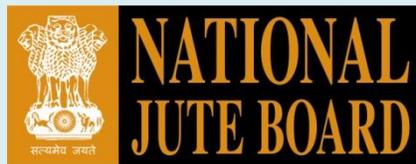


JUTE GEOTEXTILES IN RIVERS – ECONOMICS & DESIGN ELEMENTS



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**ECONOMICAL ADVANTAGES USING JUTE
GEOTEXTILES (JGT)**

Assessment of Economical Benefits using Jute Geotextiles over Conventional Design in Riverbank Protection Works

Introduction

River bank erosion is caused due to presence of erodible bank soil, fluctuation in water level and development of differential overpressure during drawdown besides high velocity of flow hugging the bank, eddies at the bank toe. Conventional granular filters overcome most of such problems. In some cases flow-regulatory measures are required to be adopted.

JGT provides effective and technically precise alternative to inverted granular filters. It prevents migration of soil and helps in developing natural graded filter (*filter cake*) by interaction with soil bed. Replacing conventional inverted filter with JGT will conserve sufficient amount of materials, time and money. Boulders are placed over JGT to avoid direct exposure to sunlight and water as well as to dissipate the thrust of wave actions.

Assumptions for Computation of riverbank construction savings –

A typical cost comparative analysis has been done assuming the following :-

Total Length of protection work = 1km

Length of Slope of protection work = 15 m

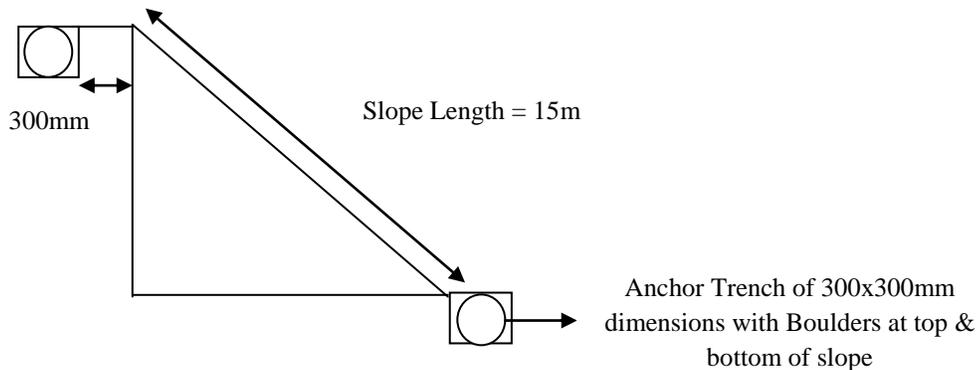
Thickness of conventional graded inverted filter = 125 mm

Quantity of JGT required for total length of protection work including anchorage (300 x 300mm trench) at toe and bottom = 17400 m²

Thickness of riprap/armor (boulders of 30 kg) = 300 mm

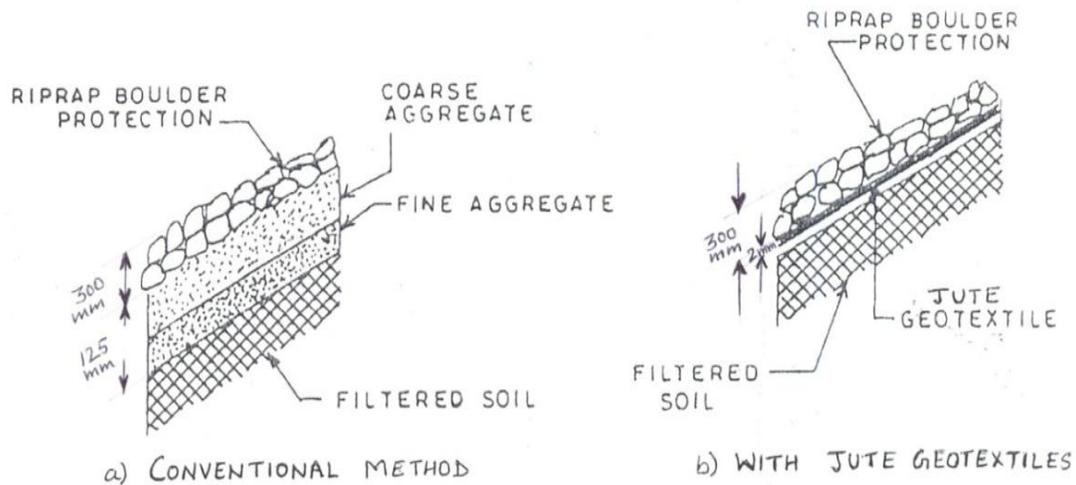
Length of riprap = 15m + 0.3 (length of toe beam) + 0.3 + 0.3 (length of trench at top & spacing) = 16 m

Thickness of JGT = 2 mm



The rates are derived from SoR, Eastern Circle, I & W Directorate, Oct 2009. Rates of stone aggregates are inclusive of carriage by road transport and loading, unloading upto 50 km to the site location with 40% hike. The rate of JGT is considered as per prevailing market price.

Comparative Cross-sectional View of Riverbank Protection works – With & Without JGT



Comparative Cost Analysis of Riverbank Protection Works

Type	Quantity	Conventional		Quantity	With Jute G.T		Savings (%)
		Rate	Amount (Rs.)		Rate	Amount (Rs.)	
Filter Layer							
a) Graded inverted filter 125mm thick	1000 x 15 x 0.125	2700.00	5062500.00	N/A	N/A	N/A	
b) Jute Geotextiles				1000 x 17.4	88.50	1539900.00	
c) Boulder 30 kg ➤ 300 mm thick riprap	1000 x 15 x 0.3	2800.00	12600000.00	1000 x 16 x 0.3	2800.00	12600000.00	
Total			Rs. 17662500.00 ≈Rs. 1177.5/m²			Rs. 13440000.00 ≈Rs. 896/m²	Rs. 280/m² (23%)

Inference : There will be direct cost savings of the order of 23% with the given set of parameters usually followed.

DESIGN METHODOLOGY WITH JUTE GEOTEXTILE

Design Approach of River Bank Protection Works with Jute Geotextiles (JGT)

At the outset it is important to point out that as degradability of jute being much quicker when in contact with water as in the case of river bank protection, the selected JGT must be durable enough to last till the bank soil stabilizes to an acceptable degree. In severe cases time taken for stabilization is longer necessitating extended effective life of JGT. Bank soil may stabilize sufficiently if filtration is effective for at least two seasons usually. Experience gained over the years shows that stabilization of bank-soil depends on severity of flow—especially its velocity, proximity to bank, change of direction as in tidal rivers, vortices at the bank-toe, waves and nature of influencing agents such as wind, tides. It is therefore important to ensure durability of JGT till such time bank soil stabilizes say for three seasons. Special additives/treatment process has recently been developed by IIT Kharagpur and also by IJIRA. The treatment developed by IIT Kharagpur is claimed to possess durability for four years in water under varying magnitude of water salinity. Both the developed treatments have been applied in the field. The performance is being monitored.

The criteria for design therefore rests on the following viz

- A. Design of JGT under site-specific conditions
- B. Durability of JGT
- C. Design of armour/riprap over JGT ensuring over-all stability of treated bank considering the tractive forces usually experienced under usual circumstances

DESIGN CONCEPT

The critical parameter for river bank erosion control is the filtration capability of the selected woven JGT. For filtration function to be effective under given hydraulic and geotechnical parameters, fabric design demands optimal pore size of JGT that can retain the maximum soil particles ('soil tightness') on the one hand and allowable permittivity to dissipate the pore water pressure in bank soil on the other. The design therefore should focus on AOS of woven JGT in relation to average grain size distribution of bank soil and permittivity of JGT vis-à-vis hydraulic conductivity of bank soil. There exist empirical relations for man-made geotextiles to address both the criteria. But then unlike man-made geotextiles JGT does not possess dimensional uniformity. Considering its lack of uniformity and for 'hairiness' of its yarns it is suggested that AOS of JGT should be given a *larger tolerance* (say 15%) over the design value.

Conceptually, designing a geotextile filter is no different from designing a graded granular conventional filter. For a geotextile to act as a filter, it is essential that a condition of equilibrium is established at soil-geotextile interface as soon as possible after installation.

A filter should prevent migration of soil particles to an acceptable extent, while at the same time allow pore water to flow through and also along the filter layer to prevent development of overpressure in bank soil.

The concepts used to establish design criteria for geotextiles are stated below :

- JGT must retain average sized soil particles to the maximum (**retention criterion**),
- Hydraulic Conductivity of the fabric should be such as to allow pore water to pass across and along the plane of fabric (**permeability and transmissivity criterion**). It may be noted that the extent of transmissivity varies with the pressure imposed on the fabric. Permeability plays a more dominant role in such cases.
- Conducting GR or HCR tests to rule out probability of clogging /blocking.
- JGT must survive installation stresses (**survivability criterion**).

SOIL RETENTION CRITERIA FOR DIFFERENT FLOW CONDITIONS

In unidirectional flow conditions larger soil particles virtually form an arch-like configuration over JGT and restrain smaller particles which in turn successively contain smaller soil particles. The altered arrangement of soil particles in bank soil takes the shape of a graded filter structure (filter cake).

In reversing flow conditions, filter cake formation in bank soil is usually partial when the cycle time does not allow sufficient time to form a graded filter. In rapidly reversing flow conditions even partial filter cake formation in bank soil may not be possible.. In such conditions, granular filter is used in conjunction with JGT. Light weight JGT is adequate for unidirectional flow conditions, whereas thick GT should be suitable for rapidly reversing flow conditions. (D J Haore, 1984).

Geotextiles & Geomembranes manual edited by T S Ingold states that permeability may be “operational”. The recommendation is --‘unlike static design where flow is unidirectional, flow through bank soil occurs under reversing, dynamic hydraulic gradients. Consequently the bank soil cannot be assumed to develop filter-cake and so the pore size required for retention will be *smaller* than for a dynamic flow regime than it might be for static flow.’

PIANC, Lawson (1982), Rijkswaterstaat, Mouw (1986), Veldhuijzen (1986) and Working Group 14 of the German Society for Soil Mechanics & Foundation Engineering (GSSMFE), Franzius Institute for hydraulic research have developed design criteria for riverbank application. Of all the designs, the one suggested by Lawson is the simplest.

It states that when U (Co-efficient of Uniformity) is less than 5, for retention criterion $O_{90} < d_{50}$ and for permeability criterion $O_{90} > d_{15}$ may be adopted. All the design criteria are based on empirical studies.

GSSMFE has suggested that retention criteria depend on the soil type and its grading. The following types of soil are prone to down slope migration.

- i) Particle size is finer than 0.06 mm and $U (d_{60}/d_{10})$ is less than 15
- ii) More than 50% particles are in the range of 0.02 to 0.1 mm
- iii) PI (Plasticity Index) is greater than 15
- iv) Clay size fraction is less than 50% of the silt size fraction

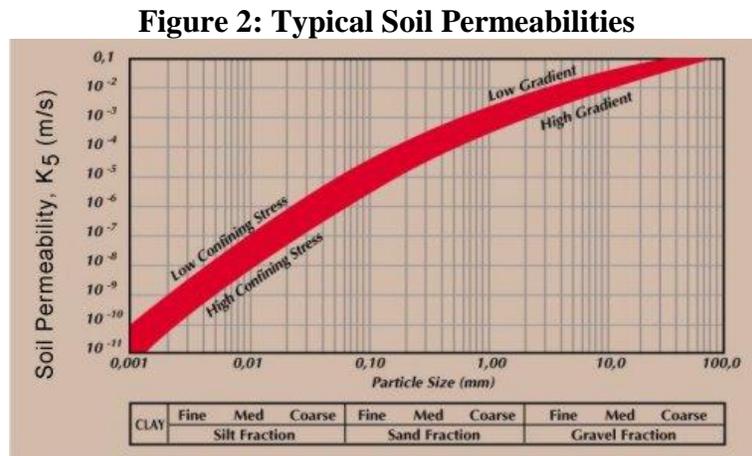
The recommendation for retention criteria is as under which may be adopted for JGT.

- a) If d_{40} is ≤ 0.06 mm, then O_{90} should be less than d_{90} , $10d_{50}$ and $300 \mu\text{m}$ separately
- b) If d_{40} is > 0.06 mm, then O_{90} should be less than $1.5 d_{10}U^{1/2}$, d_{50} and $500 \mu\text{m}$ separately

PERMEABILITY CRITERION

- General requirement of permeability criterion is $k_{\text{geotextile}} \geq i_s k_{\text{soil}}$ (Giroud, 1988) :

The principle of all permeability criteria is that as long as the permeability of the geotextile (k_g) is greater than the permeability of the soil (k_s) the flow of water will not be impeded at the soil / geotextile interface. Fig 2 shows permeabilities of different soil fraction under different hydraulic gradients.



The relationships between permeability of JGT and soil have been derived from Netherlands Coastal Works Association (1981), Franzius Institute in Germany (1981 and Calhoun (1972). Since jute fibres are rich in cellulosic content, the absorption and transmission capacity of water along and across the fabric is well pronounced and can be summarized as -

$$\Psi_{\text{JGT}} \geq k_{\text{soil}} \quad (1)$$

where,

$$\Psi_{\text{JGT}} = \text{Permittivity of JGT (/sec)} = \frac{k_{\text{JGT}}}{t_{\text{JGT}}}$$

t_{JGT} = Thickness of JGT (cm)

k_{JGT} = Permeability across JGT(cm/sec)

k_{soil} = Permeability of sub-grade soil ie. Hydraulic Conductivity (cm/sec)

(N.B. Permeability and Hydraulic Conductivity are synonymous).

Soils which are prone to down slope migration require additional protection either in the form of a granular sub-layer or thick high transmissivity geotextile (Ingold). JGT is itself a natural high transmissivity geotextile.

SURVIVABILITY CRITERIA

For survivability JGT shall have the following minimum average roll values (MARV) for armour layer stone weighs about 50 kg with stone drop height of nearly 1m –

S.No.	Property	ASTM	Units	Values
1.	Wide Width Tensile Strength (kN/m)	D 4595	kN/m	20
2.	Puncture Strength (kN)	D 4833	kN	400 (± 10%)
3.	Burst Strength (kPa)	D 3786	kPa	3100 (± 10%)

ANTI-CLOGGING CRITERION

To obviate probability of clogging and blocking of JGT Gradient Ratio Test or Hydraulic Conductivity Test should be conducted prior to deciding on the fabric porometry (AOS).

DESIGN OF RIPRAP

The third aspect is based on assessing the tractive force (shear stress) imposed by flowing water and the ability of the armour-JGT combination to withstand the force. This implies determination of the thickness of the armour as well as its dead weight.

Design of Riprap Pitching consists of thickness of pitching and weight of boulders which can be determined as below -

- i. Minimum Thickness of Pitching (T) as per IS code of 14262-1995

$$T \text{ (in metre)} = \frac{V^2}{2g(S-1)} \quad (2)$$

where, V = Maximum velocity during flood (m/s), g = Gravitational constant = 9.81 m/s²
S = Specific Gravity of Riprap

- ii. Minimum Weight of Boulders/Rocks (W) as per IS Code of 14262-1995

$$W \text{ (kg)} = \frac{0.02323}{K} \times \frac{Sm}{(Sm-1)^3} \times \quad (3)$$

Where, K = Slope Correction factor = $\sqrt{1 - \left(\frac{\sin\theta^2}{\sin\phi^2}\right)}$

V = Maximum velocity during flood (m/s), θ = Bank Slope, $\phi = 30^\circ$ = Angle of Repose

Sm = (1 - e)S

$$e = \text{Porosity} = 0.245 + \frac{0.0864}{(D50)^{0.21}}$$

Recommendations for use of JGT in River Bank Protection Works

Flow Conditions	Type of JGT		Riprap Thickness
	Tensile Strength	Porometry Range	
Cyclic Flow with slow cycle time	20 kN/m	150 – 400 μ	Refer to eqn (2)
Cyclic Flow with quick cycle time	≥ 20 kN/m	150 – 400 μ	Refer to eqn (2)

Specifications of Untreated/Grey Woven JGT to be used -

Nomenclature	Woven JGT 20 kN/m (Untreated)
Construction	1/1 DW Plain Weave
Weight (gsm) at 20% MR \geq	627
Width (cm) \geq	100
Ends x Picks / dm \geq	85 x 32
Thickness, (mm at 2 kPa)	1.7 \pm 10 %
Tensile Strength (kN/m) MD x CD \geq	20 x 20
Elongation at break (%) MDx CD \geq	12 x 12
Puncture Resistance(kN)	0.400 \pm 10 %
Burst Strength (KPa)	3100 \pm 10 %
Permittivity at 50mm constant head (/sec)	350 x 10 ⁻³ \pm 10 %
A O S (micron) O ₉₅	150 - 400