PERFORMANCE EVALUATION

OF

JUTE GEOTEXTILE

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PREFACE

Jute textiles have been used for technical applications since the early 20th century, from mills in Scotland to Strand Road in Calcutta in the 1930s. Jute Geotextiles in their present form have been familiar to geotechnical experts since the 1980s.

The Indian Jute Industries' Research Association in association with research organizations- B. E. College, Central Road Research Institute, Central Soil & Water Conservation Research & Training Institute, Tea Research Association, Jadavpur University – have conducted several exercises and field applications. These have been in the areas of geotechnical applications like soil conservation, road construction, slope management, river bank protection, mine spoil stabilization in different parts of our country.

Field trials have been conducted with end-users like Kolkata Port Trust, Irrigation & Waterways Department, Govt. of West Bengal, and have been thoroughly documented, mainly through personal efforts. While the initial results have been uniformly encouraging, no in-depth post-work investigation of the soil status (after laying of JGT) has been conducted in these trials. This has left a gap in technical understanding of soil improvement vis - a - vis fabric degradation. In laboratory studies, it has been found that the role of JGT or, for that matter, of any geotextile is that of a catalyst, functioning for a short period initially as separator/ filter/ drainage medium/initial reinforcer and ensuring natural consolidation of soil known as "filter cake" formation ultimately. Field trials corroborate this concept.

In this anthology, efforts have been made to collect and correlate the available inputs of some of the significant file trials for the preparation of a database which will certainly provide an opportunity for better technical understanding of Jute Geotextile by interested engineers/end users.

A. Bhattacharya

(A. Bhattacharya)
Secretary
Jute Manufactures Development Council

Dated 26 June 2007

CONTENTS

LABORATORY EXPERIMENTS

JUTE GEOTEXTILE FOR ROADS-LABORATORY INVESTIGATION

OBJECTIVES

I) To asses the feasibility of using jute geotextile for application in road construction.

II) To observe whether the biodegradability of jute fabric is a deterrent factor for its use as a separator in road construction.

LABORATORY INVESTIGATION

In order to study the different properties of jute fabric related to performance as a geotextile compared to other commonly used synthetic geotextiles a through investigation was made.

RESULTS

Trade name	Weight (gm/m^2) ASTM *D-1910-64*	Thickness (mm) ASTM *D-1777*	Grab tensile Strength (N) ASTM *D-1682*	Elongation At Break(%) ASTM *D-1682*	Trapezoidal Tear Strength(N) ASTM *D-2263*	Permeability (cm/s) *Falling head*	*Type*
Propex *4545*	153	-	*400 (minimum*	*50 (minimum*	-	2 x10 $^{-2}$ (min) *3 x10 $^{-2}$ (min)*	*Non-woven*
Muirafi *600 X*	-	-	1335	-	534	0.01	*Woven*
Typar	136	15 mill	580	62	312	0.02	*Non-woven*
Supac *5-P*	180	15 mill	556-670	80	325	0.05	Non-woven *(polypr opelene)*
Petromat	146	-	512	65	-	-	*Non-woven*
Terram *140*	280	1.1	1128	150	343	0.072	Non-woven (75 % Polypr. + 25 % Nylon)
Jute fabric	680-750	1.75-1.85	800-900	15-20	300-350	0.02-0.04	*Woven*

N.B. 1 mill = 1000th part of an inch

**Findings of Prof. S.D.Ramaswamy & Prof. M.A.Aziz (Deptt.Of Civil Engg,National university, Singapore) ; Published in "International Workshops on Geotextiles, 22-29 November,1989,Bangalore,India*

DYNAMIC LOAD TEST

Dynamic load test was conducted with clayey subgrade of natural water content 40 % .

A dynamic load of 8 kN and a simulated contact pressure of 255 kN / m^2 was applied : upto 1000 applications were made.

RESULTS

The results of dynamic load tests are presented in fig.1 and in the following table::-

Thickness of aggregate (mm)	Rut depth		Remarks
	without JGT	*with JGT*	
100 mm	*22 mm*	*10 mm*	*With the use of JGT more than 50 % reduction in rut depth in both the cases.*
200 mm	*18 mm*	*7 mm*	

The results of the dynamic load tests on jute fabric correlate very well with those of Lai and Robnett who carried out similar tests on a synthetic geotextile (Typar).

(Ref: Lai, J. S. and Robnett,Q. L. (1980) "Designing and Use of Geotextiles in Road Construction." Proc. 3rd Conf. Road Eng. Assoc. Asia and Australasia, Taipei,ROC.)

STATIC LOAD TESTS

Static load test was conducted on clay in layers of 100 mm. Jute fabric was placed with back filling of 100mm thick moist sand (M.C 6%) and a pavement pressure of 2.4kN/m^2 was simulated.

Short time rutting tests were performed under a series of loading pressures from simulated wheel loads of 350N, 900N &1350N while long term(6 weeks) loading tests were performed under simulated wheel loads of about 1000N on bearing plate of 200 mm diameter.

RESULTS

Results of short term static load tests and long term sustained loading tests were found satisfactory and are presented by fig 2, fig 3 & fig 4.

UNCONFINED COMPRESSIVE STRENGTH AND CBR TEST

Unconfined compressive strength and CBR tests were carried out to asses the influence of Jute geotextile on the strength of clayey subgrade at different moisture contents.

RESULTS

The findings are presented by the following tables and fig.5.

EFFECT OF JUTE GEOTEXTILE ON UNCONFINED COMPRESSIVE TRENGTH

Water content (%)	Unconfined compressive strength *(kN/m^2)*	*Strain at failure (%)*
25	110 (without fabric) *300 (with fabric)*	8 (without fabric) *26 (with fabric)*
30	45 (without fabric) *115 (with fabric)*	10 (without fabric) *30 (with fabric)*
35	36 (without fabric) *65 (with fabric)*	22 (without fabric) *42 (with fabric)*

EFFECT OF JUTE GEOTEXTILE ON CBR VALUE

Water content (%)		*20*	*25*	*30*	*35*
CBR value (%)	*Without fabric*	*5.0*	*4.7*	*3.5*	*2.6*
	With fabric	*8.0*	*6.8*	*5.2*	*4.5*

IN SITU TRIALS

Plate load test was conducted to evalute the in situ behaviour of the sub-grade. The sub-grade soil used was soft to medium silty-clay having NMC 35% and Vane shear strength (insitu) of 20kN/ m^2. Plates of 300 mm diameter were used.

RESULTS

The average results are shown in Fig.6. The results are in tune with similar tests reported with man made geotextile. (Ref: Jerret, P.M.et al (1997),'The use of Fabrics in Road constructed on Peat'; Proc. C.R. Conf. Inf. Soils Textiles, Paris,pp19-22, France.)

DURABILITY TESTS

The jute specimen consisted of blank sample treated with 40%, 50% and 60% bitumen and samples were preserved with 3.5%, 6% and 12% tanal in. They were either soaked in acid solution (pH=3), alkaline solution (pH=12) or buried under the clay in a separate container and the grab tensile strength test was performed monthly.

RESULTS

Durability studies have confirmed that the Jute geotextile retains sufficient strength for about a year.

CONCLUSION

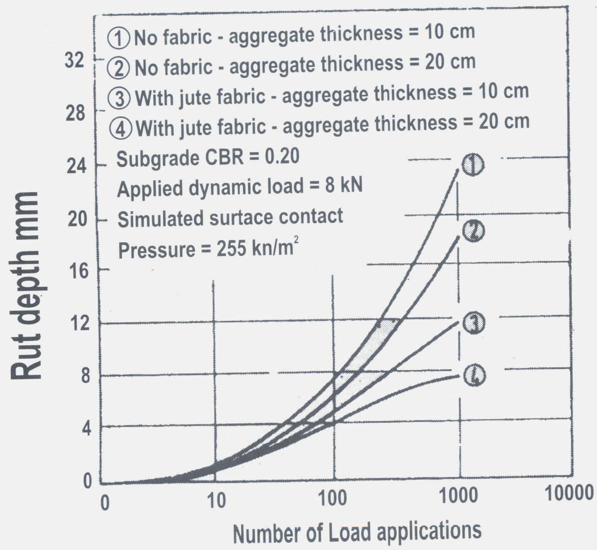
Jute geotextile appears to function quite close to symthetic counterpart.

The plate load tests confirmed that the Jute geotextile significantly improves the bearing capacity and settlement beheviour of the subgrade soil.

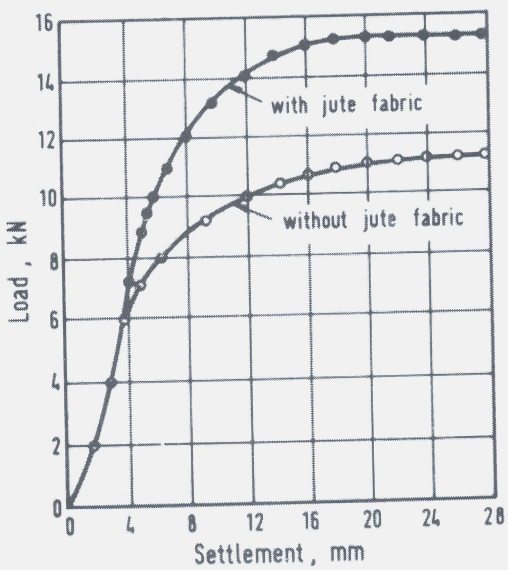
The strength and condition of Jute geotextile beyond one year after placement should not be any concern as by that time it helps provide a self-sustaining subgrade.

(N. B. : See Annex I for experimental details)

JUTE GEOTEXTILE

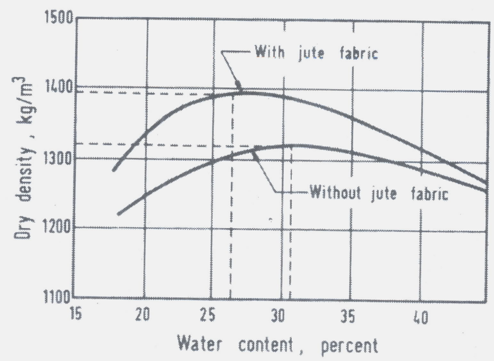


TYPICAL SURFACE PUT DEPTH VS NUMBER OF LOAD APPLICATION
FOR DYNAMIC LODING TEST USING JUTE FABRIC ALONE
(after Ramasway & Aziz, 1989)

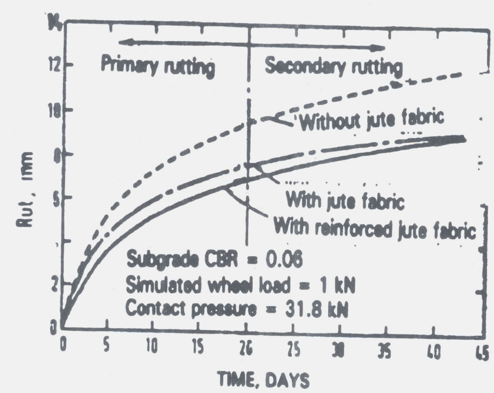


Load Settlement Relationship

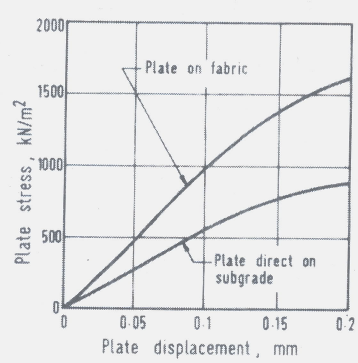
(After Ramasway & Aziz, 1989)



Effect of Jute Fabric on Compaction Characteristics of Subgrade soil
(after Ramaswamy & Aziz,1989)



Rut-time Relationship for Sustained Seven Weeks Loading Test
(after Ramaswamy & Aziz, 1989)



Effect of Jute Fabric on Bearing Capacity of Subgrade soil
(after Ramaswamy & Aziz,1989)

COMPARATIVE STUDY OF SYNTHETIC AND JUTE GEOTEXTILE ON EROSION CONTROL*

OBJECTIVE

i) Evaluation of the performance of Jute geotextile in surficial erosion control.

ii) *To assess the comparative performance of such a system, a quantitative trial has been conducted using three synthetic geotextiles, one Jute geotextile (JGT) and one composite geotextile.*

LABORATORY INVESTIGATIONS

An artificial embankment slope constructed beneath a rainfall simulator was used for the experiment. The embankment slope modeled by battered face of the soil was inclined at 26^0 to the horizontal to represent a 1:2 slope. The slope width of 5 m was divided into 6 trials bays, each 500 mm wide to allow a space between adjacent bases.

- Simulated rainfall was generated using a series of nozzles fixed to an oscillating bar above the slope.
- Rainfall drop size was 1.3 mm
- Kinetic energy of rainfall was 14 $J/m^2/mm$.
- Eight storms were used each having return period of 100 years for Eastern England.
- First five storms had rainfall intensity of 40 mm /hr. with 1 hr. duration.

The first storm was on a pre-wetted slope**. The remaining four storms at this intensity were run in pairs at three day intervals such that the first storm of each pair fall on a dry slope. Two hours duration was allowed for drainage before starting the second cycle on a wet slope. After a three day drying the same cycle was repeated.

** The study was made by Mr. Terence S. Ingold, Consultant Engineer, England and Mr. James C. Thomson, Jason Consultants S. A., Switzerland. Published in " Results of current research of synthetic and natural fibre erosion control systems" by (ITC – UNCTAD/GATT).*

*** The run-off from the dry slope was neglected as it was unrealistically low and erratic.*

- A different approach was adopted for the last three storms.

Rainfall intensity was increased to 75 mm/hr and the storm duration was decreased to 20 minutes.

The first cycle comprised one storm falling on a dray slope and after 2 hours, a second storm was caused to fall on a wet slope.

After a three-day period, the slope was pre-wetted and a single storm was applied to the wet slope.

Each of the five samples were installed on 500 mm x 1.8 m trial plot in accordance with the manufacturers' installation instruction.

The sixth plot was top soiled and seeded in the normal manner and used as a control plot. All the six plots were seeded to assess the ability of each product to resist washout of the ungerminated seed.

ABOUT THE TRIAL PLOTS AND GEOTEXTILES

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 / m^2

Geotextiles	Composition	Properties				
		Weight	Thickne ss	Tensil strength	Opening size	Durability
JGT	Jute (80 Cellulose,12 % Lignin etc)	500g / m^2	-	7.5kN/m	11 mmx18mm	2 years
Enviromat	Wood/Wool mulch contained in PP strand mesh	360 g /m^2	-	-	25mmx37mm	18 months
Enkamat 7010	Polyamide	260g / m^2	9 mm	0.8kN/m (min)	-	-
Tensarmat	Polyethlene	450g/ m^2	18 mm	4.4kN/m	6mm-8mm	-
Geoweb	HDPE	1740g / m^2	-	-	-	-

RESULTS

Some inconsistent and very low run-off values were obtained for the initial application of the 40mm/hr. intensity storm to the pre-wetted slope due to high initial rates of infiltration. Similar problems were encountered for dry slope at the higher intensity of rainfall. These results were disregarded when calculating mean run-off values so leaving reliable data for wet slopes only at the 75 mm/hr. rainfall intensity.

1. Mean Run-off as percentage of rain-fall :-

The results obtained are presented in the following table and the figures.

System	Dry slope *40mm/hr.*	Wet slope *40mm/hr.*	Wet slope *75mm/hr.*
Control	25	33	50
JGT	02	09	11
Enviromat	03	16	31
Enkamat	19	41	34
Tensarmat	28	37	23
Geoweb	16	33	23
Storm duration	01 hr.	01 hr.	20 mins.

2. SEDIMENT LOSS

The relative effects of different rainfall intensities where sediment yield expressed in **grams** are shown in the following table and figures.

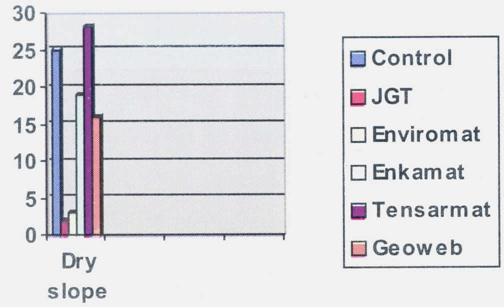
System	Dry slope (40 mm /hr)	Wet slope (40 mm / hr)	Wet slope (75 mm / hr.)
Control	70	92	263
JGT	6	25	57
Enviromat	4	23	84
Enkamat	56	121	189
Tensarmat	81	106	124
Geoweb	51	104	136

N.B.: Storm duration normalized to one hour

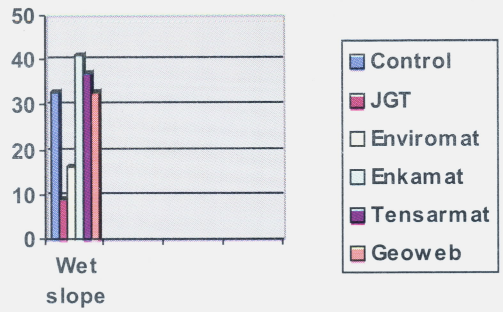
3. SOIL ERODIBILITY

Mean values of Soil Erodibility **(grams / mm)** are indicated in the following table and figure.

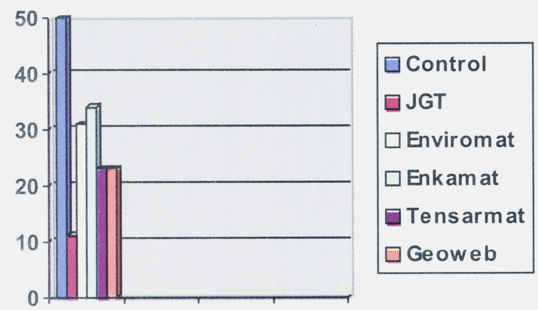
System	Dry slope (40 mm / hr)	Wet slope (40 mm / hr)	Wet slope (75 mm / hr)	Overall average
Control	7.1	8.0	5.8	7.0
JGT	16.4	1.7	2.1	6.9
Enviromat	7.5	1.1	1.0	3.6
Enkamat	10.4	6.4	3.3	7.4
Tensarmat	9.0	7.8	3.3	7.2
Geoweb	12.3	8.6	6.2	7.9
Storm Duration	1 hour	1hour	20 mins	-



Mean run-off as % of rainfall ; Dry slope; Raifall intensity 40 mm/hr for 1 hr



Mean run-off as % of rainfall Wet slope; Raifall intensity 40 mm/hr for 1 hr



Mean run-off as % of rainfall ; Wet slope; Raifall intensity 75 mm/hr for 20 min

4. MOISTURE ABSORPTION

Moisture absorbtion of different geotextiles expressed in percentage is given below.

System	Absorbed Moisture*
JGT	485
Enviromat	Not measured
Enkamat 7010	118
Tensarmat	40
Geoweb	9
*As percentage of dry weight	

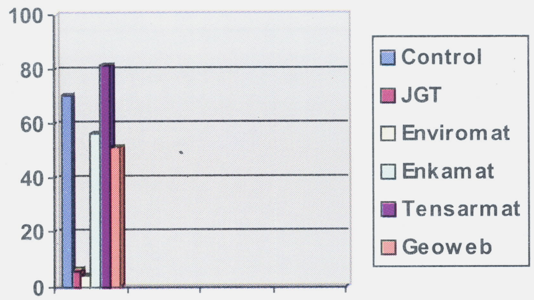
5 DIFFERENCE IN GRADINGS BETWEEN SEDIMENT AND VIRGIN SOIL

Comparison of the gradings of virgin soil with the gradings of the sediment is given below.

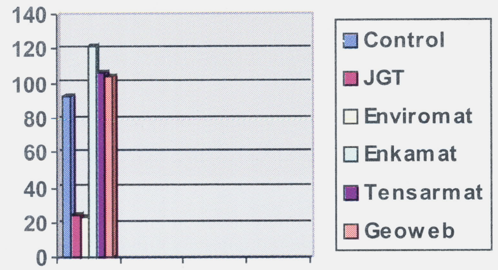
Rainfall intensity	45 mm / hr			75 mm / hr		
System	Clay	Silt	Sand	Clay	Silt	Sand
Control	- 3	- 1	+ 4	- 5	- 4	+ 8
JGT	- 4	- 7	+ 10	-	-	-
Enviromat	- 2	0	+ 2	- 5	- 10	+ 15
Enkamat	- 4	+ 4	0	- 5	- 2	+ 7
Tensermat	- 5	0	+ 5	- 5	- 5	+ 10
Geoweb	- 5	- 2	+ 7	- 6	- 5	+ 11
Virgin Grading : Clay – 12 %, Silt - 29 %, Sand – 33 %,Gravel – 26 %						

N.B. Negative values indicate that there is less of that particular fraction in the sediment than in the virgin soil and lesser erodability of the soil. Positive values indicate more of a particular fraction in the sediment that in the virgin soil.

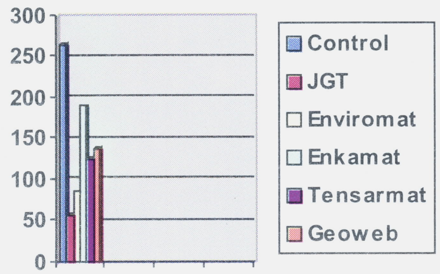
STORM DURATION NORMALISED TO ONE HOUR



Sediment loss; Dry slope;
Rainfall intensity - 40mm/hr

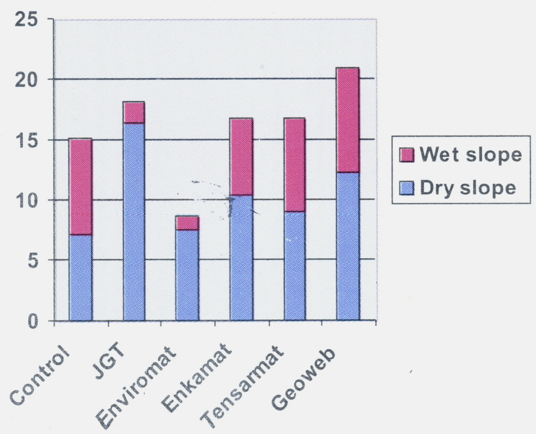


Sediment loss on Wet slope
Rainfall intensity – 40 mm/ hr



Sediment loss on Wet Slope
Rainfall intensity 75 mm / hr

SOIL ERODABILITY



CONCLUSIONS

The results clearly show that JGT and Enviromat are very effective in reducing erosion for the soil tested. All the product reduced erosion at the higher intensity rainfall where JGT proved to be the most effective. At lower intensity rainfall JGT and Enviromat gave similar performances, although the JGT tended to become more effective with time throughout the tests. Results for the other product were less conclusive, because of the very low run-off on the control plot.

The JGT seemed to operate mainly through considerable reductions in run-off. JGT is the most effective product with the higher intensity rain and also showed a tendency to become more effective with time. This is due in part to the drapability of the product when wet which helps to maintain close contact between the JGT and the soil surface.

Compared with an unprotected soil, erosion was reduced to 72% with Enkamat 7010, 52% with Geoweb, 47% with Tensarmat, 32% with Enviromat and 22% with JGT. The results for the 40mm/hr rain-fall intensity where less conclusive because of the unexpectedly high run-off recorded on the plots with Enkamat 7010, Tensarmat and Geoweb compared with unprotected plot. This was attributed to methods recommended for installing this products which created a more erodible version of the test soil. JGT reduced erosion with lower rainfall intensity to 9% and 27% than that of an unprotected soil for initially dry and wet soil conditions respectively. The comparable figures for Enviromat were 6% and 25%.

(N. B. See Annex II for further details)

EFFECTIVE USE OF JUTE GEOTEXTILE IN CONSTRUCTION OF ROADS FOR LIGHT TRAFFIC – A LABORATORY EXPERIMENT *

OBJECTIVE

Ascertainment of improvement of load bearing capacity of subgrade of a road withthe introduction of jute geotextile and one and two layers of bricks..

EXPERIMENTAL INVESTIGATIONS

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 : -

Test Set	The Test Pit	Layers of brick laid over the final level
(a)	30 cms	No brick layer
(b)	60 cms ; made 30 cms by filling with same virgin soil	One layer of brick
(c)	60 cms; made 30 cms by placing same virgin soil overJGT(60 cms x 60 cms)	No brick layer
(d)	Same as in set (c)	One layer of brick
(e)	Same as in set (b)	Two layers of brick
(f)	JGT (60 cms x 60 cms) was placed at 60 cms depth and 30 cms depth was made by placing virgin soil over JGT.	Two layers of brick

**The experimental study was made by Dr. Amalendu Ghosh, Prof., Civil Engineering Deptt, B.E.College (DU), West Bengal, India : Published in All India Seminar on "Application of Jute Geotextile in Civil Engineering" March 07, 2002.*

CHARACTERISTICS OF SOIL USED

The soil used on the test was silty clay having following properties : -

LL : -	78 %
PL : -	40 %
N.M.C. : -	30 %
Unconfined compressive strength : -	4.7 t / m^2
Proctor OMC : -	21 %
Max. Dry density : -	1.566 gm / cc

RESULTS

The yield stresses and corresponding settlements for different cases are given below : -

Type of test medium	Yield stress, t / m^2	Settlement, mm
Virgin soil (set a)	12.11	30.00
Compacted soil* underlain by single layer of brick (set b)	27.90	58.70
Compacted soil underlain by one layer of jute geotextile (set c)	19.40	70.00
Compacted soil overlain by by single layer of bricks and underlain by a layer of jute geotextile (set d)	35.50	27.00
Compacted soil overlain by two layers of bricks (set e)	21.20	26.00
Compacted soil overlain by two layers of bricks and underlain by a layer of jute geotextile (set f)	19.30	12.70

**Compacted soil was obtained in the pit near OMC at the unconfined compressive strength of the compacted fill of 6.6 t / m^2*

CHARACTERISTICS OF JUTE GEOTEXTILE USED

Weight	418 gm / m^2
Thickness	2.305 mm
Tensile strength	0.0704 Kg / cm
In-plane permeability	6.428 x 10^{-3} cm / sec
Cross plane permeability	1.358 x 10^{-3} cm / sec.

CONCLUSION

- Placement of one layer of bricks on the top of the surface of compacted soil set (b) helps on increasing the load carrying capacity quite significantly compared to virgin soil, set(a) or simply a jute geotextile layer overlain by compacted soil set(c).

- The response of two layers of bricks over compacted soil (set e) has been better. *But when one brick layer along with a jute geotextile layer (set d), the load carrying capacity is improved and is higher than that in the case when only two layers of bricks are used (set e).*

- The best result is obtained when two layers of bricks are used in addition to a layer of jute geotextile (set f) but **set (d) appears to be the most effective both from performance and economic point of view in case of low volume rural road construction.**

(N.B. See Annex III for the experimental set-up)

APPLICATION IN ROADS

CONSTRUCTION OF HIGHWAY EMBANKMENT ON SOFT MARINE SOIL USING JUTE GEOTEXTILE AT KAKINADA PORT (ANDHRA PRADESH) A CASE STUDY*

LOCATION : - Kakinada Port area , Andhra Pradesh

OBJECTIVE

Reinforcement of the highway embankment with the help of Jute geotextile by minimising post construction settlements, lateral spreading of fill material, etc. economically.

PROPERTIES OF SUB SOIL

Composition :	mainly clay upto a depth of 4 m with occasional mixture of silt or sand.
Moisture content :	70 % – 80 %
Liquid limit :	60 %
Plastic limit	28 %
Bulk density :	1.3 mg/m^3 – 1.45 mg /m^3
Undrained shear strength (insitu Vane shear test)	6.0 kN/ m^2
Compression index (C_c)	0.225
Co-efficient of consolidation (C_v)	2.0 x10^{-7} m^2 sec

** The study was made by P.J. Rao, Bindumadhava, N.Venisiri of CRRI,New Delhi and A. Sreerama Rao of J.N.T.U. College of Engineering , Kakinada under the UNDP sponsored project "Development and Promotion of Jute Geotextiles": Published in Proc. 6th . Int. Con. On Geosynthetics, Atlanta 1998, pp.779 – 782 & National Seminar on "Application of Jute Geotextile & Innovative Jute Products" New Delhi 2003, pp 59 – 65 respectively.*

DESIGN APPROACH*

Height of fill (H)	1.5 m
Unit weight (γ)	16.6 kN/m^2
Angle of internal friction(ϕ)	30 °
Depth of foundation soil(D)	4.0 m
Undrained Cohesion (C)	6 kN/ m^2

Factor of Safety (FS) against bearing failure for the un-reinforced embankment = 0.75

The bearing capacity was found inadequate without reinforcement.

Time required for 90 % consolidation of soil 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.

Factor of safety at the end of the consolidation without any reinforcing fabric would be 1.26 which is satisfactory.

PROPERTIES OF JUTE GEOTEXTILE USED**

1.	Thickness :	3 mm
2.	Weight :	750 gsm
3.	Tensile strength	20 kN / m
4.	Elongation at break	3 %
5.	Puncture Resistance	350 N.
6.	Overlap length	30 cm

** Details of the Design approach are given in Annex. IV.*

*** The woven Jute geotextile fabric was treated with Cupro-ammonium sulphate to increase the resistance of the fabric towards bio-degredability.*

Road Kakinada – A. P.

Damaged Road

Laying of JGT in
Road embankment

Finished Road

RESULTS AND DISCUSSION

1. At the end of seven months-the shear strength of the sub soil ensures the required factor of safety. The strength of fabric is no longer needed to provide reinforcing effect.

2 (a) WATER CONTENT OF SOIL BEFORE AND AFTER LAYING OF JGT

Water content %					
Location	Before laying JGT	Following laying at elapsed months of			
		3	7	21	30
1	97.4	76.3	68.7	55.0	50.0
2	72.7	69.1	56.3	45.4	35.3
3	76.4	69.1	68.7	59.0	53.4

(b) DRY DENSITY OF SOIL BEFORE AND AFTER LAYING OF JGT

Dry density (mg / m^3)					
Location	Before laying JGT	Following laying at elapsed months of			
		3	7	21	30
1.	0.70	0.85	0.89	0.95	1.05
2.	0.82	0.87	1.01	1.25	1.35
3.	0.84	0.92	0.89	0.94	1.07

(c) VOID RATIO AND COMPRESSION INDEX OF THE SOIL AT DIFFERENT ELAPSED TIMES.

Location	Void ratio					Compression index				
	Before laying	Following laying at elapsed months of				Before laying	Following laying at elapsed months of			
		3	7	21	30		3	7	21	30
1.	2.63	2.1	2	1.7	1.6	0.65	0.52	0.5	0.5	0.45
2.	2.1	1.8	2	1.3	1.1	0.61	0.56	0.5	0.4	0.38
3.	2.1	1.9	2	1.6	1.4	0.61	0.60	0.5	0.4	0.40

(d) CBR VALUES OF SUBGRADE SOIL BEFORE AND AFTER LAYING OF JGT

The test was performed 30 months after laying JGT and the following results were obtained.

Natural soil (before laying JGT) CBR (%)		Improved soil (after laying JGT) CBR(%)	
Unsoaked specimen	Soaked specimen	Unsoaked specimen	Soaked specimen
2.10	1.61	6.03	4.78

CONCLUSION

- ❖ Water content, Void ratio and Compression Index decreased while dry density and CBR value of the sub-grade soil increased by the use of Jute geotextile.
- ❖ Jute geotextile appears to be very effective even in weak sub-grade soils in reducing their compressibility and increasing their strength as reflected from the good performance even after a lapse of 7 years.

(N. B. See Annex IV for the design approach)

JUTE GEOTEXTILE USED AS SEPARATOR AT KANDLA PORT, GUJARAT - A CASE STUDY*

LOCATION : Kandla port area, Gujarat.

OBJECTIVE : To mitigate the problem of intemixing of subbase and subgrade consisting soft soil.

TREATMENT WITH JUTE GEOTEXTILE

The subgrade was compacted to the optimum moisture content and dry density of subgrade. Non woven jute geotextile was laid over the compacted subgrade as separator. Base course consisting of 300 mm thick , 60 – 125 mm size stone aggregate followed by 40 – 60 mm size stone aggregate was provided . A thin layer of 3.0 cm moorum was provided as cushion between the stone layers to reduce the direct impact of large sized aggregate on geotextile.

PROPERTIES OF JUTE GEOTEXTILE USED

Sl. No	Properties	Test value
1.	Thickness	6.91 mm
2 .	Weight	750gsm
3.	Tensile strength	2.81 kN / m
4.	CBR push through load	0.50 kN
5.	Failure strain	3 %
6.	Index puncture resistance	0.077 kN
7.	Permittivity	3.36 x 10^{-3} m / s
8.	Transmittivity	4.6 x 10^{-6} m / s
9.	Type of fabric	Nonwoven
10.	Apparent opening size (AOS)	0.05 mm

**The case study conducted by CRRI , New Delhi. Published in Proc. Workshop on Jute geotextile (1997), IJMA/JMDC ,Calcutta pp.73-87.*

RESULTS

Assessment of performance was done in respect of rut depth and other visual signs of distress.

Settlement of the test section in relation to conventional pavement section was also observed.

Settlement of the test section compared to conventional pavement section were recorded with the increase of pavement loads from 0.5 MT / m^2 to 2.0 MT / m^2 @ 0.5 MT / m^2 per month from Feb, 1997 to May, 1997.

No sign of distress. Settlement was observed negligible.

CONCLUSION

- Jute Geotextile perform the desired function.
- Use of right type of Jute geotextile for the separation purpose is desirable to obtain optimum result.

JUTE GEOTEXTILE IN CONTROLLING REFLECTION CRACKS IN GARIA STATION ROAD - A CASE STUDY*

LOCATION : Garia station road, Kolkata, West Bengal.

OBJECTIVE : Control of reflection cracks and reduction of distress of the riding surface.

TREATMENT WITH JUTE GEOTEXTILE

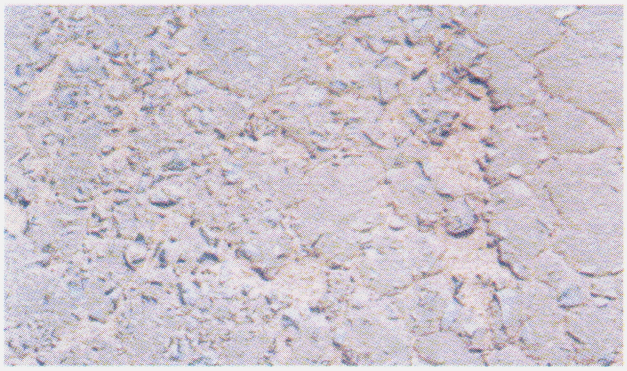
The affected stretches of road were leveled up initially with aggregates and rolled. The prepared surface was applied with a tack coat @ 3 kg / 10 m^2. Open weave jute geotextile was laid and lightly rolled. Another coat of bitumen was applied over Jute geotextile @ 5 kg / 10 m^2 followed by a layer of premix of bitumen – sand coarse aggregates (stone-chips). The average thickness of the overlay was 25 mm.

PROPERTIES OF JUTE GEOTEXTILE USED

Properties	Value
Weight (g/m^2)	292
Threads / dm (MD x CD)	12 x 12
Thickness (mm)	3
Width (cm)	122
Open area (%)	60
Strength (kN/m) [MD X CD]	10 x 10
Water holding capacity (%) on dry weight	400

** The work was executed by PW (Roads) Deptt., Govt of West Bengal.*
The case study was conducted by IJIRA / Jadavpur University

Garia Station Road



Garia Station Road,
Kolkata, W.B.
Potholes on road surface

Asphalt Overlay with JAT

Finished Road

RESULTS

The treated pavement was inspected by the Civil Engineering Depart,emt, Jadavpur University in December, 2002 after it was subjected to one full monsoon season. The following table reveals the conditions prevailing before and after the treatment.

	Potholes		Cracks		Depression
	No	%	Area	%	
Pre-work condition	770	11	1239 m^2	17.7	5 % (average thickness– 75 mm)
Post-work Condition	84	1.2	257.25 m^2	3.67	Nil

Pothole depths were confined to the thickness of the overlay. JGT was not visibly affected.

A few longitudinal cracks were seen to have developed in the middle of the road. Some minor cracks appeared at some locations in the cross direction.

CONCLUSION

- ☛ Evidently the road is in a better shape after the treatment compared to the adjoining stretches where JGT was not applied on the overlay. The trial definitely brought out the fact that JGT helps in reinforcing asphaltic overlay.

- ☛ It was observed that the overlay performed satisfactorily where its thickness was in the range of 20 mm to 25 mm.

- ☛ There has been reduction in the overall pothole area after the treatment though post-work distress areas did not correspond with those present before the treatment at all places.

WIDENING AND STRENGTHENING OF MUNSHIRHAT – RAJPUR ROAD, WEST BENGAL*

LOCATION : - Munshirhat – Penro Khila Rajpur Road (6th to 8th Km.), Howrah, West Bengal

OBJECTIVE : Strengthening at the widened portion on the both sides of the existing black top road.

TREATMENT WITH JUTE GEOTEXTILE

JGT was laid on the extended portion after compacting the sub-grade with a power roller of 8 – 10 tons capacity. A single layer brick flat soling was laid on JGT to protect JGT from the puncturing impact of coarse aggregate. Over the BF soling two layers of Jhama metal and stone metal consolidation (WBM) were laid. Finally it was finished with 20 mm thick premixed carpeting followed by 6 mm thick bituminous seal coat. The work was completed in November, 2000.

PROPERTIES OF JUTE GEOTEXTILE (ROT PROOF) USED

PROPERTIES	VALUE
Weight(g / m^2) at 20 % M.R.	760
Threads / dm (MD X CD)	102 x 39
Thickness (mm)	2
Width (cm)	76
Strength (kN/m) [MD X CD]	20 x 20
Elongation at break (%)[MD X CD]	10 x 10
Pore size (O_{90}) micron	300
Water permeability at 10 cm water head (l / m^2/ s)	50
Puncture resistance (N / cm^2)	380

**The project was carried out by Howrah Highway Division, PW (Roads) Deptt., Govt. of West Bengal with the technical advice from IJIRA/JMDC.*

PRE-WORK CHARACTERISTICS OF THE SUBGRADE

The pre work condition of the subgrade are represented in the following table : -

L. Flank, Km	Paverment Km	R. Flank Km	Type of soil	O.M.C. %	Field moisture content,%	LL %	PL %	PI	CBR %
0.40	-	-	Inorg.clay	21.0	17.2	49.3	28.4	20.9	3.5
-	1.40	-	Inorg.clay	19.8	16.8	52.1	33.5	18.6	3.6
-	-	2.4	Inorg.clay	18.7	16.2	46.8	25.2	21.6	3.4
3.4	-	-	Inorg.silty clay	19.7	17.4	47.4	31.1	16.3	3.8
-	4.4	-	Inorg.silty clay	18.4	16.2	51.8	32.3	19.5	3.4
-	-	5.4	Inorg.silty clay	18.9	15.9	46.6	26.1	20.5	3.7
6.4	-	-	Inorg.silty clay	19.2	16.8	48.7	31.2	17.5	3.2
-	7.4	-	Inorg.silty clay	19.2	17.2	53.7	38.5	15.2	3.5
-	-	8.4	Inorg.silty clay	19.7	16.2	46.5	25.1	21.4	3.6
-9.4	-	-	Inorg.silty clay	18.0	16.4	48.8	30.7	18.1	3.5
-	10.4	-	Inorg.silty clay	19.2	17.3	45.4	28.4	17.0	3.6
-	-	11.4	Inorg.silty clay	20.2	19.1	47.9	28.2	19.7	3.8
12.4	-	-	Inorg.silty clay	16.9	15.2	48.5	27.3	21.2	3.6

RESULTS

Post work study was conducted by the Civil Engineering Department, Jadavpur University in November, 2001. No distress of the existing road was noticeable. The riding surface was perfectly smooth. Excavation was made near the edge of the pavement. Soil sample was collected from the sub-grade below the JGT layer. Jute geotextile was found to have degraded. Soil below pavement was found to be highly compacted.

The laboratory test results for the soil are given below:-

Liquid Limit	42%
Plastic Limit	22%
N.M.C.	21%
Cohesion	7.5 t / m^2

CONCLUSION

♦ The average CBR value of the subgrade before application of JGT was 3.5 %. It is evident from the above findings that the subgrade had strengthened by the application of JGT and reached a CBR value of 6.0 % (interpolated from Co-hesion value).

Munshirhat – Rajpur road,

Road Construction with JGT

WBM on JGT over brick Soling

Finished Road

JUTE GEOTEXTILE USED AS SEPARATOR AND FILTER AT ANDULIA-BOYRATOLA ROAD, WEST BENGAL *

LOCATION: Andulia to Boyratala in Haroa Block, District North 24-Parganas, West Bengal.

OBJECTIVE: To prevent the problem of interpenetration of sub-base and sub-grade consisting soft soil and increase the strength of the subgrade.

Road Details :

Length of the Road: **3.5 Km.**

Width :

a) Carriageway : 3.75 m

b) Road way : 7.50 m

c) Road Land width : 12.150 m

Laboratory Investigation of Soil for Embankment Construction

Loca-tion (Km)	Type of soil	Sieve Analysis, percent passing				Sand Cont-ent	Atterberg Limits			IS soil classifi-cation	Standard Proctor test	
		4.75 mm.	2 mm.	425μ	75μ		LL (%)	PL (%)	PI		MDD (gm/cc)	OMC (%)
1	2	3	4	5	6	7	8	9	10	11	12	13
0	Organic Silty Clay	91.6	75.6	54.2	26.8	64.8	45.2	27.1	18.1	OL		
1.5	Organic Silty Clay	92.5	77.5	49.5	26.3	66.2	48.5	28.2	20.3	OL	1.72	23.5
2.5	Organic Silty Clay	94.1	77.3	46.3	26.1	68.0	42.7	25.7	17.0	OL		
3.5	Brown Clay with little sand	95.5	75.9	60.3	48.2	47.3	45.7	29.8	15.9	MH		

C. B. R.

Soaked CBR value at 2.5mm penetration : 3.22%
Soaked CBR value at 5.0mm penetration : 3.16%

** The project was carried out by North 24-Parganas Zilla Parishad, West Bengal with the Technical advice from IJIRA/JMDC. Post Construction evaluation was carried out by Civil Engineering Department; Bengal Engineering & Science University, Shibpore, West Bengal.*

Design Approach

Woven Jute Geotextile (JGT) was considered to be laid on the prepared Sub-grade of the road for improving its CBR. Pavement was designed with CBR value enhanced by 150% for JGT as per findings of Prof. S.D.Ramaswamy and Prof. M.A.Aziz (1989). The in situ CBR value of 3.16 has been enhanced by 1.5 times (3.16 x 1.5) = 4.74%, which is rounded off to 4% during designing the pavement.

The volume of traffic on the road as per traffic census with its annual growth rate @ 6% per year, CBR value of 4.0% (B Curve- Number. of Commercial Vehicle / Day being 15 to 45) and taking annual average rainfall to be 1500 mm, the pavement thickness is designed as per IRC: SP: 20:2002 using CBR value for flexible pavement design.

The Pavement thickness according to CBR Curve is 350 mm (as per IRC:SP:20-2002 page 98).

The thickness of pavement for the proposed road provided	=	350 mm
1. Base Course	=	150 mm
2. Sub-base Course	=	200 mm
Total	=	350 mm

Properties of Jute Geotextile used :

Type	-	Woven, 30 kN/M
Width (mm)	-	760
Weight (gsm)	-	810

Thickness	-	2 mm
Tensile Strength (kN/m)		
MD	-	30
CD	-	30
Elongation at break (%)		
MD	-	9
CD	-	9

Burst strength (kPa)	-	4500
Puncture Resistance (kN)	-	0.600
Permittivity at 50 mm constant head (per sec.)	-	350×10^{-5}
A. O. S. (micron) 0_{95}	-	150

Results

Post work evaluation was conducted by the Civil Engineering Department of Bengal Engineering and Science University , Shibpur 18 months after completion of the work. The CBR value as obtained from the field CBR test under unsoaked condition of the soil at the sub-grade level is stated hereunder:

Unsoaked Field CBR = 10.47% at 0.25 km & 14.0% at 1.40 km

&

14.0 % at 1.40 km

Conclusion

The study substantiates the proven concept that limited durability of JGT is not a discouraging factor in as much as soil gets consolidated to its maximum within a year or so in view of its catalytic function for a limited initial period. The consolidation is effected as a result of arrest of movement of soil particles on the one hand and concurrent release of pore water due to imposition of extraneous loads on the other (filtration function). Separation of sub-base and sub-grade also contribute to gradual and natural consolidation of the sub-grade. It has been found from extensive case studies that the soil consolidation maximizes between one and two years depending on the type of soil, its moisture content and the extent and frequency of extraneous loads. In the instant field study the control CBR value got enhanced to more than 3 times despite loss strength of JGT.

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	369 mm
Max. rainfall intensity	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

CHARACTERISTICS & UNIT	PROJECT AREA UNDER JGT
1. Texture Class	SL(Sandy loam)
2. Sand (%)	66.60
3. Silt (%)	19.50
4. Clay (%)	13.90
5. pH	08.10
6. $CaCO_3$ (%)	68.10
7. Total Nitrigen (%)	00.016
8. Available P_2O_5 (kg /ha)	03.78
9. Available K_2O (kg / ha)	44.10

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

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

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)

Description	Ca	Mg	SO_4
Untreated mine	389	120	756
Treated mine	74	34	138
Standards	75	50	250

e) SOIL IMPROVEMENT –

- ☛ Organic carbon content increased from 0.13 % to 0.26%.
- ☛ Available P_2O_5 increased from 5.4 kg /ha to 32 kg / ha.
- ☛ $CaCo_3$ 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

Laying of JGT on
the mine spoil

Condition of JGT
treated stabilized
slope after 9 yrs.

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 :

Size grading, mm	<0.2	0.2-12.5	12.5-25	25-50	>50
% of fraction	6.3	35.4	18.1	30.4	9.8

PHYSICO CHEMICAL CHARACTERISTICS OF MINE-SPOIL

Characteristics & Unit	Project area under JGT
1. Texture Class	SL(Silty Loam)
2. pH	7
3. Organic Carbon (%)	0.003
4. Available P_2O_5 (kg / ha)	0.8
5. Available K_2O (kg / ha)	5.7

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.

Properties	Value
Weight (g / m^2) at 20 % moisture regain	500
Threads / dm (MD x CD)	6.5 x 4.5
Thickness (mm)	4
Width (cm)	122
Open area (%) mesh size ?	50
Strength (kN / m) [MD x CD]	10 x 7.5
Water holding capacity on dry weight (%)	500

**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)

JGT laid on prepared slope of bridge approach road

Vegetation on slope after 1 year of laying JGT

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 Geosynthetics in water resourecs projects, CBIP, January 1992, New Delhi.*

GENERAL COMPOSITION OF BANK SOIL

Depth	sand Med. (2.0 – 0.425 mm)	sand Fine (0.425 – 0.075mm)	silt (0.075 – 0.002mm)	clay (< 0.002mm)
3 m	--	0.50%	65.50%	34.0%
6m	--	0.30%	61.70%	38.0%
9 m	0.32 %	50.80 %	48.88 %	

- Organic 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 /cm^2
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

Stabilisied River Bank

Puncture resistance (Kgf / cm^2)	37.9
Air permeability (m^3 / m^2 / min)	16.2
Water permeability at 10 cm water head(l / m^2 / sec.)	20.4
Pore size (microns)	150

RESULTS

- ✳ No subsidence 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.

- ✳ 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 the laboratory of Jadavpur University. The test results are presented below : -

Sample No	N. M.C. (%)	M.C.(saturated) (%)	Bulk Density	Saturated Density	Permeability (cm /sec)
1	54.20	57.15	1.67	1.72	3.60×10^{-4}
2	47.07	53.91	1.64	1.70	0.89×10^{-4}
3	46.72	55.0	1.63	1.71	6.7×10^{-5}
4	51.83	57.92	1.67	1.76	……
5	46.71	54.88	1.65	1.74	1.266×10^{-4}

Sample No.	L. L. (%)	P. L. (%)	P.I. (%)	Sand (%)	Silt (%)	Clay (%)
1	54	20	34	.....	51	49
2	51	24	27	.....	51.5	48.5
3	50	26	24	8.5	58.5	33
4	51	25	26	14	49	37
5	49	26	23	.....	60.5	39.5

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^{o}

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/JMDC*

Preparation of embankment slope

Stone Boulder armour on JGT

Finished embankment with JGT (after three years of completion).

APPLICATION
IN
RAILWAY EMBANKMENT

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.
- ❖ Side slopes of the embankment varies between 1: 2 to 1 : 1.5.
- ❖ The cess at the side of the southern track was almost non existant due to unabated erosion of the surficial soil.
- ❖ Borrow pits almost touch the toe of the embankment at most places with water within.
- ❖ No sand cushion was observed under the ballast layer.

PROPERTIES OF SUBGRADE SOIL

Properties	Value
Type of soil	Shrinkable but not black cotton type.
Shear strength(T/sq m)	1.47 – 1.96
Natural dry density	70% - 80%

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

TREATMENT WITH JGT

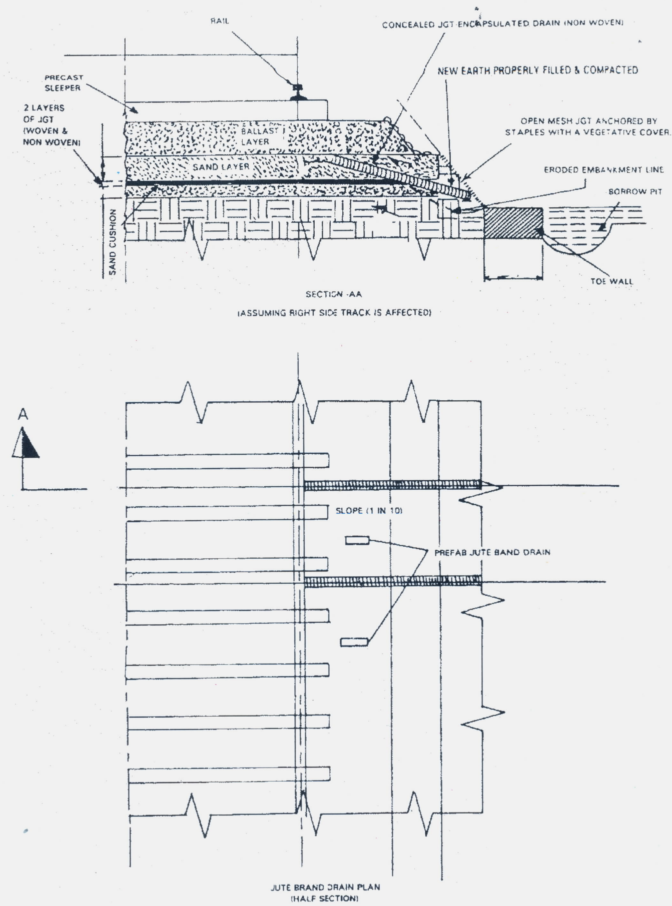
Woven JGT was laid on the sand spread over the subgrade and non-woven JGT was laid over woven JGT. Woven JGT was used to check the movement of subgrade and helps allow pore–water to seep through the fabric pores. Non woven JGT was placed as shock absorber and as drainage medium.

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 δ slope (slope 1:2.5).

PROPERTIES OF JUTE GEOTEXTILES USED

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



PREVENTION OF RAILWAY TRACK SUBSIDENCE - REMEDIAL ARRANGEMENT

RESULTS

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

CONCLUSION

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

- No short 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 ply board of 20-mm thickness was applied. This surcharge load provided an over burden pressure equivalent to 10 kN / m^2 . 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 / m^2.

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.

Annex-II

ABOUT THE TRIAL PLOTS AND GEOTEXTILES

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 / m^2.

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 / m^2
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 guage 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. Environmat had the following properties :-

Weight	360 g / m^2

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 / m^2.
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 guage 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 / m^2.
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 2.4m 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 / m^2.

The installation procedure for the trial involved grading the slope surface approximately 100mm 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

Annex-III

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 levelof 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.

Annex IV

DESIGN APPROACH

Height of fill (H)	1.5 m
Unit weight (γ)	16.6 kN/m^2
Angle of internal friction(ϕ)	30°
Depth of foundation soil(D)	4.0 m
Undrained cohesion (C)	6 kN/m^2

Thus, vertical stress due to fill (α_γ) =16.6 x 1.5 = 24.9 kN/m^2

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

($CN_cc/\gamma H$) = (6 x 3.14) / 24.9 = 0.75

N_c = 3.14 in the unreinforced state

So the bearing capacity is inadequate without reinforcement.

By providing a geotextile reinforcement, the bearing capacity factor, Nc increases to $\pi + 2 = 5.14$ and the factor of safety works to (6 x5.14) / 24.9 =1.23 which is a satisfactory value.

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

$P_a = (K_a \alpha_\gamma H^2) / 2 = (0.33 \times 16.6 \times 1.5 \times 1.5) / 2 = 6.16$ 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 $C_\gamma = 2 \times 10^{-7}$ m^2 / 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
$S\mu = 0.18 \times\ = 0.18 \times \Delta\alpha\gamma\, 24.9 = 4.48$ kPa.

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

Factor of safety at the end of the consolidation without any reinforcing fabric would thus be : - FS = (10 x 3.14) / 16.6 x 1.5 =1.26 which is satisfactory.

Annex V

REMEDIAL MEASURES UNDERTAKEN

Based on the topographical, vegetative and soil surveys, a corrective plan consisting of a combination of engineering and vegetative measures were implemented. The critically eroded areas for stabilization in the mined watershed were identified as (a) unstable mine-spoil slopes and (b) drainage channels. Engineering measures were first implemented to provide stability to the slopes and checked the excessive run-off and debris flow. Mild slopes (< 30 %) were stabilized by digging contour trenches (0.3 m X 0.3 m) at a vertical interval of about 1 m and planted with suitable vegetative species. Steep slopes were vegetated with the application of Jute Geotextile. The steep land slide affected slopes were stabilized with log wood crib structures. Small gullies and channels were treated with loose stones / brushwood checked dams. The main drainage channels, transporting the bulk of debris load, required the most intensive treatment.

Gabion (stone filled wire meshes,checked dams/ cross barriers and silt detention basis across the channels width (6 m – 15 m) were constructed to reduce channels slope and thereby reduce the transportability of the flow within non-erosive limits, and retain the debris within the water shed. Series of such structures (230 nos.) were constructed along with channels length of about 1500 m. Spurs (16 Nos) and toe walls (150 m) were constructed in the lower reach of channels to guide the flow and prevent bank erosion. Jute Geotextile was spread loosely on 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 like Saccharum spontaneum (Kans) and Thysanolaena maxima (Broom grass) and cutting bushes like Ipomoea carnea (Besharam), Vitex negundo (Simalu) , Arundo donax and Giant napier etc. were planted in opening between JGT strands at close spacings.

At one of the locations trenches (30 cm X30 cm) were dug which were filled with good soil from outside and mixed with Napier grass.