ECONOMICS AND ENVIRONMENTAL BENEFITS OF USING JUTE GEOTEXTILES IN LOW VOLUME ROADS, BANK PROTECTION AND SLOPE MANAGEMENT WORKS

Tapobrata Sanyal¹ & Rumki Saha²

ABSTRACT

Economy in construction cost is one of the basic criterion of a good design. A good design necessitates precise assessment of the governing parameters like geotechnical characteristics, proper design methodology and selection of the appropriate materials of construction. The principle is followed in design of all types of construction which includes low volume roads, protective works in eroded river banks, failed slopes etc.

It is common knowledge that use of locally available materials will contribute to economizing cost of construction. The cost of such material warrants pre-determination of their properties. Geotextiles made of natural fibre, jute – Jute Geotextile (JGT) is one such material that can address many soil related adversities if used judiciously. It can functionally compare with its synthetic counterpart and has the added advantage of being eco-concordant unlike synthetic geotextiles. JGT is eco-compatible, biodegradable and its technical suitability as geotextiles stands proven after more than 200 field applications in India and concurrent laboratory studies in Research Institutes of repute.

The present global emphasis is on use of such construction material that has eco-compatibility as the aim is to reduce carbon footprint in construction.

The paper will present through an analytical model case study of economical and environmental advantages of using Jute Geotextiles in low volume (rural) roads, protective works in river banks and management of failed slopes.

Keywords – Economy, Eco-concordant, Low Volume Roads, Riverbank Protection, Slope Management, Jute Geotextiles.

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ABSTRACT: Construction of any road and riverbank requires assessment of loads (dynamic), geotechnical characteristics of the sub-grade & bank soil and proper design methodology, careful choice of materials for construction in terms of both cost effectiveness and eco-compatibility. Cost of construction is another important criterion as high cost may upset a work plan. Currently much importance is laid on environmental aspects with emphasis on using materials with low carbon footprint. Jute Geotextiles (JGT) may be used with technical, environmental and economical advantage for the purposes stated above. The paper presents through an analytical model case study of economical and environmental advantages of using Jute Geotextiles in low volume (rural) roads, protective works in river banks and management of failed slopes.

INTRODUCTION

Geotextiles in construction is not a new technology; however this innovative technology needs support from the frontline engineers so that it can be used and datas related to its performance can be gathered. Geotextiles-- both Synthetic and Natural-- serve the basic functions of a Geo-textile, i.e, Separation, Filtration, Drainage & Reinforcement.

Jute Geotextiles (JGT), the natural variant of geotextiles, belongs to the class of technical textiles under GEOTECH category. Significant features of jute such as high moisture absorbing capacity, excellent drapability, low extension at break, high roughness coefficient, high spinnability, soil nourishing characteristics have been utilized to manufacture application-specific geotextiles to address a host of geotechnical problems encountered in civil engineering as well as reduces construction cost of applications in road, river and slope management.

The current global emphasis is on use of eco-friendly material in various applications with an aim to reduce carbon footprint. JGT fits in with the trend in view of its ability to sequester carbon, release of oxygen and other associated environmental benefits. JGT renders benefits both environmentally and economically. This paper provides inputs to corroborate this contention.

A. LOW VOLUME ROAD CONSTRUCTION WITH JGT

I. Economical Aspects

It has been found from laboratory studies corroborated by approximately 50 field trials that with JGT application, CBR enhances by 1.5 – 3 times over the control value of sub-grade in all cases and even more in few field trials since consolidation is a long drawn process and continues for years with JGT triggering the process and optimizing the sub-grade consolidation during its life-time. With respect to such observations, a design example is shown below assuming CBR enhances by minimum 1.5 times the control value.
Basic Assumptions for Computation of Construction Cost of a rural road–

The calculated construction cost depends on variable parameters like region of construction, choice of materials, distance of construction site from sources of raw materials, type of sub-grade soil (CBR) over which road will be constructed and traffic volume (Cumulative ESAL) for design life of road. The following text is an example to indicate the economical benefits of using JGT in a rural road over a conventionally design road and with SGT design road for common value of CBR and ESAL range.

As an example CBR of sub-grade soil is taken as 4% which is enhanced by 1.5 times the control value by use of JGT to 6%. The following are the assumptions for the example -

a) CBR of sub-grade soil : 4%
b) Considering Enhancement of CBR of sub-grade soil by 1.5 times from control value of 4%:6%
c) Cumulative Traffic ESAL : 60,000 – 1,00,000
d) Length of Pavement : 1000 m
e) Carriageway Width of Pavement : 3.75 m
f) Roadway Width : 7.5 m
g) Thickness of sub-grade : 300 mm
h) Width of JGT with 10% overlapping : 8.6 m
i) Width of SGT with 10% overlapping : 8.6 m (as no sand layer is provided for drainage purpose in case of SGT)
j) Site selected for construction of road is near Howrah and is about 20 km from Dankuni station.
k) The rates of materials are taken from SoR, PWD, Roads & Bridges, West Bengal, August, 2014.
l) The rates of riding surface not included

The calculated savings are considered under idealized conditions of road construction. Also the calculated savings may vary from region to region and distance between worksite from source of materials.

Cross-section of pavement is designed as per guidelines mentioned in IRC:SP:72-2007 as shown in Table 1 below.

Granular Sub-base Grading II consists of 1st class brick aggregates (40mm down) & sand (in proportion 60:40) and Granular Sub-base Grading III consists of stone chips and sand (2.36 mm below) distributed as per Technical Specifications of Rural Road. Water Bound Macadam Grading II consists of 63 – 45 mm size and Grading - III consists of 53 – 22.4 mm size with stone screening Type B. Rate of JGT is considered as per prevailing market price and transportation charges are included in the rates.
Table 1 Pavement constituents

<table>
<thead>
<tr>
<th>ITEMS</th>
<th>Pavement Thickness with Conventional Design</th>
<th>Pavement Thickness with JGT</th>
<th>CBR 4%</th>
<th>Enhanced CBR 6% (1.5 times of 4% CBR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WBM – III</td>
<td>75mm</td>
<td>75mm</td>
<td>4%</td>
<td>6%</td>
</tr>
<tr>
<td>WBM – II</td>
<td>75mm</td>
<td>75mm</td>
<td>4%</td>
<td>6%</td>
</tr>
<tr>
<td>GSB – III</td>
<td>75mm</td>
<td>125mm</td>
<td>4%</td>
<td>6%</td>
</tr>
<tr>
<td>GSB-II</td>
<td>100mm</td>
<td>---</td>
<td>4%</td>
<td>6%</td>
</tr>
<tr>
<td>Total</td>
<td>325 mm</td>
<td>275 mm</td>
<td>4%</td>
<td>6%</td>
</tr>
</tbody>
</table>

Cost Analysis of Pavement Constituents with Conventional Design

Conventional Design follows IRC:SP:72-2007 guidelines and cost analysis is shown in table 2 below.

Cost Analysis of Pavement Constituents with JGT

It has been found from laboratory studies corroborated by approximately 50 field trials that with JGT application, CBR enhances by 1.5 times at least over the control value of sub-grade in all cases and even more in few field trials. The design example assumes a minimum 150% increment of CBR of sub-grade by use of JGT. The cost analysis of pavement constituents with stated assumptions is shown in table 3 below.

N.B.: An additional 25 mm each thin layer of sand is to be laid above and below woven JGT fabric to overcome puncturing from sub-base layer and to delay its degradation of JGT.
Table 2 – Cost Analysis of Road Design with Conventional Method (Cost per km Basis)

<table>
<thead>
<tr>
<th>S.No.</th>
<th>DESCRIPTION OF ITEMS</th>
<th>LENGTH (m)</th>
<th>WIDTH (m)</th>
<th>THICKNESS (m)</th>
<th>QUANTITY (m³)</th>
<th>RATE (Rs.)</th>
<th>AMOUNT (Rs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>GSB – II</td>
<td>1000</td>
<td>8.8</td>
<td>0.1</td>
<td>880</td>
<td>1962.5</td>
<td>1727000</td>
</tr>
<tr>
<td>2.</td>
<td>GSB – III</td>
<td>1000</td>
<td>4.05</td>
<td>0.075</td>
<td>303.75</td>
<td>1456.335</td>
<td>442362</td>
</tr>
<tr>
<td>3.</td>
<td>WBM (Gr. II)</td>
<td>1000</td>
<td>3.9</td>
<td>0.075</td>
<td>292.5</td>
<td>2725.37</td>
<td>797171</td>
</tr>
<tr>
<td>4.</td>
<td>WBM (Gr.III)</td>
<td>1000</td>
<td>3.75</td>
<td>0.075</td>
<td>281.25</td>
<td>2757.205</td>
<td>775464</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>3741997</strong></td>
</tr>
</tbody>
</table>

Table 3 - Cost Analysis of Road Design with JGT (Cost per km Basis)

<table>
<thead>
<tr>
<th>S.No.</th>
<th>DESCRIPTION OF ITEMS</th>
<th>LENGTH (m)</th>
<th>WIDTH (m)</th>
<th>THICKNESS (m)</th>
<th>QUANTITY (m³)</th>
<th>RATE (Rs.)</th>
<th>AMOUNT (Rs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Medium Sand below JGT</td>
<td>1000</td>
<td>8.6</td>
<td>0.025</td>
<td>215</td>
<td>896</td>
<td>192640</td>
</tr>
<tr>
<td>2.</td>
<td>Woven JGT</td>
<td>1000</td>
<td>8.6</td>
<td></td>
<td>8600 m²</td>
<td>73.70</td>
<td>633820</td>
</tr>
<tr>
<td>3.</td>
<td>Medium Sand above JGT</td>
<td>1000</td>
<td>8.6</td>
<td>0.025</td>
<td>215</td>
<td>896</td>
<td>192640</td>
</tr>
<tr>
<td>4.</td>
<td>GSB – III</td>
<td>1000</td>
<td>4.05</td>
<td>0.125</td>
<td>506.25</td>
<td>1456.335</td>
<td>737270</td>
</tr>
<tr>
<td>5.</td>
<td>WBM (Gr. II)</td>
<td>1000</td>
<td>3.9</td>
<td>0.075</td>
<td>292.5</td>
<td>2725.37</td>
<td>797171</td>
</tr>
<tr>
<td>6.</td>
<td>WBM (Gr.III)</td>
<td>1000</td>
<td>3.75</td>
<td>0.075</td>
<td>281.25</td>
<td>2757.205</td>
<td>775464</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>3329005</strong></td>
</tr>
</tbody>
</table>

Table 4. Inference Drawn on Comparative Cost Analysis (Cost per km basis)

| Conventional Method vis-à-vis with JGT | 11.4% Savings using JGT |

B. RIVER BANK PROTECTION WITH JGT

I. Economical Aspects

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 an 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 m$^2$

Thickness of riprap/armor (boulders of 30/45 kg) = 300 mm
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 30% hike. The rate of JGT is considered as per prevailing market price.

Table 5 will show cost analysis of river bank protection work of conventional vis-à-vis JGT
Table 5. Comparative Cost Analysis of Riverbank Protection Works

<table>
<thead>
<tr>
<th>Type</th>
<th>Conventional</th>
<th>With Jute G.T</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Quantity</td>
<td>Rate</td>
</tr>
<tr>
<td>Filter Layer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) Graded inverted filter 125mm thick</td>
<td>1000 x 15 x 0.125</td>
<td>2020.00</td>
</tr>
<tr>
<td>b) Jute Geotextiles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c) Boulder 30/45 kg riprap</td>
<td>1000 x 15 x 0.3</td>
<td>2100.00</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Percentage Savings Using Jute Geotextile (JGT) -

Construction Cost Savings Per m²(%) = \( \frac{\sum_{\text{Conventional}} - \sum_{\text{JGT}}}{\sum_{\text{Conventional}}} \times 100 \approx 19 \%

II. Environmental Aspects

This study looks at indirect savings caused at construction phase only. For delivering of materials to site required for construction of road, fuel consumed in transportation is a reflection of emitting carbon in the environment as well as depletion of non-renewable resource like diesel and natural stones. There is 125mm thick conventional filter will be replaced by JGT. Effect of JGT on Carbon Sequestration in the Life Cycle Analysis of Jute products has not been included which could have further substantiated its potential for quantification of carbon footprint reduction.

Assuming capacity of Punjab Body Truck to carry materials = 14 ft x 7 ft x 5 ft = 14 m³

Now, Volume of saved quantity of 125 mm filter thickness for 1 km and 15 m wide = 1875 m³

Number of trips required for carrying 1875 m³ of granular layer to site = \( \frac{1875}{14} \approx 134 \)

Average Weight of JGT carried by Punjab Body truck = 9000 kg
Weight of required 17400 m$^2$ of 627 g/m$^2$ JGT for 1 km sketch = 10910 kg

Number of trips required for transporting 17400 m$^2$ of 627 gsm JGT to construction site = 2

Effective Reduction in number of trips using JGT = 132

a) **Quantification of diesel consumption**

Considering a truck consumes 5 lts/km of diesel and distance between nearest quarry site to construction site is within 50 km

Distance travelled to site for 132 trips = 132 x 50 = 6600 km and thus Diesel Saved ≈ 1320 litres.

Since diesel is a non-renewable energy/fossil fuel and its rate of depletion (exploitation) far exceeds rate of (re)generation and once consumed cannot be regenerated

b) **Quantification of natural resources consumption**

Natural resource extraction activities have the potential to generate significant environmental impacts, including transporting resources on large lorries and mining/quarrying of construction aggregates (gravel, hard rocks), boulders etc affects ecological balance i.e. carbon emission during production.

With JGT application as a filter layer, quantity of aggregate conserved = 1875 m$^3$ which reduces both costs and use of scarce resources. Additionally, less hauling of granular materials will result in significant emissions reduction.

c) **Quantification of vehicular emissions**

Emissions are quantified based on number of vehicles and distance travelled is given by (Gurjar et al., 2004)

$$E_i = \sum (Veh x D) \times E_{ij,km}$$  \hspace{1cm} (1)

where,

- $E_i$ = Emission of compound
- Veh = No. of vehicles of each type
- $D$ = Distance travelled from quarry site to construction site = 50 km
- $E_{ij,km}$ = emission of compound from vehicle per driven kilometer = 515.2 gm/km of CO$_2$ from trucks (Mittal and Sharma, 2003)

Emissions released ($E_b$) = 132 x 1 x 50 x 515.2 = 3400 kg of CO$_2$ is emitted in 132 trips

This indicates that fuel and energy consumed for transportation of 132 trips of granular filter materials is associated to carbon emissions can be reduced by incorporating JGT at the interface of bank soil and riprap.

C. **HILL SLOPE MANAGEMENT USING JGT**

I. **Economical Aspects**

In slope management works there will be no direct savings using JGT from conventional methods. As conventional methods aim at remedial concepts like slope correction, structural measures of toe-wall construction, retaining walls etc. that cannot be done using JGT or any other type of Geotextiles. JGT prevents soil erosion aiming soil bio-engineering concept. But JGT can be compared from other available geotextiles shown in Table 6. below.
Table 6. Typical cost of different types of geotextiles -

<table>
<thead>
<tr>
<th>Rate of Synthetic GT. (Rs./sq.m)</th>
<th>Rate of Coir GT. (Rs./sq.m)</th>
<th>Rate of Jute GT. (Rs./sq.m)</th>
<th>Savings (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>65.00</td>
<td>40.00</td>
<td>20.00</td>
<td>69.23 % (SGT)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>50 % (Coir GT)</td>
</tr>
</tbody>
</table>

N.B. Rates of fabric are indicative.

It must be noted that there will be no direct savings due to use of geotextiles but will be obvious environmental advantages for using JGT.

II. Environmental Aspects

Jute fibres can absorb water about 5 times its dry weight. JGT attenuates extremes of temperature, acts as mulch after degradation & creates a congenial micro-climate ensuring quick growth of dense vegetation. Finally root-system of vegetation ensures soil retention and also provides sustainable solution to the problems of erosion.

JGT, a natural product, fosters vegetation growth and paves a way for bio-engineering solution to soil erosional problem.

**INFERENCES:**

Eco-concordance, cost competitiveness and technical suitability of JGT make it a material worth trying in low volume road construction, river bank protection and hill slope management. In view of the fact, the following inference can be drawn over its application in table 7 and table 8 below.

### Table 7

<table>
<thead>
<tr>
<th>Applications</th>
<th>Economical Aspects Using JGT vis-à-vis Conventional Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Rural Road Construction Works</td>
<td>11.4% reduction in initial construction cost of pavement constituents.</td>
</tr>
<tr>
<td>b) Riverbank Protection Works</td>
<td>19% reduction in initial cost construction.</td>
</tr>
</tbody>
</table>
| c) Hill Slope Management Works       | i. 62% reduction in cost of fabric from Man-made GT  
                                       | ii. 23% reduction in cost of fabric from Coir GT |

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**Note:** Table 7 provides a comparison of the economic aspects of using JGT versus conventional methods for selected applications. It shows the percentage reduction in initial construction cost for pavement constituents and fabric costs for different types of GT.
### Table 8.

<table>
<thead>
<tr>
<th>Applications</th>
<th>Ecological Aspects Using JGT as compared to Conventional Method</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Savings in Diesel Consumption</td>
<td>Savings in Natural Resources (Stones)</td>
</tr>
<tr>
<td>a) Riverbank Protection Works</td>
<td>1320 litres</td>
<td>1875 m$^3$</td>
</tr>
<tr>
<td>b) Hill Slope Management Works</td>
<td>Paves a way for soil bio-engineering creating a congenial micro-climate degradation that fosters growth of vegetation</td>
<td></td>
</tr>
</tbody>
</table>

**ACKNOWLEDGEMENT:**

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**REFERENCES:**
