CASE STUDIES ON APPLICATION FOR MINE-SPOIL STABILIZATION
APPLICATION OF JGT FOR MINE-SPOIL STABILIZATION IN UTTARANCHAL AND HIMACHAL PRADESH*

UTTARANCHAL MINE SPOIL

LOCATION: Dhandaula Kharawan lime stone quarry, Shasradhara, 18 Km away from Dehradun, Uttaranchal.

OBJECTIVE: Stabilization of the land slope. Checking the slide of soil, debris and boulders during heavy rains. Restoration of vegetative cover destroyed due to mining activities. Improvement of water quality.

PHYSIOGRAPHY

The 64 hectares area having elevation ranging from 842 m to 1310 m comprises of exposed cut rock surface, mine spoils deposits, landslide and gullies.

The average slope of the area was about 50%.

The mine spoil flows directly into the river Baldi, a tributary of Ganga.

RAINFALL

3000 mm (average) annually 80% of which is received during monsoon months (mid June to mid September)

Max. one day (24 hrs.) rainfall Max. rainfall intensity

369 mm 240 mm/hr (5 min. duration) &

120 mm/hr (3 min duration)

VEGETATION

Ecologically this area is an example of vegetation of edaphic sub-climax i.e. vegetation changes with modifications in soil composition.

*The study was conducted by Dr. J.S. Samra (Director, CSWCRTI), G.P. Juyal (Sr. Scientist), R.K. Arya (Tech. Officer) of CSWCRTI, Dehradun, published in Indian Journal on Soil Cons. 24 (3) :179-186 1996.
PHYSICO–CHEMICAL CHARACTERISTICS

<table>
<thead>
<tr>
<th>CHARACTERISTICS</th>
<th>PROJECT AREA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texture Class</td>
<td>S ( Sandy loam )</td>
</tr>
<tr>
<td>Sand ( % )</td>
<td>66.60</td>
</tr>
<tr>
<td>Silt ( % )</td>
<td>19.50</td>
</tr>
<tr>
<td>Clay ( % )</td>
<td>13.90</td>
</tr>
<tr>
<td>pH</td>
<td>08.10</td>
</tr>
<tr>
<td>CaCO₃ ( % )</td>
<td>68.10</td>
</tr>
<tr>
<td>Total Nitrogen ( % )</td>
<td>00.016</td>
</tr>
<tr>
<td>Available P₂O₅ ( kg /ha )</td>
<td>03.78</td>
</tr>
<tr>
<td>Available K₂O ( kg /ha)</td>
<td>44.10</td>
</tr>
</tbody>
</table>

TREATMENT WITH JUTE GEOTEXTILE

Based on the topographical, vegetative and soil surveys, a corrective plan consisting of a combination of engineering and vegetative measures was implemented. Steep slopes were vegetated with the application of Jute Geotextile.

Jute Geotextile was spread in conformity with the shape of the contour of the mine-spoil. The two adjoining widths were overlapped by about 10 cm and fastened with jute threads. Wooden sticks (1.5-2m long and 5-7 cm dia) were driven about 1 m deep to secure the matting at places which also provided mechanical support to unstable slopes.

Rooted slips of grasses were planted in opening between JGT strands at close spacings. At one of the locations trenches (30 cm X 30 cm) were dug which were filled with good soil from outside and mixed with Napier grass.
PROPERTIES OF JUTE GEOTEXTILE USED

<table>
<thead>
<tr>
<th>Properties</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (gsm) at 20 % moisture regain</td>
<td>500</td>
</tr>
<tr>
<td>Threads / dm (MD x CD)</td>
<td>6.5 x 4.5</td>
</tr>
<tr>
<td>Thickness (mm)</td>
<td>4</td>
</tr>
<tr>
<td>Width (cm)</td>
<td>122</td>
</tr>
<tr>
<td>Open area (%)</td>
<td>50</td>
</tr>
<tr>
<td>Strength (kN / m) [MD x CD]</td>
<td>10 x 7.5</td>
</tr>
<tr>
<td>Water holding capacity on dry weight (%)</td>
<td>500</td>
</tr>
</tbody>
</table>

RESULTS

a) VEGETATION ESTABLISHMENT –
Thysanolaena maxima grass recorded an yield of 3052 kg/ha (oven dry) compared to 640 kg/ha in control after 3 years of plantation. Hybrid napier when planted in contour trenches filled with good soil mixed with farm yard manure (FYM) recorded an excellent yield of 9850 kg/ha compared to 1960 kg/ha in control.

b) MOISTURE IMPROVEMENT –
The JGT helped in moisture conservation (40-50 %). It was observed that in the slopes treated with JGT, moisture control reached below wilting point in 7 days compared to 3 days only in control after a rainfall of 20 mm (in the top 15 cm layer). There was still good amount of moisture below 30 cm depth after one month from the day of 20 mm rainfall.
c) **EROSION CONTROL** –

Reduced the monsoon run-off from 57% - 37 %,
Delayed and attenuated the flood peaks by 20 minutes and more than 60% respectively.
The soil erosion was reduced to 8 ton per / ha - near permissible limits-within a period of 6 years. The structure retained a huge quantity of debris (62,000 cu m).

d) **WATER RESOURCE IMPROVEMENT** –

With more infiltration of run-off water into the soil profile by conservation measures new water sources / springs regenerated in the water shed.
The dry weather flow measured in the months of November and February was 265 cu m and 100 cu m per day respectively, augmenting the water availability for domestic and irrigation purposes.

**IMPROVEMENT IN WATER QUALITY (PPM)**

<table>
<thead>
<tr>
<th>Description</th>
<th>Ca</th>
<th>Mg</th>
<th>SO₄</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated mine</td>
<td>389</td>
<td>120</td>
<td>756</td>
</tr>
<tr>
<td>Treated mine</td>
<td>74</td>
<td>34</td>
<td>138</td>
</tr>
<tr>
<td>Standards</td>
<td>75</td>
<td>50</td>
<td>250</td>
</tr>
</tbody>
</table>

e) **SOIL IMPROVEMENT** –

- Organic carbon content increased from 0.13 % to 0.26%.
- Available P₂O₅ content increased from 5.4 kg /ha to 32 kg / ha.
- CaCo₃ content decreased from 55 to 34% and
- pH value reduced from 8.1 to 7.7 over a period of 7 years.
Mine Spoil Stabilisation

Mine Spoil,
Sahasradhara, Uttaranchal

Condition of JGT treated stabilized slope after 9 yrs.

Laying of JGT on the mine spoil
HIMACHALPRADESH MINE SPOIL

LOCATION: Bharli Rudhana Mine, 40 km from Paonta Sahib & Pamta Mine, 48 km from Paonta.

OBJECTIVE: To control the heavy debris flow and landslide from the mine spoil areas.

PHYSIOGRAPHY:

The Project sites are situated in the mid Himalayas with undulating and steep mountainous terrain. The mine sites are located at about 1400 m – 1500 m above MSL. The mine spoils had steep slopes (75% – 80%) and are thus highly unstable and prone to slide in.

Rainfall

The average annual rainfall in the area is about 1700 mm, 80% of which is received during monsoon (mid June to mid September).

GEOLOGY & MINE SPOIL CHARACTERISTICS:

The area forms part of lesser Himalayan ranges and exhibits a rugged mountainous terrain with moderate relief. The rocks found in the area from part of a regional tectonic unit called as Krol belt which comprise sand stone, shale, lime stone, schists etc. Formed over a period stretching from 1 to over 600 million years.

The mine-spoil material mostly consists of gravel and boulder. From the sieve analysis of the mine-spoil material of the sites the following grading was found:

<table>
<thead>
<tr>
<th>Size grading, mm</th>
<th>&lt;0.2</th>
<th>0.2-12.5</th>
<th>12.5-25</th>
<th>25-50</th>
<th>&gt;50</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of fraction</td>
<td>6.3</td>
<td>35.4</td>
<td>18.1</td>
<td>30.4</td>
<td>9.8</td>
</tr>
</tbody>
</table>
PHYSICO CHEMICAL CHARACTERISTICS OF MINE-SPOIL

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Project area under JGT</th>
</tr>
</thead>
<tbody>
<tr>
<td>&amp; Unit</td>
<td></td>
</tr>
<tr>
<td>1. Texture Class</td>
<td>SL (Silty Loam)</td>
</tr>
<tr>
<td>2. pH</td>
<td>7</td>
</tr>
<tr>
<td>3. Organic Carbon (%)</td>
<td>0.003</td>
</tr>
<tr>
<td>4. Available P&lt;sub&gt;2&lt;/sub&gt;O&lt;sub&gt;5&lt;/sub&gt; (kg / ha)</td>
<td>0.8</td>
</tr>
<tr>
<td>5. Available K&lt;sub&gt;2&lt;/sub&gt;O (kg / ha)</td>
<td>5.7</td>
</tr>
</tbody>
</table>

TREATMENT WITH JUTE GEOTEXTILE

Same as in the previous case study.

RESULTS

JGT was applied during monsoon in 1988. The project sites were surveyed after monsoon in February’ 1999.

The mine-spoil area treated with JGT was seen to have well stabilized and vegetation had established nicely with negligible mortality.

The survival rate of plants in the JGT area was about 70 % compared to 30 % only in the control (without JGT).

CONCLUSION

Open mesh JGT is proved to be very effective biotechnical measure to revegetate and stabilize the highly erodable slopes. Care should be taken that JGT are to be used at sites that are geotechnically stable with fast growing and locally adapted grasses.

(N.B. See Annex V for details)
APPLICATION OF JGT FOR SLOPE STABILIZATION AT MUNDESWARI BRIDGE APPROACH ROAD, WEST BENGAL*

Location: Baidyabati-Tarakeswar-Champdanga Road, Arambag, (West Bengal).

Objective: (i) Dissipation of raindrop impact by JGT
(ii) Increasing soil permeability through JGT and plant roots
(iii) Creating micro-barriers to overland flow by JGT, reducing its velocity
(iv) Entrapment of detached soil particles by JGT

Reinforcement of the soil by the vegetative root system on degradation of JGT

Geotechnical characteristics of the fill of the embankment with its features:

The embankment height is about 11 metre in height near the bridge approach with its slope angle close to 40°. Length of the bridge approach embankment 70 meters on the eastern side and 82 meters on the western side approach of the bridge. Slope consists of non-cohesive soil with varying PI Value. Average annual rain fall in the area is about 1400 mm. Toe protection of the embankment was done with Brick Masonry toe walls.

Selection and Treatment with JGT
Considering the height of the embankment and slope, 500 gsm Open Mesh Woven JGT was chosen having the following features.

<table>
<thead>
<tr>
<th>Properties</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (g / m²) at 20 % moisture regain</td>
<td>500</td>
</tr>
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<tr>
<td>Width (cm)</td>
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</tr>
<tr>
<td>Open area (%) mesh size ?</td>
<td>50</td>
</tr>
<tr>
<td>Strength (kN / m) [MD x CD]</td>
<td>10 x 7.5</td>
</tr>
<tr>
<td>Water holding capacity on dry weight (%)</td>
<td>500</td>
</tr>
</tbody>
</table>

*The work was executed by P W Deptt. Arambag Sub-division, Govt. of West Bengal with the technical advice from IJIRA/JMDC.
Top and bottom ends of JGT were anchored in the trench (250 mm X 300 mm) at the edge of road flank and on the bottom of the slope above the toe wall and is covered with course sand.

JGT was laid on the embankment slope with side overlaps 100 mm and stapled with bamboo pegs at a distance of 750 mm spacing on all sides. Grass seeds (Hybrid napier) were spread uniformly over the slope before laying JGT.

Results : It has been found that JGT treated slope fully covered with vegetation within one year from application of JGT. Embankment slopes stand stabilized after two years.

Conclusion : JGT can be used effectively for slope stabilization and soil erosion control of high embankments on bridge approaches as a bio-engineering erosion control system. (Refer Guidelines---- IS 14986 :2001)
CASE STUDIES ON APPLICATION FOR RIVER BANK PROTECTION
CONTROL OF BANK EROSION NATURALLY-
A PILOT PROJECT IN NAYACHARA ISLAND (WEST BENGAL) - IN THE RIVER HUGLI*

LOCATION: Nayachara Island, 21 nautical miles away from the face of Bay of Bengal.

OBJECTIVE: To protect the island from severe erosion which made hindrance on navigation.

GEOHYDROLOGICAL DATA

Tides
- Semi diurnal with periodicity of 12.42 hrs.
- Average flood period – 5 hrs.
- Average ebb period – 7.42 hrs

Tidal Range
- Maximum spring – 6.25 meter
- Minimum neap – 0.71 meter

Current
- Peak velocity in spring -3.0 meters/ second

Wind
- Mid – April to mid–September – strong southwesterly winds
- March to May – Norwesters reaching up to 9 in Beaufort Scale.

Wave
- Wind generated waves - 1.6 meters high.
- Periodicity – 6 to 8 seconds.

* The study was made by Tapabrata Sanyal, Chief Hydraulic Engineer, Kolkata Port Trust. Published in National workshop, on Role of Geosyntheties in water resources projects, CBIP, January 1992, New Delhi.
GENERAL COMPOSITION OF BANK SOIL

<table>
<thead>
<tr>
<th>Depth</th>
<th>sand</th>
<th>silt</th>
<th>clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 m</td>
<td>-</td>
<td>0.50%</td>
<td>65.50%</td>
</tr>
<tr>
<td>6m</td>
<td>-</td>
<td>0.30%</td>
<td>61.70%</td>
</tr>
<tr>
<td>9 m</td>
<td>0.32%</td>
<td>50.80%</td>
<td>48.88%</td>
</tr>
</tbody>
</table>

Matter content ranged from 0.5 to 2 %

pH varies between acidic to alkaline with seasonal variation.

Salinity varied from 6 ppt. during freshets to 18 ppt. in the post freshet season.

TREATMENT WITH JGT

For preventing of migration of soil particles from the bank and also for providing escape routes to the confined water to neutralize the differential over pressure, Jute geotextile smeared with bitumen was used on the embankment.

For entrapping silt through extraneous contrivances mangrove vegetation over Jute geotextile was made as an alternative method to the conventional practice of using bamboo cages with bricks fixed on them, concrete hexapods etc.

PROPERTIES OF JUTE GEOTEXTILE USED

Material: D. W. Twill – 8 x 12 –
850 gsm bitumen treated

Thickness: 2.83 mm at 100 g/cm²

Breaking strength (kN/m): 33.2 (warp way)
                      28.2 (weft way)

Elongation at break (%): 11.8 (warp way)
                        13.5 (weft way)
River Bank Protection - Nayachar

River Bank at Nayachar, River Hooghly, WB.

JGT laid on prepared slope of the eroded bank

Stabilized River Bank
Puncture resistance (Kgf / cm²) 37.9
Air permeability (m³ / m² / min) 16.2
Water permeability 20.4
at 10 cm water head (l / m²/ sec.)
Pore size (microns) 150

RESULTS

γ- Nosubsidence or disturbance of the protected stretch has taken place after a period of one and half years. Samples of jute were also tested. Strength in both directions was found to be reduced by about 70%. But there appears to be no adverse effects on performance. The average siltation over this period has been estimated to be around 50 cm over the boulders.

γ- Inspection was again carried out in November, 2001. No subsidence and disturbance of the armour layer were observed. Jute geotextile samples were exhumed from the site. At some locations they were in place. The samples taken out showed that they had not lost their porometry features; the bituminous treatment was also in excellent shape. There certainly has been considerable degradation in their strength but the samples were neither torn nor punctured. The fabric perfectly draped the bank soil. Soil samples collected below Jute geotextile were tested in the laboratory of Jadavpur University. The test results are presented below:

<table>
<thead>
<tr>
<th>Sample No</th>
<th>N. M.C. (%)</th>
<th>M.C.(saturated) (%)</th>
<th>Bulk Density</th>
<th>Saturated Density</th>
<th>Permeability (cm/ sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>54.20</td>
<td>57.15</td>
<td>1.67</td>
<td>1.72</td>
<td>3.60 x 10⁻⁴</td>
</tr>
<tr>
<td>2</td>
<td>47.07</td>
<td>53.91</td>
<td>1.64</td>
<td>1.70</td>
<td>0.89 x 10⁻⁴</td>
</tr>
<tr>
<td>3</td>
<td>46.72</td>
<td>55.0</td>
<td>1.63</td>
<td>1.71</td>
<td>6.7 x 10⁻⁵</td>
</tr>
<tr>
<td>4</td>
<td>51.83</td>
<td>57.92</td>
<td>1.67</td>
<td>1.76</td>
<td>......</td>
</tr>
<tr>
<td>5</td>
<td>46.71</td>
<td>54.88</td>
<td>1.65</td>
<td>1.74</td>
<td>1.266 x 10⁻⁴</td>
</tr>
<tr>
<td>Sample No.</td>
<td>L. L. (%)</td>
<td>P. L. (%)</td>
<td>P.I. (%)</td>
<td>Sand (%)</td>
<td>Silt (%)</td>
</tr>
<tr>
<td>------------</td>
<td>-----------</td>
<td>-----------</td>
<td>---------</td>
<td>----------</td>
<td>----------</td>
</tr>
<tr>
<td>1</td>
<td>54</td>
<td>20</td>
<td>34</td>
<td>…</td>
<td>51</td>
</tr>
<tr>
<td>2</td>
<td>51</td>
<td>24</td>
<td>27</td>
<td>…</td>
<td>51.5</td>
</tr>
<tr>
<td>3</td>
<td>50</td>
<td>26</td>
<td>24</td>
<td>8.5</td>
<td>58.5</td>
</tr>
<tr>
<td>4</td>
<td>51</td>
<td>25</td>
<td>26</td>
<td>14</td>
<td>49</td>
</tr>
<tr>
<td>5</td>
<td>49</td>
<td>26</td>
<td>23</td>
<td>…</td>
<td>60.5</td>
</tr>
</tbody>
</table>

**CONCLUSION**

- Use of JGT in river bank protection appears to be an efficient alternative to conventional methods in respect of capital investment and recurring maintenance cost.

- The undisturbed bank after 11 years implies that JGT performed its designated functions and helped in natural consolidation of the bank soil and durability of JGT beyond 1½ years, even under continuing adverse conditions, proved to be redundant due to catalytic function of JGT.
APPLICATION OF JUTE GEOTEXTILE FOR RIVER BANK EROSION CONTROL AT RIVER PHULAHAR*

LOCATION : River Phulahar in the District of Malda, West Bengal.

CAUSES OF EROSION : Concavity of the Course Heaving up of water during the monsoon due to the constricted course of the River Strong Protective Work on the opposite bank.
Soil: Fine sand (0.175 mm)
Co-efficient of soil permeability – 10^{-4} Sec.
Monsoon discharge – 9330 Cusec
Maxm. Velocity – 2 meters per second
Angle of internal friction - 30°

REMEDIAL MEASURES : Construction of a toe wall with crated boulders(900 x 1200)
Preparation of Bank slope to 1 : 2
Laying of Bitumen – Treated JGT on the prepared Slope
Laying of armour (450 thick)

TYPE OF JGT USED : WEIGHT – 760 gsm (1200 gsm after bitumen treatment)
Tensile Strength (MD X CD)-20 X 20 kN/m after treatment
Porometry – 150 microns
Permittivity at constant head – 350 X 10^{-5} Sec
Puncture Resistance – 400 N.

PERFORMANCE EVALUATION : The treated stretch is in a fine shape after three years of its completion in 2004 as per the written report of I & W Deptt., Govt. of West Bengal.

Based on excellent performance of JGT, I &W Deptt. has undertaken the bank protection work with JGT in other stretches of the same river.

*The work was executed by Irrigation and water ways Deptt., Govt. of West Bengal with the technical advice from IJIRA/IMDC
Preparation of embankment slope

Stone Boulder armour on JGT

Finished embankment with JGT (after three years of completion).
CASE STUDIES ON APPLICATION OF JGT IN RAILWAY TRACK SETTLEMENT
PREVENTION OF RAILWAY TRACK SUBSIDENCE
WITH JUTE GEOTEXTILE
- A CASE STUDY UNDER EASTERN RAILWAY*

LOCATION: Gurap section of Howrah – Bardhaman Chord line, 36 Km away from Howrah.

OBJECTIVE: To restore the settled track to the desired level by improving bearing capacity of the fills under respective dynamic loads. The track has been undergoing persistent settlement in the last 25 years. Short term remedial intervention did not work.

PRE–REMIDIAL SITUATION AT THE SITE

❖ The old railway embankment was built with cohesive fills of varying composition – silty clay to silty loam.
❖ The embankment height varies between 1 m to 6 m from G.L.
❖ Sideslopes of the embankment varies between 1: 2 to 1 : 1.5.
❖ The cess at the side of the southern track was almost non existent due to unabated erosion of the surficial soil.
❖ Borrow pits almost touch the toe of the embankment at most places with water within. ❖ Nosand cushion was observed under the ballast layer.

PROPERTIES OF SUBGRADE SOIL

<table>
<thead>
<tr>
<th>Properties</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of soil</td>
<td>Shrinkable but not black cotton type.</td>
</tr>
<tr>
<td>Shear strength(T/sq m)</td>
<td>1.47 – 1.96</td>
</tr>
<tr>
<td>Natural dry density</td>
<td>70% - 80%</td>
</tr>
</tbody>
</table>

*The study was conducted by Eastern Railway & IJIRA / JMDC. Published in “Case Histories of Geosynthetics in Infrastructure Projects” (289) CBIP Nov,2003 pp. 202 - 211 on the basis of a concept paper by Tapobrata Sanyal, Geotech Advisor, JMDC, presented in IGC Conference, 2000 in Mumbai.
TREATMENT WITH JGT

Woven JGT was laid on the sand spread over the subgrade and non-woven JGT was laid over woven JGT. Woven JGT was used to check the movement of subgrade and helps allow pore-water to seep through the fabric pores. Non woven JGT was placed as shock absorber and as drainage medium.

Non woven JGT was used as encapsulated rubble (brick ballast) drains at a suitable gradient by inserting them under the subgrade with their open ends exposed on the embankment slope.

Open weave JGT was used to guard against erosion caused by precipitation on a slope (slope 1:2.5).

PROPERTIES OF JUTE GEOTEXTILES USED

<table>
<thead>
<tr>
<th>Properties</th>
<th>Woven (Bitumen treated)</th>
<th>Non woven</th>
<th>Open mesh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight((g/m^2)) at 20% MR</td>
<td>1200</td>
<td>1000</td>
<td>500</td>
</tr>
<tr>
<td>Threads/dm((MDXCD))</td>
<td>102 x 39</td>
<td>-</td>
<td>6.5 x 4.5</td>
</tr>
<tr>
<td>Thickness((MM))</td>
<td>2</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Width((cm))</td>
<td>76</td>
<td>150</td>
<td>122</td>
</tr>
<tr>
<td>Strength((kN/m) [MDXCD])</td>
<td>21 x 21</td>
<td>6 x 7</td>
<td>10 x 7.5</td>
</tr>
<tr>
<td>Elongation at break% ([MDXCD])</td>
<td>10 x 10</td>
<td>20 x 25</td>
<td>-</td>
</tr>
<tr>
<td>Pore size((O_{90})) Micron</td>
<td>150</td>
<td>300</td>
<td>-</td>
</tr>
<tr>
<td>Water permeability at 10 cm water head ((l/m^2/s))</td>
<td>20</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Puncture resistance</td>
<td>400</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Coefficient of water permittivity((m/s))</td>
<td>-</td>
<td>3.4 x 10^-7</td>
<td>-</td>
</tr>
<tr>
<td>Water holding capacity(% on dry wt.)</td>
<td>-</td>
<td>-</td>
<td>500</td>
</tr>
<tr>
<td>Open area (%()</td>
<td>-</td>
<td>-</td>
<td>50</td>
</tr>
</tbody>
</table>
RESULTS

The affected stretch did not undergo any subsidence even after 3 seasons.

CONCLUSION

8Themethodology was so planned as not to interrupt train movement during the entire period of execution (83 days).

8Noshort term remedial intervention was necessary for the first time in the last 25 years.
Control of Railway Track Subsidence

Settlement of Railway Track, E.R. Madhusudanpur.

Exposing Subgrade.

Laying of JGT (Woven & Nonwoven.)

Finished Railway Track after 3 years.
STATIC LOAD TESTS:

Annex-I

Equipment used: - A tank of 1 m dia., 1.2 m high (made of 8 mm thick G.I. sheet)

Experiments: - G.I. tank was filled with clay in layers of 100 mm at a time and compacted. Total 600 mm clay was compacted. A surcharged load of 0.8 tones (8 kN) over a plywood of 20-mm thickness was applied. This surcharge load provided an over burden pressure equivalent to 10 kN/m². Altogether, 6 pressure cells were installed into each of the 3 tanks used. It took about a month to complete the surcharge operation in all the tanks and the settlement as much as 6 mm. Afterwards, the surcharge was removed and the moisture content and vane shear value of the clayey subgrade were evaluated. This was followed by placement of jute fabrics in the test tank with a back filling of 100 mm thick sand with moisture content 6%. This was overlaid by a plywood board with a surcharge loading of 170 Kg simulating a pavement pressure of about 2.4 kN/m².

Short time rutting test (about 12 min) were carried out under a series of three loading pressures from simulated loads of 350 N, 900 N & 1350 N. The first test tank was provided with a thin compacted layer of sand (100 mm) without jute fabric. Second test tank was provided with an ordinary layer of jute fabric at the subgrade/subbase interface. The third tank was provided with jute reinforced with coconut-coir grid mat.

ABOUT THE TRIAL PLOTS AND GEOTEXTILES

Annex-II

The control plot and other five plots were covered with 200 mm top-soil comprising 12% clay, 29% silt, 33% sand and 26% gravel. Seeding was done by hand using commercially available grass seed @ 28 grams/m².

Jute geotextile (JGT) - made of 100% natural fibre (about 80% natural cellulose, 12% lignin etc.) used in one of the plots had the following properties:

- Weight: 500 g/m²
- Tensile strength (MD): 7.5 kN/m
- Opening Size: 11 mm x 18 mm
- Durability: 2 years

Installation was simply done only by rolling down JGT to cover the top soil and fixing in position by using 11 gauge wire staples.

EnviroMat – is a composite comprising a wood wool mulch contained between two layers of light weight synthetic mesh. The wood wool is poplar and/or pine, while the mesh is 0.02 mm diameter black or green polypropylene strand. EnviroMat had the following properties:

- Weight: 360 g/m²
- Aperture size of the mesh: 25 mm x 37 mm (approximately)

Wood wool is completely biodegradable and also the PP strand in about 18 months depending on the intensity of UV light exposure.
Installation was done simply by rolling down it and pegging at required points.

**Enkamat**: Enkamat 7010 was used in this case. It was a 9 mm thick open mat made by heat bonding black polyamide filaments having the following properties:

- Weight: 260 g / m²
- Tensile strength (min): 0.8 kN / m

Installation procedure was slightly different for this product. The mat was first rolled down the slope over the graded topsoil prior to seeding. After pegging down the mat grass seed was applied by hand and topsoil worked into the structure of the mat until the mat was filled and the topsoil was uniformly flush with the top surface of the mat. Since the particular topsoil used contained quite coarse gravel, it was found that only the finer fractions of the topsoil would penetrate the mat structure.

**Tensar Mat**: This product has a very complex structure made up of multiple layers of black polyethylene mesh. The lower two layers are each a lightweight orthogonal square grid with an aperture size of 6 mm. These two layers are laid down flat so that the grid aperture in the two layers are out of phase. Above this comes two layers of heavier gauge diamond shaped mesh with an aperture size of 8 mm. The four layers are bound together by spot heat bonding which causes a regular series of depressions in the upper layers of diamond mesh and gives an appearance similar to a button backed Chesterfield sofa. On the underside the two lower layers of square grid remain planar so making the mat flat backed.

The mat had the following properties:
- Weight: 450 g / m²
- Tensile strength: 4.4 kN / m
- Thickness: 18 mm

Installation procedure for Tensarmat was similar to what followed for Enkamat.

**Geoweb**: This had a completely different structure from the already discussed products. The raw material of Geoweb was 1.2 mm thick HDPE sheet. In its collapsed form Geoweb is 3.4 m wide, 130 mm long and 100 mm or 200 mm deep. When the collapsed structure is drawn open during installation the 130 mm length expands to 6 m whilst the width decreases from 3.4 m in the collapsed state to 2.4 m installed. The product comes in two depth sizes and in the particular trial the 100 mm deep Geoweb was used. This material had a mass per unit area of approximately 1740 g / m²

The installation procedure for the trial involved grading the slope surface approximately 100 mm lower than of the control section. The Geoweb was then stretches out over the surface of the trial plot and pegged into position. Having secured the Geoweb the cells were then filled by hand using the standard top soil.
EXPERIMENTAL SET-UP

Six sets of plate load tests were conducted with 25 mm thick steel plate of 30 cm x 30 cm size. The plate was placed centrally into the test pit of size 150 cm x 150 cm & 30 cm deep. The conventional method was followed for the plate load test. The schedule of the tests are given below :

Set (a): - The pit was excavated in the campus of B.E. college. The plate was placed centrally on the virgin soil at a depth of 30 cm from G.L. and the test was performed.

Set (b): - The pit was excavated upto a depth of 60 cm and then filled with same soil by compacting in three layers, providing the final level of the pit at 30 cm below the G.L. . The plate was placed centrally over a layer of brick and the load test was performed in the usual manner.

Set (c): - The similar pit was excavated upto a depth of 60 cm and 60 cm x 60 cm jute geotextile (A Twill) layer was placed centrally on virgin soil and then the final level of soil was raised by 30 cm by placing soil over the jute geotextile in three layers and compacting respectively. Then the test plate was placed centrally and loaded to failure.

Set (d): - Compacted soil was placed on jute geotextile upto a height of 30 cm as in set(c) and was underlain by a layer of bricks over which the test plate was placed and tested to failure.

Set (e): - Plate load test was conducted with the plate over two layers of bricks, placed centrally in the pit, overlaying compacted soil of 30 cm depth as in set(b).

Set (f): - A layer of jute geotextile (60 cm x 60 cm) being placed over virgin soil at a depth of 60 cm was underlain by compacted soil as in set (c) and two layers of bricks were laid over the final level of compacted soil. Then the load test was performed by placing the plate centrally over the brick layer.

DESIGN APPROACH

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height of fill (H)</td>
<td>1.5 m</td>
</tr>
<tr>
<td>Unit weight (γ)</td>
<td>16.6 kN/m²</td>
</tr>
<tr>
<td>Angle of internal friction(φ)</td>
<td>30°</td>
</tr>
<tr>
<td>Depth of foundation soil(D)</td>
<td>4.0 m</td>
</tr>
<tr>
<td>Undrained cohesion (C)</td>
<td>6 kN/ m²</td>
</tr>
</tbody>
</table>

Thus, vertical stress due to fill (α)=16.6 x 1.5 = 24.9 kN/m²

Factor of Safety (FS) against bearing failure for the un-reinforced embankment : -

\[
\frac{CNCc}{\gamma H} = \frac{6 \times 3.14}{24.9} = 0.75
\]

\[Nc = 3.14\] in the unreinforced state
So the bearing capacity is inadequate without reinforcement.

By providing a geotextile reinforcement, the bearing capacity factor, \( N_c \) increases to \( \pi + 2 = 5.14 \) and the factor of safety works to \( \frac{6 \times 5.14}{24.9} = 1.23 \) which is a satisfactory value.

The horizontal force to be resisted by tension in the fabric:

\[
P = \frac{K \cdot \alpha \cdot H}{2} = \frac{0.33 \times 16.6 \times 1.5}{2} = 6.16 \text{ kN/m}
\]

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

For a fabric having a tensile strength 20 kN / m, the factor of safety available is 3.2 and is thus adequate.

Time required for 90 % consolidation of soil having \( C = 2 \times 10^{-7} \text{ m}^2 / \text{sec} \) works out to be 205 days or about seven months.

Settlement was estimated to be at the order of 175 to 205 mm, by using standard calculations.

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

\[
S_H = 0.18 \times \Delta \gamma \times 24.9 = 4.48 \text{ kPa}.
\]

Average Undrained cohesion at the end of consolidation would thus be of the order of \( (6.0 + 4.48) \) say 10 kPa.

Factor of safety at the end of the consolidation without any reinforcing fabric would thus be:

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