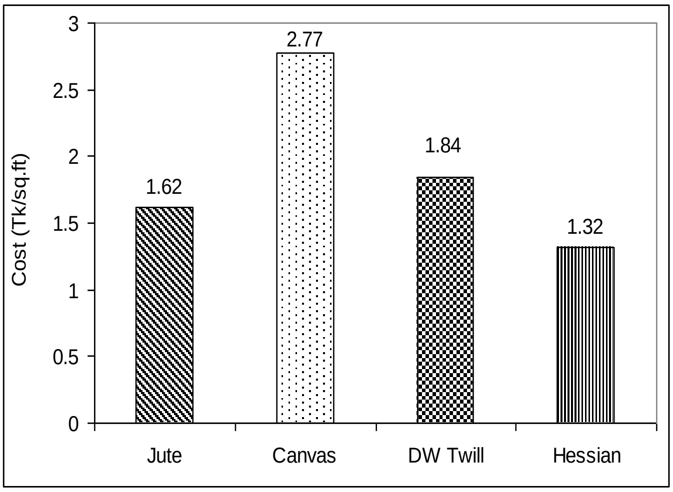


Figure 7: Comparative costs of the tested untreated geojute samples

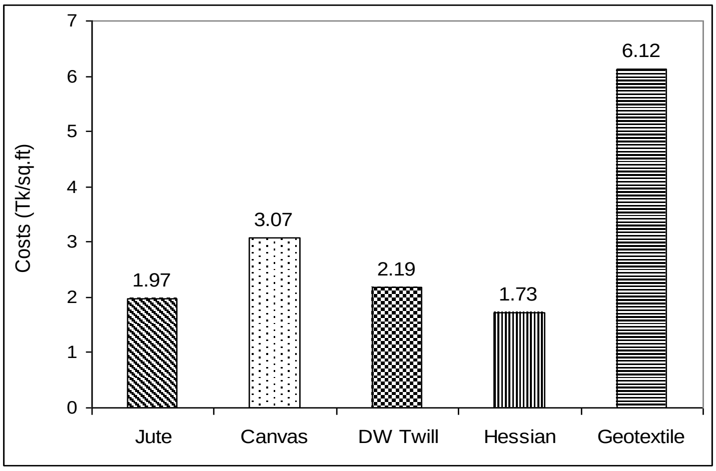


Figure 8: Comparative costs of treated geojute samples with geotextiles available in Bangladesh

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 wax resinous materials with the collaboration of BJMC and other governmental and non-governmental organizations are listed in Table 9.

Table 9: Summary of Cost of Jute Blended with Different Materials at BJRI

Type	Composition	Durability (month)	Wt./Unit (gm)	Cost Tk/yd^2
Woven Jute in different structure	Jute	2-6	220-800	8-18
Woven Jute in different structure	Jute, Coir	5-12	220-800	12-32
Woven Jute but treated composite	Jute Bitumen Carbon	6-48	Var. Wt.	12-35
Non woven	Jute blanket	6-18	800	65
Woven with different construction	Jute latex	60-240	≥ 800	20-40
Non woven	Jute Blanket + Latex	60-240	≥ 800	80

8.0 ECONOMIC BENEFIT OF USING GEOJUTE IN DIFFERENT APPLICATIONS

On the basis of the analysis and design with geojute and 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 geojute materials instead of geotextiles, a cost benefit of 35%-50% may be obtained. However, the technical shortcomings and durability restrictions of geojute materials must be appreciated prior to any application.

9.0 CONCLUDING REMARKS

It is appreciated that the inherent drawback of the untreated geojute materials is their short life span due to biodegradability. BJRI has been able to develop some treatment techniques by means of which it is possible to ensure 'designed biodegradability' of these materials. 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 geotextiles, geojute materials seem to be a potential alternative. This is further accentuated by the significant cost benefit that may be accrued from using geojute materials instead of geotextiles.

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