JUTE MARK INDIA

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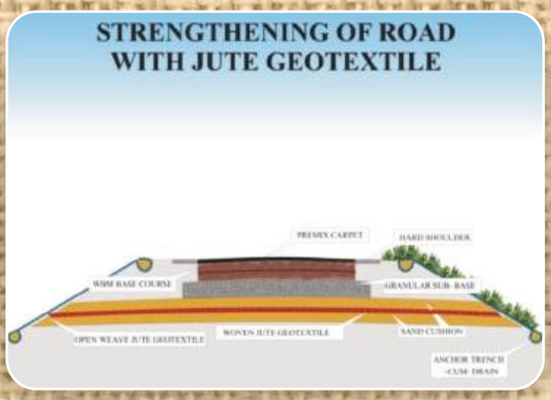
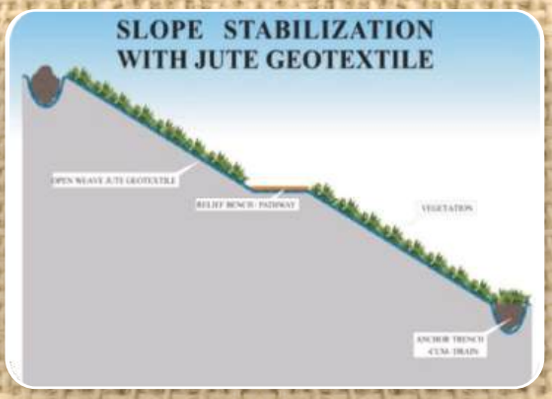
National Jute Board | Ministry of Textiles | Govt. of India

CASE STUDIES WITH JUTE GEOTEXTILES (JGT)





NATIONAL JUTE BOARD

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MINISTRY OF TEXTILES
UDYOG BHAWAN, NEW DELHI - 110 011

Bharat tex 2024
Global Textile Expo
New Delhi | Feb 26-29
TEXTILES FASHION SUSTAINABILITY

Azadi Ka Amrit Mahotsav

12th December 2023

FOREWORD

I am happy to know that the National Jute Board is organizing a Jute Symposium with special focus on Jute Geotextiles on 21st December 2023 in New Delhi.

Jute is a globally accepted natural, eco-friendly biodegradable fibre which grows abundantly in Eastern part of the country. Apart from its traditional use, jute has high growth potential due to its inherent advantages such as, strength, dimensional stability, hygroscopicity, low extensibility and abundant availability at reasonable price in the country. Therefore, jute is now increasingly being used to produce various jute diversified products and technical textiles.

Jute being one of the most versatile natural fibre has a long history in technical applications. Jute Geo Textiles (JGT) are being used for road construction, erosion control, hill slope management and soil stabilization etc.

National Jute Board has been working on development and promotion of this engineering fabric. BIS standard and IRC guidelines have already been published. Some State Governments and organisations such as Indian Railways have included JGT as an item of work in their Schedule of Rates (SoR). So far, more than 800 civil engineering projects using JGT have been carried out across States. The case studies published in this book will be of immense help to geotechnical and civil engineers engaged in construction and related fields.

I hope that this compilation of case studies and deliberations during the Jute Symposium will help in promoting the use of Jute Geotextiles.

I convey my best wishes for the success of the event.

Rachna

(Rachna Shah)

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Joint Secretary

सत्यमेव जयते

आज़ादी का अमृत महोत्सव

भारत सरकार
वस्त्र मंत्रालय
Government of India
Ministry of Textiles
Udyog Bhawan
New Delhi-110 011

MESSAGE

I am happy to learn that the National Jute Board is organizing the Jute Symposium with special focus on Jute Geotextiles on 21st December 2023 in New Delhi.

Jute is agro-renewable, available in abundance, reusable, recyclable and an eco-friendly sustainable fibre also. Sustainability is the buzz word and in the present context sustainable approach is the only solution for all temporary problems.

Role of Jute Geotextiles and its efficacy has been well established in rural infrastructure development and to mitigate soil erosion related problems including embankment of Highways, Railways and River banks etc. Under the National Jute Development Programme, the National Jute Board has further sponsored many research and product development projects to different Technical Institutes and research associations to enhance the performance of Jute Geotextiles in Civil Engineering applications.

The book on Case Studies with Jute Geotextiles being released during Jute Symposium is an updated version and compilation of the continuous efforts taken by the National Jute Board to showcase the effectiveness and superiority of Jute Geotextiles over other materials.

I am sure that this book of National Jute Board will be very much helpful for the engineers engaged in soil and ground management to a great extent.

I convey my best wishes to the organizer NJB, speakers, delegates and others for the success of the event.

(Prajakta L Verma)

New Delhi
8th December, 2023

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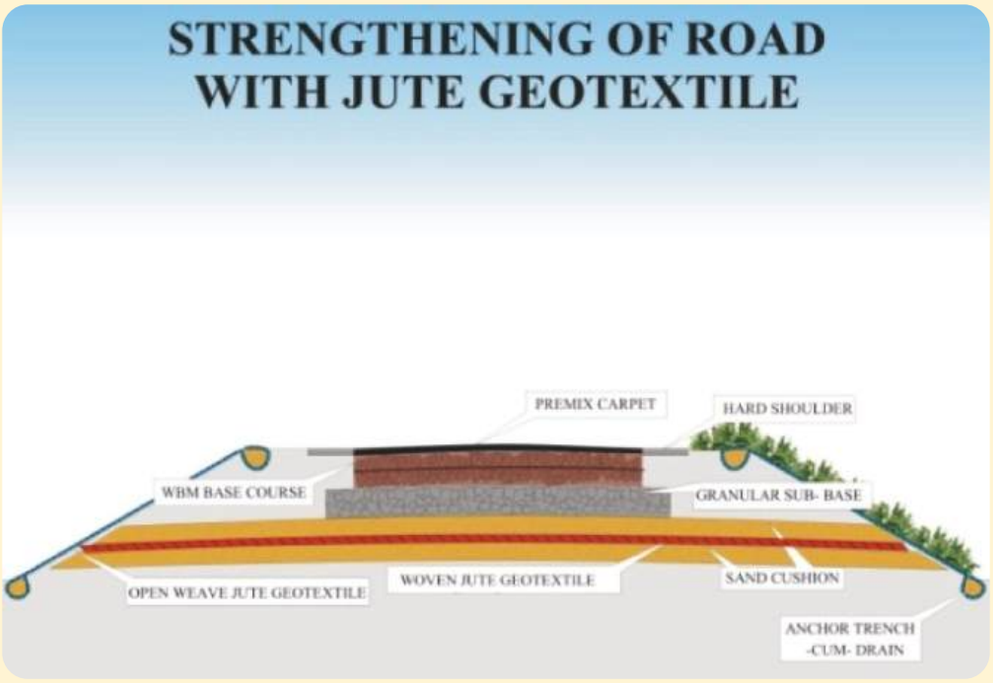
APPLICATION IN ROAD CONSTRUCTION



CASE STUDY 1

CONSTRUCTION OF UNPAVED ROAD IN KAKINADA PORT[1]

LOCATION - Kakinada Port Area, Andhra Pradesh

ROAD LENGTH – 360 metres

YEAR OF CONSTRUCTION - 1996

NAME OF THE CLIENT- Kakinada Municipality

PROPERTIES OF SUB SOIL

Average soil profile consists of soft clay about 8.5 inch thick followed by 3 metre thick sandy silt. This in turn, is underlain by a 6 metre thick clayey silt layer. The water table fluctuates from 0.2 m to 1.0 m.

Type of soil	CH
Moisture content	70 % – 80 %
Liquid Limit	60 %
Plastic Limit	28 %
Bulk density	1.3 – 1.45 mg/m^3
Un-drained Shear Strength (in situ Vane Shear Test)	6.0 kN/ m^2
Compression Index (C_c)	0.225
Co-efficient of Consolidation	2.0 x10^{-7} m^2 sec
Soaked CBR%	1.61
Unsoaked CBR%	2.1

ESTIMATED COST The cost of JGT used in the project was of the order of Rs. 18/- per sq.m.and quantity of JGT required was 25000 sq. m.

PROPERTIES OF JUTE GEOTEXTILE USED

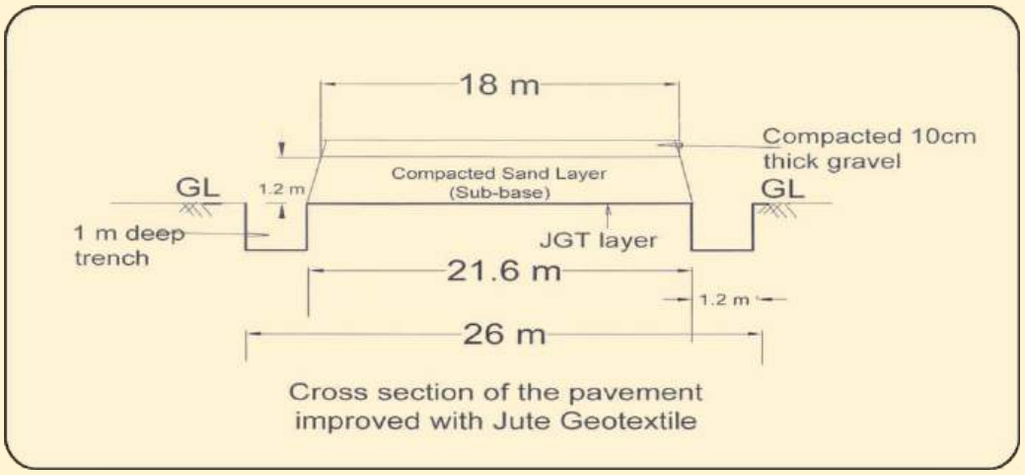
Design of JGT was based on themethodology given by Jewell (1996).

Type of JGT	Woven treated with Cupro-ammonium sulphate
Thickness	3 mm
Weight	750 gsm
Tensile strength	20 kN / m
Elongation at break	30 %
Puncture Resistance	350 N

1 The study was made by P.J. Rao, Bindumadhava, N.Venisiri of CRRI, New Delhi and A. SreeramaRao 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.

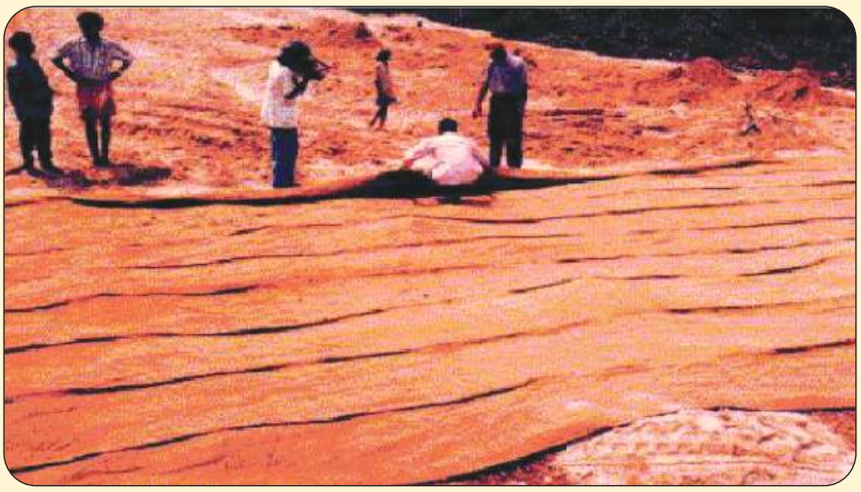
VIEW OF DAMAGED CONDITION OF ROAD

CROSS-SECTIONAL DETAILS OF PAVEMENT WITH JUTE GEOTEXTILE



Cross section of the pavement improved with Jute Geotextile

VIEW DURING LAYING OF JGT



RESULTS AND DISCUSSION

1. At the end of seven months, the shear strength of the sub soil ensured the required factor of safety. The strength of fabric thereafter ceased to be of prime concern. (Study by P J Rao)

2. Following are the findings by Prof. Sree Rama Rao from J.N.T.U College of Engineering in which soil samples were collected at elapsed times of 3, 7, 21, 30 months after laying of JGT

(a) Water content of soil before and after laying 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	50.0
2	72.7	69.1	56.3	45.4	35.3
3	76.4	69.1	68.7	59	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	0.7	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) Time-related change in values of void ratio and compression index of soil

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 sub-grade soil before and after laying of JGT

The test was performed 30 months after laying JGT and the following results were obtained. The increase in CBR% was almost 3 times for un-soaked soil and more than 3 times for the soaked one.

Natural soil (before laying JGT)		**Improved soil (after laying JGT)**	
Un-soaked CBR (%)	**Soaked CBR (%)**	**Un-soaked CBR (%)**	**Soaked CBR (%)**
2.1	1.61	6.03	4.78

(e) It may be mentioned that the stabilized road section was unaffected by the severe cyclone of 6th Nov 1996 in which Kakinada was devastated and the roads in other areas of port were badly damaged.

3. Visual Observation

Unpaved road is in good condition with no noticeable distress on surface even after 17 years of construction

VIEW OF CONDITION OF ROAD AFTER 17 YEARS (2014)

CASE STUDY 2

CONSTRUCTION OF PAVED PMGSY ROAD IN DARRANG DISTRICT, ASSAM[2]

NAME OF THE ROAD – UT Road to Jorabari

LOCATION - Udalguri in Darrang district, Assam

YEAR OF APPLICATION –2007

NAME OF THE CLIENT - Chief Engineer PWD, Rural Road Works, Assam

ROAD LENGTH - 4.6 Km

SITE CONDITION

This was an earthen road under PMGSY Pilot project. Flash flooding of the area does occur occasionally. Deep ruts had formed at some locations. Average annual rainfall is 1600 – 1700 mm. The water table is 3 to 4 m below GL during summer and 1.5 to 2 m during monsoon.

PROPERTIES OF SUB-GRADE SOIL

Soaked CBR %	**4%**
Soil type	**ML**
Liquid Limit	24%
Plastic Limit	Non-plastic
Sieve Analysis	Percent finer
4.75 mm	99.4 %
2.36 mm	98.6 %
1.18 mm	97.6 %
600 micron	96.8 %
425 micron	96.2 %
300 micron	91.6 %
150 micron	77.8 %
75 micron	52.4 %

ESTIMATED COST– Total cost of construction was Rs. 1,98,42,423 out of which cost of Woven JGT was Rs. 12,89,110 i.e. about 6.5% of total construction cost.

PRE-WORK TRAFFIC STATUS

- CVPD was on an average 7 with laden weight of 3T or more at the time of traffic counts which was likely to be 20 in the base year after road had been constructed.
- CVPD for the purpose of pavement design was based on an assumed growth rate of 6% annually at the end of the design life of 10 years which worked out to $20(1+6/100)^{10} = 36$ conforming to **Curve B** as per Rural Road Manual IRC:SP:20 – 2002.

2 The design of pavement as well as performance evaluation were carried out by CRRI

VIEW OF CONDITION OF ROAD BEFORE CONSTRUCTION

PROPERTIES OF JUTE GEOTEXTILE USED

Type of JGT	Woven (Rot-proof)
Weight	643/760/810 gsm
Tensile Strength	15/20/30 kN/m
Pore Size (O_{90})	200/ 180/ 150 micron
Elongation at break (%) (MD x CD)	6 x 6 / 8 x 8 / 9 x 9
Puncture Resistance (kN)	0.4 / 0.5 / 0.6
Burst Strength (kPa)	3100 / 3500 / 4500
Permittivity at50 mm constant head (/sec)	350 x 10^{-5}

RESULTS AND DISCUSSION

(a) CBR values of sub-grade soil before and after laying of JGT

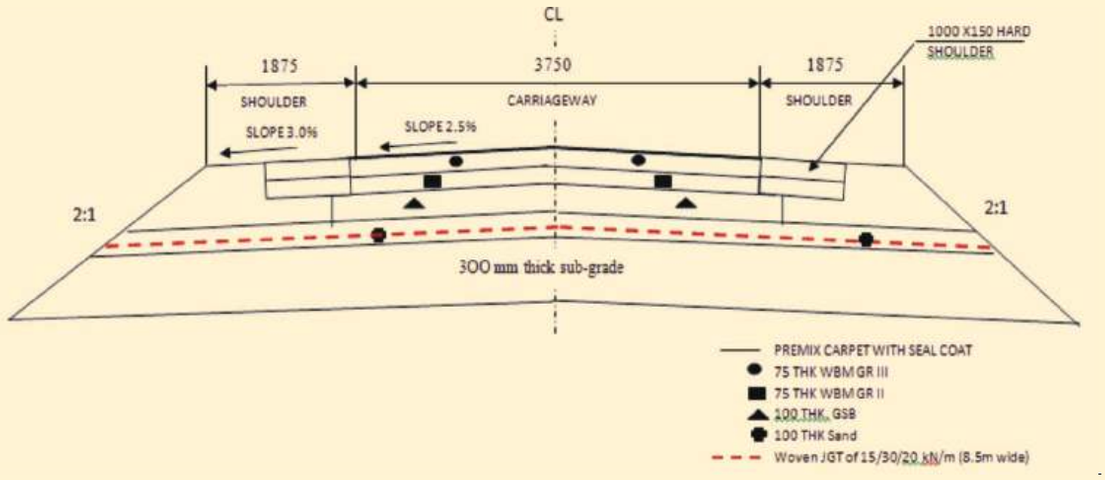
The test was performed 23 months from end of construction and the following results were obtained.

Natural soil (before laying JGT)	Improved soil (after laying JGT)
Soaked CBR (%)	**CBR (%) from DCP Test**
4	10 – 18.3 (range of CBR at different sections of Woven JGT)

(b) Visual observations (after 23 months)

- The blacktopof pavement surface was distress-free during the entire period of performance monitoring.
- Shoulders as well as side slope condition was good without any rain-cuts or settlement with the use of Open Weave JGT at the slope.

CROSS-SECTIONAL DETAILS OF PAVEMENT WITH JUTE GEOTEXTILE



VIEW DURING LAYING OF JGT &FINISHED CONDITION ROAD AFTER 23 MONTHS

CASE STUDY 3

CONSTRUCTION OF PAVED PMGSY ROAD IN NAGAON DISTRICT, ASSAM[3]

NAME OF THE ROAD – Rampur Satra to Dumdumia

LOCATION - Batadrava Block in Nagaon district, Assam

YEAR OF APPLICATION –2007

NAME OF THE CLIENT - Chief Engineer PWD, Rural Road Works, Assam

ROAD LENGTH - 4.2 Km

SITE CONDITION

This was an earthen road under PMGSY Pilot Project. Flash flooding of the area does occur occasionally. Deep ruts had formed at some locations. Average annual rainfall of 1500 – 1600 mm observed in the area. The water table is 3 to 4 m below GL during summer and 2 to 3 m during monsoon.

PROPERTIES OF SUB-GRADE SOIL

Soaked CBR %	3%
Soil type	CL
Liquid Limit	34%
Plastic Limit	21 %
Sieve Analysis	Percent finer
4.75 mm	100 %
2.36 mm	99.9 %
1.18 mm	99.7 %
600 micron	99.1 %
425 micron	98.5 %
300 micron	96.8 %
150 micron	88.8 %
75 micron	69.6 %

ESTIMATED COST– Total cost of construction was Rs. 1,66,72,671 out of which cost of woven JGT was Rs. 11,92,705 i.e.about 7.2% of total construction.

PRE-WORK TRAFFIC STATUS

- CPVD taken as 60 in the base year after road had been constructed considering both, the harvesting and non – harvesting seasons.
- CVPD for the purpose of pavement design was based on an assumed growth rate of 6% annually at the end of the design life of 10 years which worked out to $60(1+6/100)^{10} = 108$ conforming to '**Curve C'** as per Rural Road Manual IRC:SP:20 – 2002.

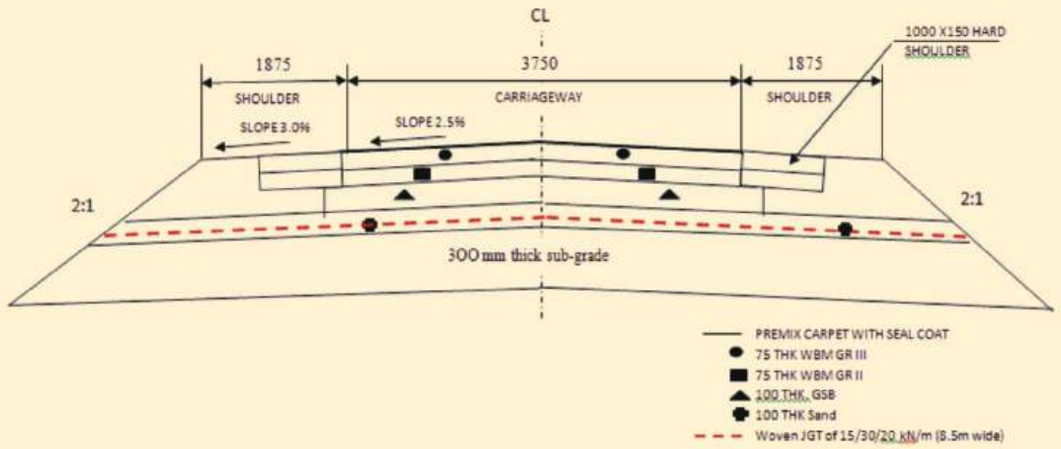
3 The design of pavement as well as performance evaluation were carried out by CRRI

VIEW OF DISTRESSED CONDITION OF ROAD BEFORE CONSTRUCTION

PROPERTIES OF JUTE GEOTEXTILE (JGT) USED

Type of JGT	Woven (Rot-proof)
Weight	643/760/810 gsm
Tensile Strength	15/20/30 kN/m
Pore Size (O_{90})	200/ 180/ 150 micron
Elongation at break (%) (MD x CD)	6 x 6 / 8 x 8 / 9 x 9
Puncture Resistance (kN)	0.4 / 0.5 / 0.6
Burst Strength (kPa)	3100 / 3500 / 4500
Permittivity at 50 mm constant head (/sec)	350 x 10^{-5}

CROSS-SECTIONAL DETAILS OF PAVEMENT WITH JUTE GEOTEXTILE



RESULTS AND DISCUSSION

(a) CBR values of sub-grade soil before and after laying of JGT

The test was performed 24 months from end of construction and the following results were obtained.

Natural soil (before laying JGT)	Improved soil (after laying JGT)
Soaked CBR (%)	**CBR (%) from DCP Test**
3	9.3 – 26.1 (range of CBR at different sections of JGT)

(b) Visual observations (after 24 months)

The blacktop pavement surface was distress-free during the entire period of performance monitoring

VIEW DURING LAYING OF JGT &FINISHED CONDITION OF ROAD AFTER 2 YEARS

CASE STUDY 4

CONSTRUCTION OF PAVED PMGSY ROAD IN JAJPUR DISTRICT, ODISHA[4]

NAME OF THE ROAD – Chatumary to MDR 14

LOCATION - JajpurDistrict,Odisha

YEAR OF APPLICATION – 2007

NAME OF THE CLIENT - Chief Engineer PWD, Rural Road Works - II, Odhisa

ROAD LENGTH - 2.67 Km

SITE CONDITION

This was an earthen road under PMGSY Pilot project. Deep ruts had formed at some locations. Average annual rainfall is 1400 mm. The water table is at a depth of 1.5 to 3 m.

PROPERTIES OF SUB-GRADE SOIL

Soaked CBR %	3%
Soil type	ML
Liquid Limit	27%
Plastic Limit	Non-plastic
Sieve Analysis	Percent finer
4.75 mm	99.0 %
2.36 mm	98.5 %
1.18 mm	97.9 %
600 micron	97.3 %
425 micron	96.9 %
300 micron	96.2 %
150 micron	95.3 %
75 micron	68.8 %

ESTIMATED COST– Total cost of construction was Rs. 1,69,71,425 out of which cost of woven JGT was Rs. 11,78,550 i.e.about 6.94% of total construction.

PRE-WORK TRAFFIC STATUS

- CVPD was on an average 7 with laden weight of 3T or more which was projected to be 44 in the base year after road had been constructed.
- CVPD for the purpose of pavement design was based on an assumed growth rate of 6% annually at the end of the design life of 10 years which worked out to $44(1+6/100)^{10}$ = 79 conforming to '**Curve B'**as per Rural Road Manual IRC:SP:20 – 2002.

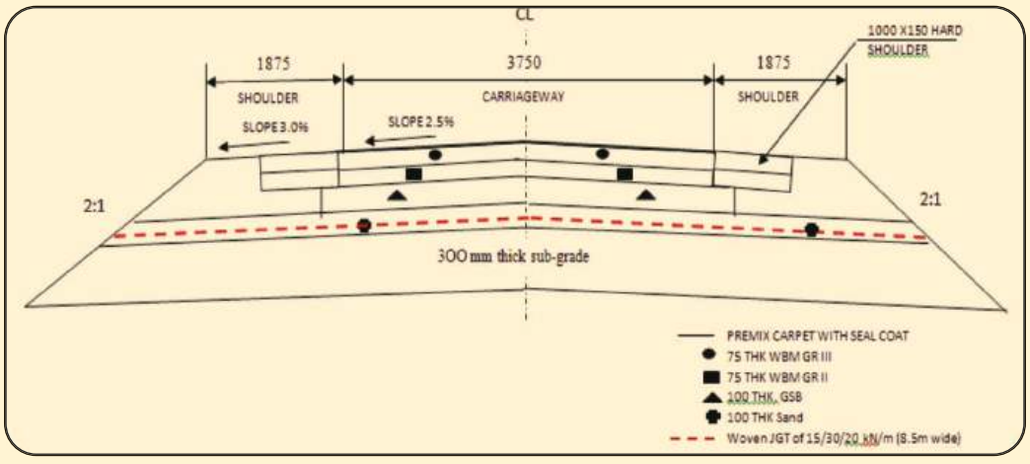
4 The design of pavement as well as performance evaluation were done by CRRI

VIEW OF CONDITION OF ROAD BEFORE CONSTRUCTION

PROPERTIES OF JUTE GEOTEXTILE USED

Type of JGT	Woven (Rot-proof)
Weight	643/760/810 gsm
Tensile Strength	15/20/30 kN/m
Pore Size (O_{90})	200/ 180/ 150 micron
Elongation at break (%) (MD x CD)	6 x 6 / 8 x 8 / 9 x 9
Puncture Resistance (kN)	0.4 / 0.5 / 0.6
Burst Strength (kPa)	3100 / 3500 / 4500
Permittivity at50 mm constant head (/sec)	350 x 10^{-5}

CROSS-SECTIONAL DETAILS OF PAVEMENT WITH JUTE GEOTEXTILE



RESULTS AND DISCUSSION

(a) CBR values of sub-grade soil before and after laying of JGT

The test was performed 31 months from end of construction and the following results were obtained.

Natural soil (before laying JGT)	Improved soil (after laying JGT)
Soaked CBR (%)	**CBR (%) from DCP Test**
3	3 – 10 (range of CBR at different sections of Woven JGT)

Visual observations (after 31 months)

- The blacktop of pavement surface was distress-free during the entire period of performance monitoring
- Shoulders as well as side slope condition were in good shape without any rain-cut or settlement with the use of Open Weave JGT at the slope..

VIEW DURING LAYING OF JGT & FINISHED CONDITION OF ROAD AFTER 31 MONTHS

CASE STUDY 5

CONSTRUCTION OF PAVED PMGSY ROAD IN NORTH 24-PARAGANAS DISTRICT, WEST BENGAL[5]

NAME OF THE ROAD – Andulia (Kalupukur More) to Boyratala

LOCATION - Haroa Block, District -North 24-Paraganas, West Bengal

YEAR OF APPLICATION – 2005

NAME OF THE CLIENT - North 24-Paraganas ZillaParishad, West Bengal

ROAD LENGTH – 3.3 Km

SITE CONDITION

It is a rural road under PMGSY with a problem of overall decrease in pavement thickness than the designed one because the sub-grade consists of soft soil. Average rainfall of the area is 1500mm.

PROPERTIES OF SUB-GRADE SOIL

Soaked CBR %	3.22 %
OMC	23.5 %
MDD	1.72 gm/cc
Soil type	**OL**
Liquid Limit	48.5%
Plastic Limit	28.2 %
Sieve Analysis	Percent finer
4.75 mm	92.5 %
2.36 mm	77.5 %
425 micron	49.5 %
75 micron	26.3 %

ESTIMATED COST– Total cost of project was Rs. 1,48,00,000 out of which cost of JGT was about 4.34% of total project cost.

PRE-WORK TRAFFIC STATUS

CVPD for the purpose of pavement design was based on an assumed growth rate of 6% annually at the end of the design life of 10 years conforming to **Curve B** as per Rural Road Manual IRC:SP:20 – 2002.

5 The performance evaluation were carried out by Civil Engineering Department, Bengal Engineering and Science University (now IIEST), Shibpur, WB

VIEW OF CONDITION OF ROAD BEFORE CONSTRUCTION

PROPERTIES OF JUTE GEOTEXTILE USED

Type of JGT	Woven (Rot-proof)
Weight	810 gsm
Thickness	2 mm
Width	76 cm
Tensile Strength	30 x 30 kN/m
Elongation – at – break	9 x 9 %
Pore Size (O_{90})	150 micron
Burst Strength	4500 kPa
Puncture Resistance	0.6 kN
Permittivity at 10 cm water head	350 x 10^{-5}/s

RESULTS AND DISCUSSION

Post work study was conducted by the Civil Engineering Department, Bengal Engineering and Science University (now IIEST), Shibpur, WB

CBR values of sub-grade soil before and after laying of JGT

The test was performed after 18 months from end of construction and the following results were obtained.

Natural soil (before laying JGT)	**Improved soil (after laying JGT)**
Soaked CBR (%)	**Field CBR (%)**
3.22	14

Visual observations

The surface of pavement was in distress-free shape even after one and half year of completion of road.

CROSS-SECTIONAL DETAILS OF PAVEMENT WITH JUTE GEOTEXTILE

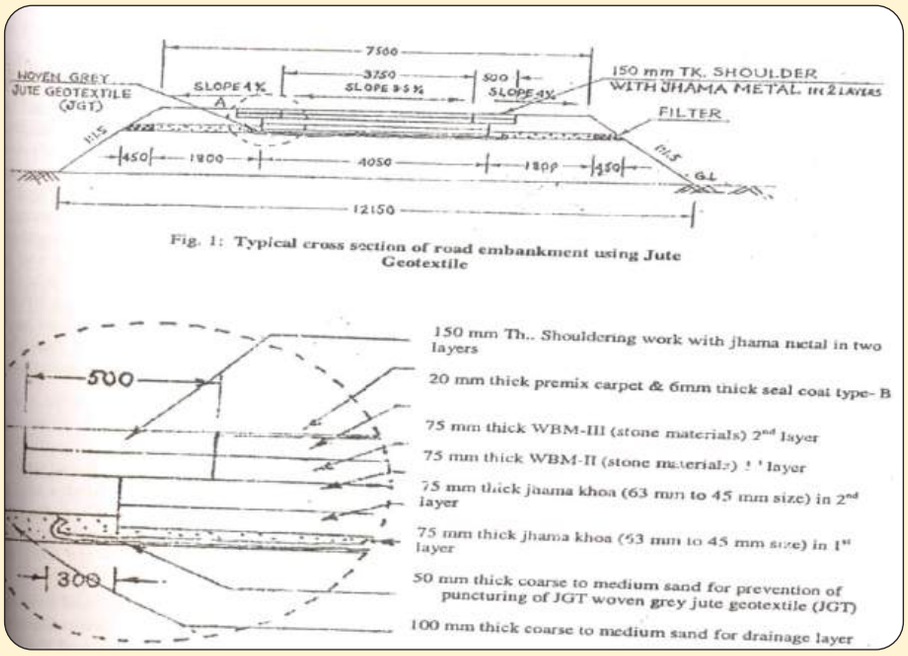


Fig. 1: Typical cross section of road embankment using Jute Geotextile

VIEW DURING LAYING OF JGT & FINISHED CONDITION OF ROAD AFTER 18 MONTHS

CASE STUDY 6

CONSTRUCTION OF PAVED PMGSY ROAD IN KAWARDHA DISTRICT, CHHATTISGARH[6]

NAME OF THE ROAD - Kherajiti to Ghirghosa

LOCATION - Kawardha Tehsil ofKawardha district, Chhattisgarh

YEAR OF APPLICATION - 2007

NAME OF THE CLIENT - Chief Executing Officer, Chhattisgarh Rural Road Development Agency, Govt. of Chhattisgarh

ROAD LENGTH - 5.50 Km

SITE CONDITION

This was an earthen road under PMGSY Pilot project. The soil type was black cotton soil of high compressibility that led to deep ruts under the wheel paths over a major portion of the length. Average annual rainfall observed as 1000 mm. The earthen track transverses through both plain and rolling terrain,water table found to be about 3 to 4 m below GL.

PROPERTIES OF SUB-GRADE SOIL

Type of soil	Black cotton soil of high compressibility
Soaked CBR %	2%
Soil type	CH
Liquid Limit	53 %
Plastic Limit	26.5%
Sieve Analysis	Percent finer
4.75 mm	100 %
2.36 mm	100%
1.18 mm	99.7 %
600 micron	99.6 %
425 micron	99.4 %
300 micron	99.1 %
150 micron	97.90 %
75 micron	96.10 %

ESTIMATED COST – Total cost of construction was Rs. 1,86,21,481 out of which cost of JGT was Rs. 17,69,363i.e.about 9.5% of total construction cost.

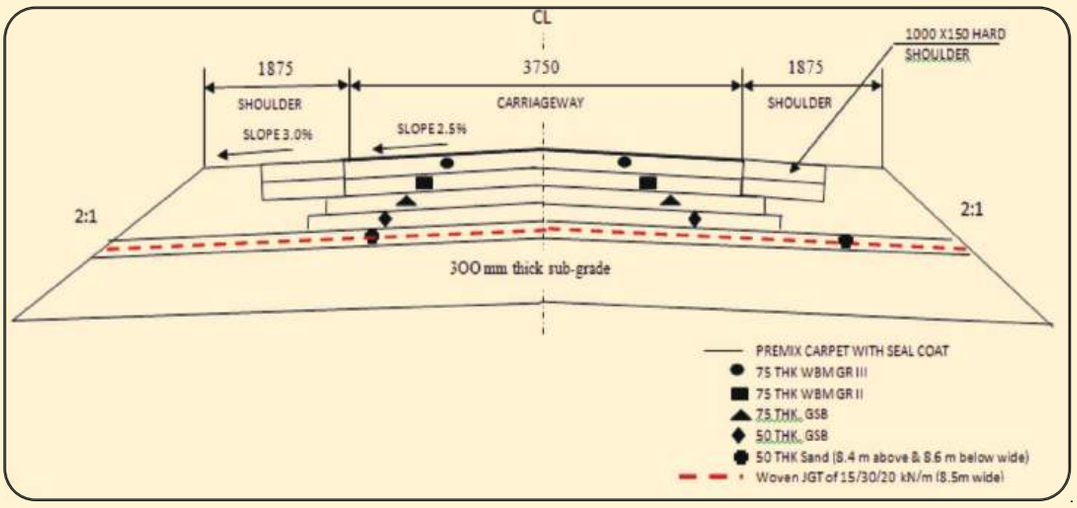
PRE-WORK TRAFFIC STATUS

- CVPD likely to be 40 in the base year after road had been constructed.
- CVPD for the purpose of pavement design was based on an assumed growth rate of 6% annually at the end of the design life of 10 years which worked out to $40(1+6/100)^{10} = 72$ conforming to '**Curve C'**as per Rural Road Manual IRC:SP:20 – 2002.

6 The design of pavement as well as performance evaluation were carried out by CRRI

VIEW OF CONDITION OF ROAD BEFORE CONSTRUCTION

CROSS-SECTIONAL DETAILS OF PAVEMENT WITH JUTE GEOTEXTILE



PROPERTIES OF JUTE GEOTEXTILE USED

Type of JGT	Woven (Rot-proof)
Weight	643/760/810 gsm
Tensile Strength	15/20/30 kN/m
Pore Size (O_{90})	200/ 180/ 150 micron
Elongation at break (%) (MD x CD)	6 x 6 / 8 x 8 / 9 x 9
Puncture Resistance (kN)	0.4 / 0.5 / 0.6
Burst Strength (kPa)	3100 / 3500 / 4500
Permittivity at 50 mm constant head (/sec)	350 x 10^{-5}

RESULTS AND DISCUSSION

The pavement was designed to evaluate whether Jute Geotextiles (JGT) work in black cotton soil without stabilizing the behavior of the soil. As a treatment, JGT fabric laid above 50 mm thick sand layer above sub-grade in case of JGT treated section and in control section only 100 mm thick sand was provided over sub-grade. The following observations were noticed during two performance evaluation of the road -

CBR values of sub-grade soil before and after 26 months

Natural soil (before laying JGT)	CBR (%) from DCP Test after 26 months (2010)
Soaked CBR (%)	With JGT section
2	7.6 – 25.6 (at in-situ moisture content 5.3 – 18.3%)

Visual observations (after 26 months)

- Distresses like cracks were observed in some stretches of both the sections, i.e control as well as in JGT laid sections.
- Shoulders as well as side slope condition was good without any rain-cuts or settlement with the use of Open Weave JGT at the slope.

VIEW OF FINISHED CONDITION ROAD AFTER 16 and 27 MONTHS FROM END OF CONSTRUCTION

Control section after 26 Months (2009)

JGT laid section after 26 Months (2009)

Initiation of distress at Control section after 26 Months (2009)

Initiation of distress at JGT laid section after 26 Months (2009)

CASE STUDY 7

WIDENING AND STRENGTHENING OF SUB-GRADE OF PAVED MAJOR DISTRICT ROAD IN HOWRAH DISTRICT, WEST BENGAL[7]

NAME OF THE ROAD – Munshirhat to Rajpur

LOCATION- Howrah, West Bengal

YEAR OF APPLICATION - 2000

NAME OF THE CLIENT- Howrah Highway Division, PW (Roads) Department, Government of West Bengal

ROAD LENGTH - 2 Km

SITE CONDITION

JGT was laid on the extended portion. The minimum temperature in the month of January varies from 11.5^{0}C to 18^{0}C and the highest temperature registers as the month of May. Average annual rainfall observed as above 1500 mm.

PROPERTIES OF SUB-GRADE SOIL

Type of soil	**Inorganic silty clay**
Soaked CBR %	**3.5 %**
Field Moisture Content %	15.2 – 19.1%
Liquid Limit	46.5 – 52.1 %
Plastic Limit	25.1 – 38.5 %
Plasticity Index	15.2 – 21.4 %

VIEW OF ROAD DURING WIDENING

JGT laid over sub-grade

7 The performance evaluation were carried out by the Civil Engineering Department, Jadavpur University

Brick metal laid over JGT

PROPERTIES OF JUTE GEOTEXTILE USED

Type of JGT	Woven
Weight	760gsm
Ends x Picks	102 x 39 /dm
Thickness	2 mm
Width	76 cm
Tensile Strength	20 x 20 kN/m
Elongation – at – break	10 x 10 %
Pore Size (O_{90})	300 micron
Puncture Resistance	380 N/m^2
Water permeability at 10 cm water head	50 l/m^2/s

RESULTS AND DISCUSSION

Post work study was conducted by the Civil Engineering Department, Jadavpur University in November 2001

(a) **CBR values of sub-grade soil before and after laying of JGT**

The test was performed after 1 year from end of construction and the following results were obtained.

Natural soil (before laying JGT)	Improved soil (after laying JGT)
Soaked CBR (%)	**Soaked CBR (%)**
3.5	6

(b) **Comparative Lab test results of soil**

Test	Natural soil (before laying JGT)	Improved soil (after laying JGT)
Liquid Limit (%)	46.5 – 52.1	42
Plastic Limit (%)	25.1 – 38.5	22
Normal Moisture content (%)	15.2 – 19.1	21
Cohesion (t/m^2)	–	7.5

(c) **Visual Condition of road**

- No distress of road was noticeable
- Riding surface was smooth

VIEW OF FINISHED CONDITION ROAD AFTER 1 YEAR

CASE STUDY 8

CONSTRUCTION OF PAVED PMGSY ROAD IN SOUTH DINAJPUR DISTRICT, WEST BENGAL[8]

NAME OF THE ROAD - Udal to Chakbrahma

LOCATION - Kumarganj Block ofSouth Dinajpur District, West Bengal

YEAR OF APPLICATION - 2011

NAME OF THE CLIENT - Chief Engineer,WestBengalRural Road Development Agency, Govt. of West Bengal

ROAD LENGTH - 4.75 Km

SITE CONDITION

This was an earthen road under PMGSY Pilot projectin plain terrain condition.The condition of road was poor almost throughout the stretch. The minimum temperature in the month of January varies from 11.5^{0}C to 18^{0}C and the highest temperature registers as the month of May. Average annual rainfall observed as above 1500mm.

PROPERTIES OF SUB-GRADE SOIL

Test Results as mentioned in DPR	
Soaked CBR	**3.54%**
Soil type	**ML**
Liquid Limit	25 %
Plastic Limit	10%
Max Dry Density	1.63 gm/cm^3
Optimum Moisture Content	13.5 %
Sieve Analysis	Percent finer
4.75 mm	100 %
2.36 mm	100%
425 micron	99.4 %
75 micron	96.10 %

ESTIMATED COST - Total cost of construction was Rs. 2,68,31,754 out of which cost of JGT was Rs. 19,39,575i.e.about 7.23% of total construction cost.

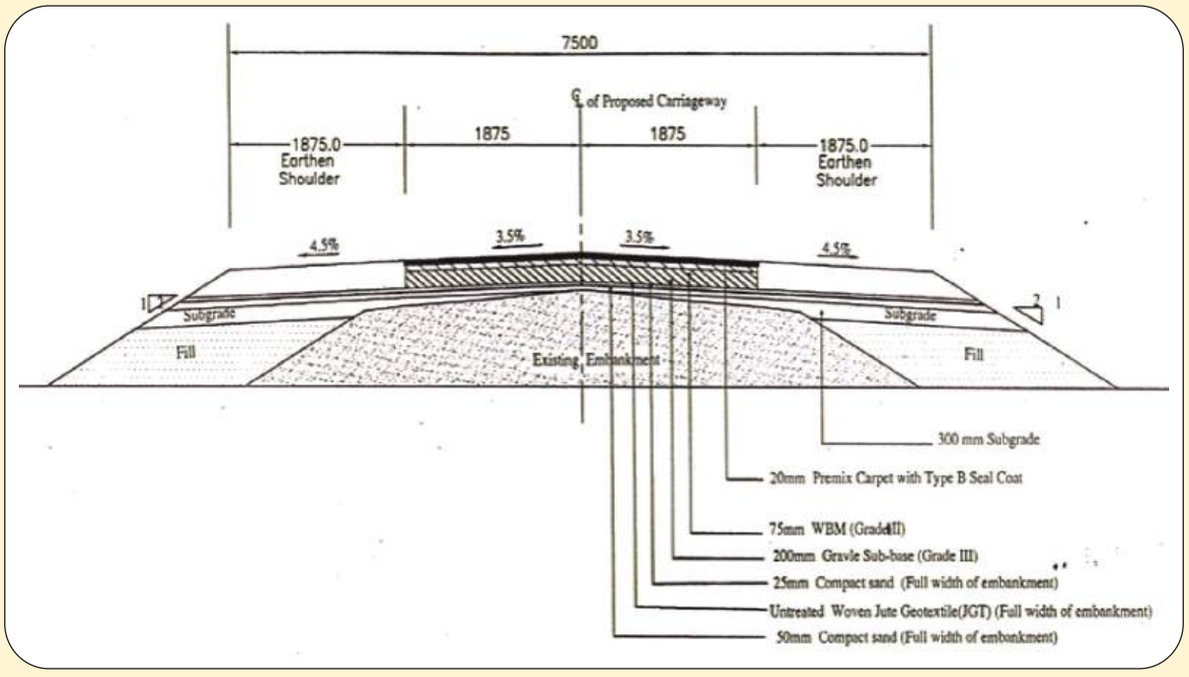
PRE-WORK TRAFFIC STATUS

- Average Daily Traffic (ADT) likely to be 459 in the base year and time period between traffic count & opening of road taken as 2 years.
- Cumulative ESAL over 10 years of design life period @ 6% growth rate which worked out to 87319.65 conforming to '**T_3 Traffic Category'**as per Low Volume Road Manual IRC:SP:72 – 2007.

8 The performance evaluation is carried out by National Jute Board – JGT Cell with IIEST Shibpur erstwhile BESUS under CFC/IJSG/21 International Project.

VIEW OF CONDITION OF ROAD BEFORE CONSTRUCTION

CROSS-SECTIONAL DETAILS OF PAVEMENT WITH JUTE GEOTEXTILE



PROPERTIES OF JUTE GEOTEXTILE USED

Type of JGT	Woven
Weight at 20% MR	721gsm
Width	102 cm
Wide Width Tensile Strength (MD x CD)	23.27 x 22.90 kN/m
Pore Size (O_{90})	245 micron
Elongation at break (MD x CD)	12.0 x 7.0
Permittivity at 50 mm constant head	0.92 /sec

RESULTS AND DISCUSSION

(a) **CBR values of sub-grade soil before and after 4 years from end of construction**

Natural soil (before laying JGT)	Improved soil after 3 years (2015) with JGT	
Soaked CBR (%)	CBR (%) from DCP Tests	Field CBR (%)
2.8 (at OMC : 17.5% & MDD : 1.72 gm/cm^3)	**12.5**	**6.44** (at FMC* : 18.44% & FD** : 1.76 gm/cm^3)

FMC* is Field Moisture content & FD** is Field Density

(b) **Visual observations (after 3 years)**

- The riding surface is in good condition with no sign of distresses
- No pot holes or rutting observed.
- Shoulders as well as side slope condition is in good condition without any rain-cuts or settlement at the slope.

VIEW OF LAYING OF JGT & FINISHED CONDITION ROAD

Layer of sand spread over JGT

Finished Condition of road after 3 years (2015)

CASE STUDY 9

CONSTRUCTION OF PAVED PMGSY ROAD IN SOUTH DINAJPUR DISTRICT, WEST BENGAL[9]

NAME OF THE ROAD - Nihinagar to Hazratpur

LOCATION - Tapan Block of South Dinajpur District, West Bengal

YEAR OF APPLICATION - 2012

NAME OF THE CLIENT - Chief Engineer, West Bengal Rural Road Development Agency, Govt. of West Bengal

ROAD LENGTH - 7.90 Km

SITE CONDITION

This was an earthen road under PMGSY Pilot projectin plain terrain condition. The condition of road was poor almost throughout the stretch. The minimum temperature in the month of January varies from 11.5^{0}C to 18^{0}C and the highest temperature registers as the month of May. Average annual rainfall observed as above 1500 mm.

PROPERTIES OF SUB-GRADE SOIL

Test Results as mentioned in DPR	
Soaked CBR	3.25%
Soil type	ML
Liquid Limit	34.25 %
Plastic Limit	26.72%
Max Dry Density	1.66gm/cm^3
Optimum Moisture Content	21.82 %
Sieve Analysis	Percent finer
4.75 mm	100 %
2.36 mm	100%
425 micron	97 %
75 micron	88 %

ESTIMATED COST - Total cost of construction was Rs. 4,51,34,817 out of which cost of JGT was Rs. 32,24,380 i.e.about 7.14% of total construction cost.

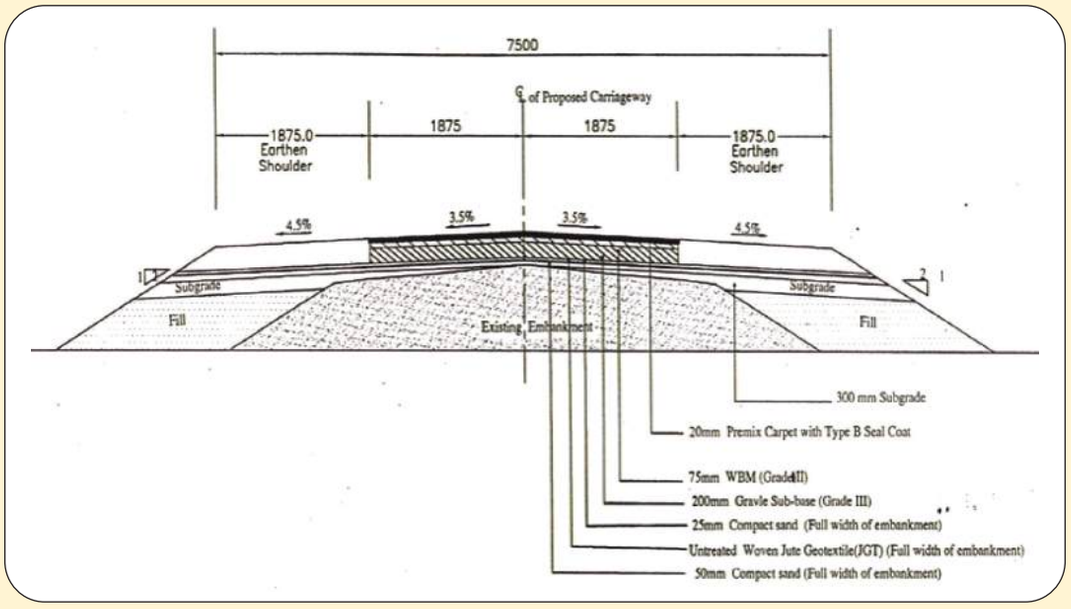
PRE-WORK TRAFFIC STATUS –

- Average Daily Traffic (ADT) likely to be 398 in the base year and time period between traffic count & opening of road taken as 2 years.
- Cumulative ESAL over 10 years of design life period @ 6% growth rate which worked out to 72020.67conforming to '**T_3 Traffic Category'**as per Low Volume Road Manual IRC:SP:72 – 2007.

9 The performance evaluation is carried out by National Jute Board – JGT Cell with IIEST Shibpur erstwhile BESUS under CFC/IJSG/21 International Project.

VIEW OF CONDITION OF ROAD BEFORE CONSTRUCTION

CROSS-SECTIONAL DETAILS OF PAVEMENT WITH JUTE GEOTEXTILE



PROPERTIES OF JUTE GEOTEXTILE USED

Type of JGT	Woven
Weight at 20% MR	740 gsm
Wide Width Tensile Strength (MD x CD)	25.12 x 25.77 kN/m
Pore Size (O_{90})	247 micron
Puncture Resistance	0.54 kN
Elongation at break (MD x CD)	13.0 x 9.0
Permittivity at 50 mm constant head	0.63 /sec

RESULTS AND DISCUSSION

(a) CBR values of sub-grade soil before and after 2 years from end of construction

Natural soil (before laying JGT)	Improved soil after 2 years (2015) with JGT	
Soaked CBR (%)	CBR (%) from DCP Tests	Field CBR (%)
2.2 (at OMC : 17.2% & MDD : 1.73gm/cm^3)	**17**	**7.82** (at FMC : 18 % & FD : 1.92gm/cm^3)

FMC* is Field Moisture content & FD** is Field Density

(b) Visual observations (after 2 years)

- The riding surface is in good condition with no sign of distresses
- No pot holes or rutting observed.
- Shoulders as well as side slope condition is in good condition without any rain-cuts or settlement at the slope.

VIEW OF LAYING OF JGT & FINISHED CONDITION ROAD

Pegging of overlapped portions of JGT

Finished Condition of road after 2 years (2015)

CASE STUDY 10

CONSTRUCTION OF PAVED PMGSY ROAD IN MURSHIDABAD DISTRICT, WEST BENGAL[10]

NAME OF THE ROAD - Kanksa to Bati

LOCATION - Murshidabad – Jiagunj Block of Murshidabad District, West Bengal

YEAR OF APPLICATION - 2013

NAME OF THE CLIENT - West Bengal Rural Road Development Agency, Govt. of West Bengal

ROAD LENGTH - 8.06 Km

SITE CONDITION

This was an earthen road under PMGSY Pilot projectin plain terrain. The condition of road was poor almost throughout the stretch. The minimum temperature in the month of January varies from 7.8^{0}C to 15.5^{0}C and the highest temperature registers as the month of May about 38^{0}C. Average annual rainfall observed as above 1593mm.

PROPERTIES OF SUB-GRADE SOIL

Test Results as mentioned in DPR	
Soaked CBR	2.7%
Soil type	CL
Liquid Limit	38.61 %
Plastic Limit	19.08%
Max Dry Density	1.646 gm/cm^3
Optimum Moisture Content	20.06 %
Sieve Analysis	Percent finer
4.75 mm	100 %
2.36 mm	100%
425 micron	95.76 %
75 micron	89.13 %

ESTIMATED COST - Total cost of construction was Rs. 4,44,58,330 out of which cost of JGT was Rs. 26,32,448i.e.about 6 % of total construction cost.

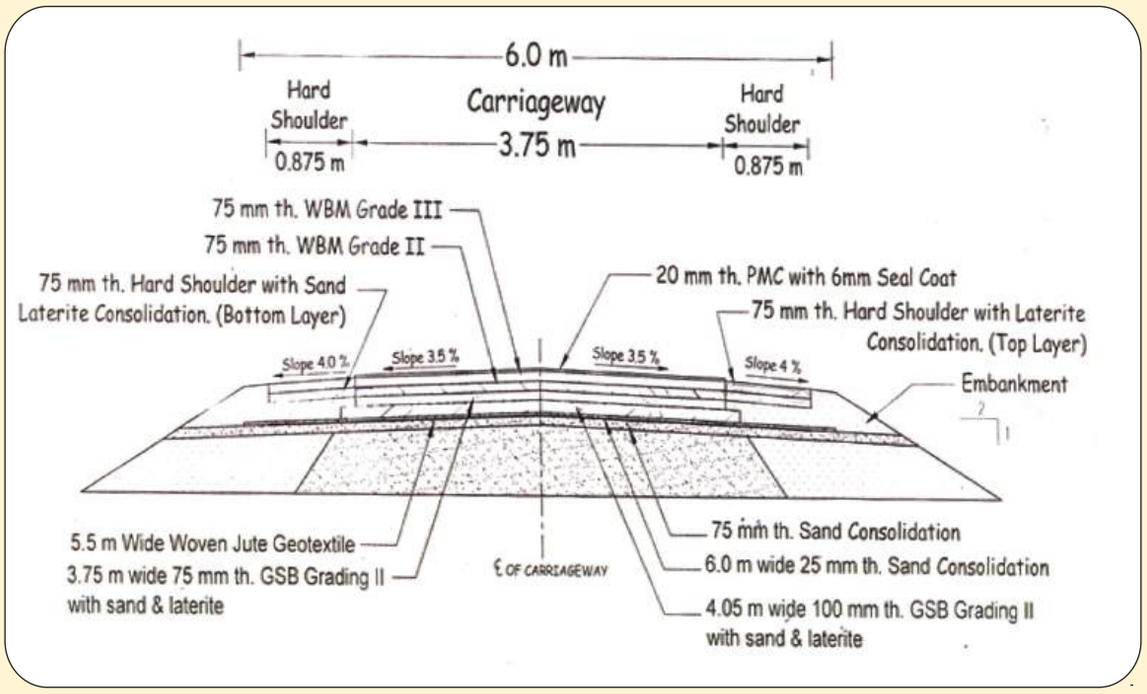
PRE-WORK TRAFFIC STATUS

- Average Daily Traffic (ADT) likely to be 249 in the base year and time period between traffic count & opening of road taken as 2 years.
- Cumulative ESAL over 10 years of design life period @ 6% growth rate which worked out to 70096conforming to '**T_3 Traffic Category'**as per Low Volume Road Manual IRC:SP:72 – 2007.

10 The performance evaluation is carried out by National Jute Board – JGT Cell with IIEST Shibpur erstwhile BESUS under CFC/IJSG/21 International Project.

VIEW OF CONDITION OF ROAD BEFORE CONSTRUCTION

CROSS-SECTIONAL DETAILS OF PAVEMENT WITH JUTE GEOTEXTILE



PROPERTIES OF JUTE GEOTEXTILE USED

Type of JGT	Woven
Weight at 20% MR	728 gsm
Width	102 mm
Thickness	2.0 mm
Wide Width Tensile Strength (MD x CD)	25.2 x 25.5 kN/m
Pore Size (O_{90})	182 micron
Elongation at break (MD x CD)	9.1 x 10.9

RESULTS AND DISCUSSION

(a) **CBR values of sub-grade soil before and after 1 year from end of construction**

Natural soil (before laying JGT)	Improved soil after 1 year (2015) with JGT	
Soaked CBR (%)	CBR (%) from DCP Tests	Field CBR (%)
3.8 (at OMC : 15.0% & MDD : 1.76gm/cm^3)	**9**	**16.68** (at FMC : 10.22 % & FD : 1.99gm/cm^3)

FMC* is Field Moisture content & FD** is Field Density

(b) **Visual observations (after 1 year)**

- The riding surface is in good condition with no sign of distresses
- No pot holes or rutting observed.
- Shoulders as well as side slope condition is in good condition without any rain-cuts or settlement at the slope.

VIEW OF LAYING OF JGT & FINISHED CONDITION ROAD

JGT laid over sand

Finished Condition of road after 1 year (2015)

Note : The movement of heavy loaded truck of about 25 – 30 tonnes carrying sand, bricks on this road has increased immensely to about 30-35 passes in a day.

CASE STUDY 11

CONSTRUCTION OF PAVED PMGSY ROAD IN SOUTH 24-PARAGANAS DISTRICT, WEST BENGAL[11]

NAME OF THE ROAD - Bagdimarimulo Barada Nagar to Damkal Kheya Ghat

LOCATION - Mathurapur – II Block of South 24 Paraganas District, West Bengal

YEAR OF APPLICATION - 2013

NAME OF THE CLIENT - Chief Engineer, West Bengal Rural Road Development Agency, Govt. of West Bengal

ROAD LENGTH - 8.724 Km

SITE CONDITION

This was an earthen road with brick pitching under PMGSY Pilot project in plain terrain. The minimum temperature in the month of January varies from 10^0C to 15^0C and the highest temperature registers as the month of May about 42^0C. Average annual rainfall observed as above 1500 mm.

PROPERTIES OF SUB-GRADE SOIL

Test Results as mentioned in DPR	
Soaked CBR	**3.2 %**
Soil type	**CL**
Liquid Limit	42.50 %
Plastic Limit	22.50%
Max Dry Density	1.66 gm/cm^3
Optimum Moisture Content	20.61 %
Sieve Analysis	Percent finer
4.75 mm	100 %
1.18 mm	99.5%
425 micron	98.30 %
75 micron	95.95 %

ESTIMATED COST - Total cost of construction was Rs. 6,02,27,455 out of which cost of JGT was Rs. 41,14,188i.e.about 6.83% of total construction cost.

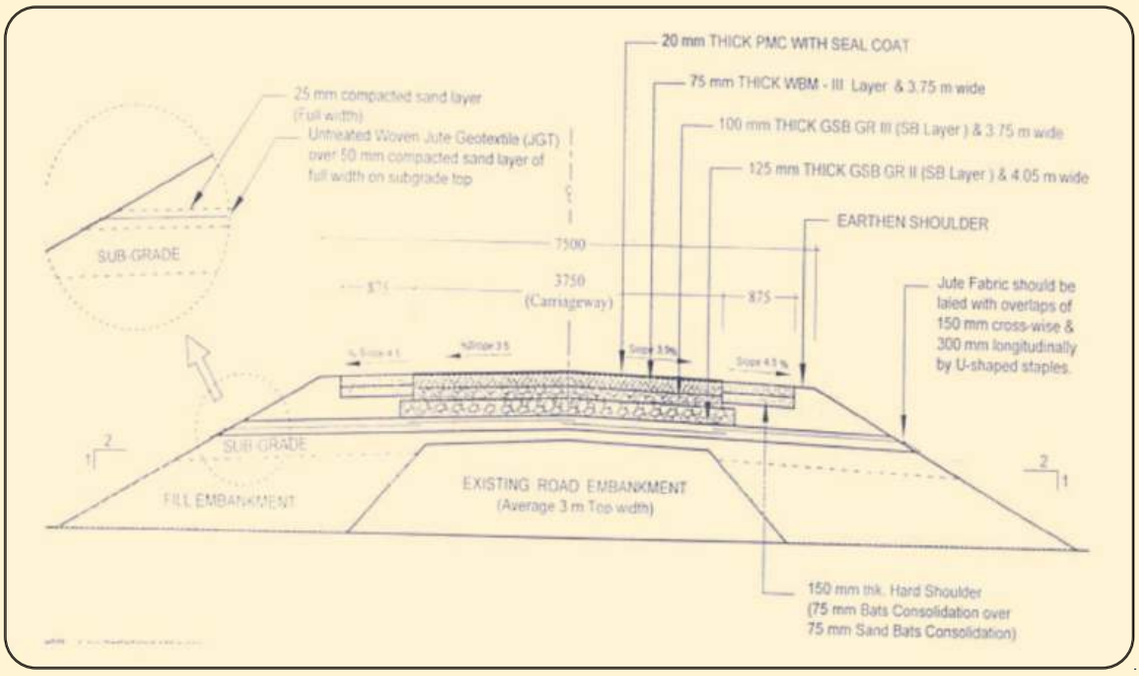
PRE-WORK TRAFFIC STATUS

- Average Daily Traffic (ADT) likely to be 371 in the base year and time period between traffic count & opening of road taken as 2 years.
- Cumulative ESAL over 10 years of design life period @ 6% growth rate which worked out to 64402 conforming to '**T_3 Traffic Category'** as per Low Volume Road Manual IRC:SP:72 – 2007.

11 The performance evaluation is carried out by National Jute Board – JGT Cell with IIEST Shibpur erstwhile BESUS under CFC/IJSG/21 International Project.

VIEW OF CONDITION OF ROAD BEFORE CONSTRUCTION

CROSS-SECTIONAL DETAILS OF PAVEMENT WITH JUTE GEOTEXTILE



PROPERTIES OF JUTE GEOTEXTILE USED

Type of JGT	Woven
Weight at 20% MR	789 gsm
Width	102 mm
Thickness	2.0 mm
Wide Width Tensile Strength (MD x CD)	27.91 x 26.51 kN/m
Pore Size (O_{90})	178 micron
Elongation at break (MD x CD)	5.58 x 7.58

RESULTS AND DISCUSSION

(a) **CBR values of sub-grade soil before and after 1 year from end of construction**

Natural soil (before laying JGT)	Improved soil after 1 year (2015) with JGT	
Soaked CBR (%)	CBR (%) from DCP Tests	Field CBR (%)
3.5 (at OMC : 14.8% & MDD : 1.76 gm/cm^3)	**10**	**7.07** (at FMC : 20.43 % & FD : 1.90gm/cm^3)

FMC* is Field Moisture content & FD** is Field Density

(b) **Visual observations (after 1 year)**

- The riding surface is in good condition with no sign of distresses
- No pot holes or rutting observed.
- Shoulders as well as side slope condition is in good condition without any rain-cuts or settlement at the slope.

VIEW OF LAYING OF JGT & FINISHED CONDITION ROAD

Pegging of overlapped sections of JGT

Finished Condition of road after 1 year (2015)

CASE STUDY 12

CONSTRUCTION OF PAVED PMGSY ROAD IN DAVANAGERE DISTRICT, KARNATAKA[12]

NAME OF THE ROAD - V. KoracharahattitoT-10 Road

LOCATION - Harapanahali Taluk of Davanagere District, Karnataka

YEAR OF APPLICATION - 2013

NAME OF THE CLIENT - Chief Operating Officer, Karnataka Rural Road Development Agency, Govt. of Karnataka

ROAD LENGTH - 2.00 Km constructed with JGT out of 4.03

SITE CONDITION

This was an earthen road under PMGSY Pilot projectin plain terrain. Average annual rainfall observed as above 1300 mm.

PROPERTIES OF SUB-GRADE SOIL

Test Results as mentioned in DPR	
Soaked CBR	4.0%
Soil type	SC
Liquid Limit	36 %
Plastic Limit	17 %
Max Dry Density	1.80 gm/cm^3
Optimum Moisture Content	15 %
Sieve Analysis	Percent finer
Gravel	11.7 %
Sand	13.3 %
Silt & Clay	75 %
425 micron	82 %

ESTIMATED COST : Total cost of construction for 2 km road constructed with JGT was Rs. 73,91,722 out of which cost of JGT was Rs. 5,49,505i.e.about 7.43 % of total construction cost.

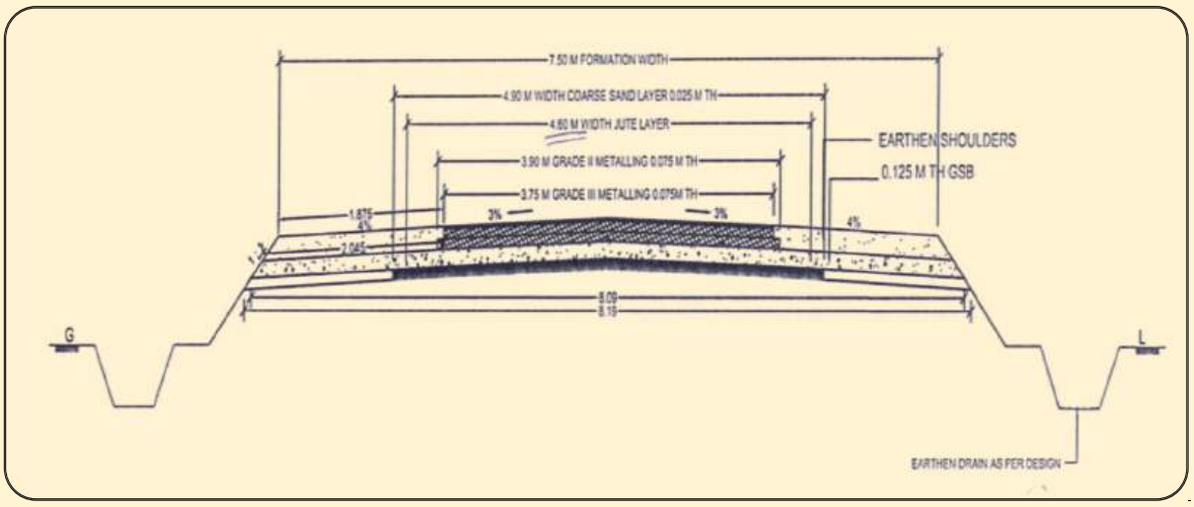
PRE-WORK TRAFFIC STATUS :

- Cumulative ESAL over 10 years of design life period @ 6% growth rate which worked out to 93045conforming to '**T_3 Traffic Category'** as per Low Volume Road Manual IRC:SP:72 – 2007.

12 The performance evaluation is carried out by National Jute Board – JGT Cell with University BD. T. College of Engineering under Visvesvaraya Technological University, Davanagere.

VIEW OF CONDITION OF ROAD BEFORE CONSTRUCTION

CROSS-SECTIONAL DETAILS OF PAVEMENT WITH JUTE GEOTEXTILE



PROPERTIES OF JUTE GEOTEXTILE USED

Type of JGT	Woven
Weight at 20% MR	755 gsm
Width	132.5 mm
Thickness	1.82 mm
Wide Width Tensile Strength (MD x CD)	26.4 x 25.1 kN/m
Pore Size (O_{90})	213 micron
Elongation at break (MD x CD)	10.9 x 9.2
Bursting Strength	3250 kPa
Puncture Resistance	0.505 kN
Permittivity	740 x 10^{-3} /sec

RESULTS AND DISCUSSION

(a) **CBR values of sub-grade soil before and after $1^{1/2}$ year from end of construction in control section (without JGT) & JGT treated section**

Natural soil (before laying JGT)	Improved soil after $1^{1/2}$ year (2015)	
Soaked CBR (%)	Soaked CBR (%) in Control section	Soaked CBR (%) in JGT treated section
4.0 (at OMC : 15.0% & MDD : 1.8gm/cm^3)	**10.8** (at OMC : 15.3 % & MDD : 1.83gm/cm^3)	**12.2** (at OMC : 14.8 % & MDD : 1.88 kg/m^3)

(b) **Visual observations (after 1½ year)**

- The riding surface is in good condition with no sign of distresses
- No pot holes or rutting observed.
- Shoulders as well as side slope condition is in good condition without any rain-cuts or settlement at the slope.

VIEW OF LAYING OF JGT & FINISHED CONDITION ROAD

Laying of JGT

Finished Condition of road after 1½ year (2015)

CASE STUDY 13

CONSTRUCTION OF PAVED PMGSY ROAD IN HAVERI DISTRICT, KARNATAKA[13]

NAME OF THE ROAD - Devarahospet to Gundur Road

LOCATION - Hanagal Taluk of Haveri District, Karnataka

YEAR OF APPLICATION - 2013

NAME OF THE CLIENT - Chief Operating Officer, Karnataka Rural Road Development Agency, Govt. of Karnataka

ROAD LENGTH - 3.00 Km constructed with JGT out of 11.35

SITE CONDITION

This was an earthen road under PMGSY Pilot projectin rolling terrain. Average annual rainfall observed as above 1300 mm.

PROPERTIES OF SUB-GRADE SOIL

Test Results as mentioned in DPR	
Soaked CBR	2.7 %
Soil type	CI
Liquid Limit	45.10 %
Plastic Limit	27.10 %
Max Dry Density	1.65 gm/cm^3
Optimum Moisture Content	18.40 %
Sieve Analysis	Percent finer
Gravel	7.5 %
Sand	20.6 %
Silt & Clay	71.90 %

ESTIMATED COST– Total cost of construction for 3 km road constructed with JGT was approx. Rs. 1,24,77,000 out of which cost of JGT was Rs. 15,00,000 i.e.about 12.02% of total construction cost.

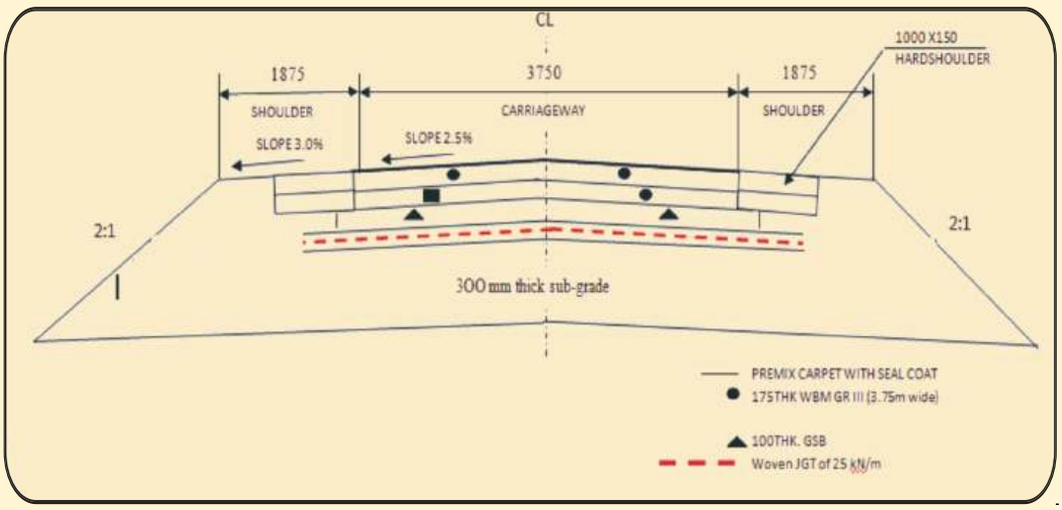
PRE-WORK TRAFFIC STATUS –

- Cumulative ESAL over 10 years of design life period @ 6% growth rate which worked out to 162419.36 conforming to '**T_4 Traffic Category'**as per Low Volume Road Manual IRC:SP:72 – 2007.

13 The performance evaluation is carried out by National Jute Board – JGT Cell with University BD. T. College of Engineering under Visvesvaraya Technological University, Davanagere under CFC/IJSG/21 Project.

VIEW OF CONDITION OF ROAD BEFORE CONSTRUCTION

CROSS-SECTIONAL DETAILS OF PAVEMENT WITH JUTE GEOTEXTILE



PROPERTIES OF JUTE GEOTEXTILE USED

Type of JGT	Woven
Weight at 20% MR	755 gsm
Width	132.5 mm
Thickness	1.82 mm
Wide Width Tensile Strength (MD x CD)	26.4 x 25.1 kN/m
Pore Size (O_{90})	213 micron
Elongation at break (MD x CD)	10.9 x 9.2
Bursting Strength	3250 kPa
Puncture Resistance	0.505 kN
Permittivity	740 x 10^{-3} /sec

RESULTS AND DISCUSSION

(a) **CBR values of sub-grade soil before and after $1^{1/2}$ year from end of construction in control section (without JGT) & JGT treated section**

Natural soil (before laying JGT)	Improved soil after $1^{1/2}$ year (2015)	
Soaked CBR (%)	Soaked CBR (%) in Control section	Soaked CBR (%) in JGT treated section
2.7 (at OMC : 18.4% & MDD : 1.65gm/cm^3)	**12.5** (at OMC : 15.8 % & MDD : 1.878gm/cm^3)	**12.8** (at OMC : 15.2 % & MDD : 1.906 kg/m^3)

(b) **Visual observations (after $1^{1/2}$ year)**

- The riding surface is in good condition with no sign of distresses
- No pot holes or rutting observed.
- Shoulders as well as side slope condition is in good condition without any rain-cuts or settlement at the slope.

VIEW OF LAYING OF JGT & FINISHED CONDITION ROAD

Pegging of JGT

Finished Condition of road after $1^{1/2}$ year (2015)

CASE STUDY 14

CONSTRUCTION OF PAVED PMGSY ROAD IN WEST TRIPURA DISTRICT, TRIPURA[14]

NAME OF THE ROAD - Promod Nagar to Muga Chandra Para

LOCATION - Bishalgarh Block ofWest Tripura District, Tripura

YEAR OF APPLICATION - 2013

NAME OF THE CLIENT - Chief Executing Officer,Tripura Rural Road Development Agency, Govt. of Tripura

ROAD LENGTH - 5.990 Km

SITE CONDITION

This was an earthen road under PMGSY Pilot projectin rolling terrain. Average annual rainfall observed as above 2000 mm.

PROPERTIES OF SUB-GRADE SOIL

Test Results as mentioned in DPR	
Soaked CBR	**7.13%**
Soil type	**Sandy loam to loamy clay**
Max Dry Density	1.843 gm/cm^3
Optimum Moisture Content	14.60 %

ESTIMATED COST – Total cost of construction was Rs. 3,50,05,853 out of which quantity of JGT required was 26,000 sq. meter.

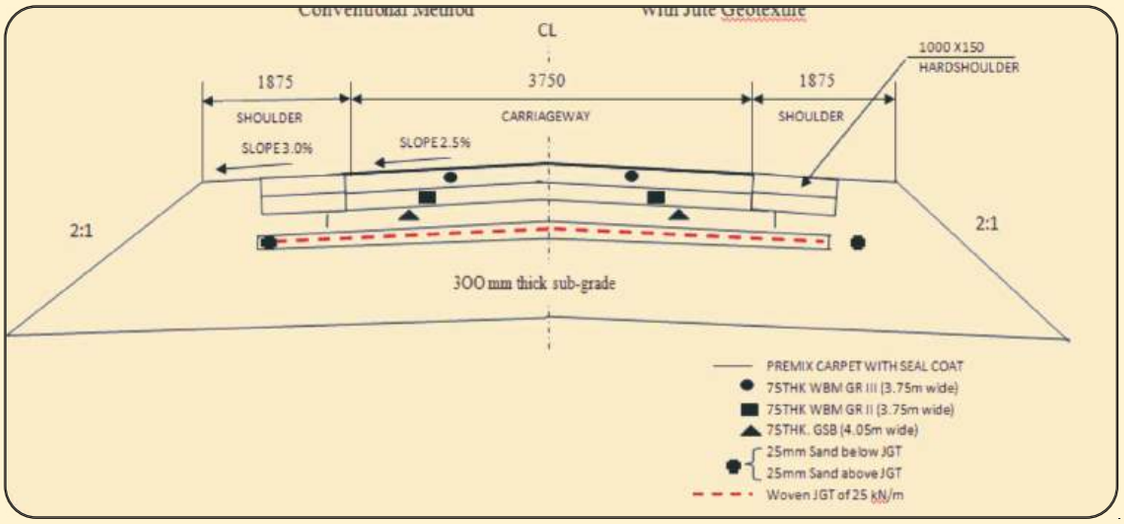
PRE-WORK TRAFFIC STATUS

- Cumulative ESAL over 10 years of design life period @ 6% growth rate conforming to '**T_4 Traffic Category'**as per Low Volume Road Manual IRC:SP:72 – 2007.

VIEW OF CONDITION OF ROAD BEFORE CONSTRUCTION

14 The performance evaluation is carried out by National Jute Board – JGT Cell with North East Soil Testing (NEST), West Tripura) under CFC/IJSG/21 Project.

CROSS-SECTIONAL DETAILS OF PAVEMENT WITH JUTE GEOTEXTILE



PROPERTIES OF JUTE GEOTEXTILE USED

Type of JGT	Woven
Weight at 20% MR	743 gsm
Width	101 mm
Thickness	1.88 mm
Wide Width Tensile Strength (MD x CD)	24.9 x 24.50 kN/m
Pore Size (O_{90})	250 micron
Elongation at break (MD x CD)	13.0 x 9.0
Bursting Strength	25.60 kg/cm^2
Puncture Resistance	0.54 kN
Permittivity	0.35 /sec

RESULTS AND DISCUSSION

(a) **CBR values of sub-grade soil before and after 2year from end of construction**

Natural soil (before laying JGT)	Improved soil after 2 year (2015)
Soaked CBR (%)	Soaked CBR (%) in JGT treated section
7.13 (at OMC : 14.60% & MDD : 1.843gm/cm^3)	**10.42** (at OMC : 13.82 % & MDD : 1.87 g/cm^3)

(b) **Visual observations (after 2 year)**

- The riding surface is in good condition with no sign of distresses
- No pot holes or rutting observed.
- Shoulders as well as side slope condition is in good condition without any rain-cuts or settlement at the slope.

VIEW OF LAYING OF JGT & FINISHED CONDITION ROAD

Laying of JGT

Finished Condition of road after 2 years (2015)

CASE STUDY 15

WIDENING OF MAJOR DISTRICT ROAD IN WEST TRIPURA DISTRICT, TRIPURA[15]

NAME OF THE ROAD - Agartala – Mohanpur – Chebri Road

LOCATION - West Tripura District, Tripura

YEAR OF APPLICATION - 2007

NAME OF THE CLIENT - Chief Engineer, Roads & Building, Govt. of Tripura

ROAD LENGTH - 200 metre

SITE CONDITION

The road was widened 1.75 metreon both the sides and JGT was applied on subgrade-sub base interface as well as in sub base-base course interface as an experimental study in widened left hand portion.

PROPERTIES OF SUB-GRADE SOIL

Test Results as mentioned in DPR	
Soaked CBR	4.8 – 5.6%
Soil type	Clayey Sandy silt / Silty sand
Optimum Moisture Content	11.50 – 13.5 %
Field Dry Density	1.65 – 1.96 T/m^3
Field Moisture Content	10.81 – 22.02 %
Liquid Limit	24 – 29%
Plastic Limit	12.5 – 16.8 %
Sand	35 – 55 %
Silt	20 – 50 %
Clay	3 – 30 %
Soil Permeability	2.34 – 4.39 x 10^{-4} cm/sec

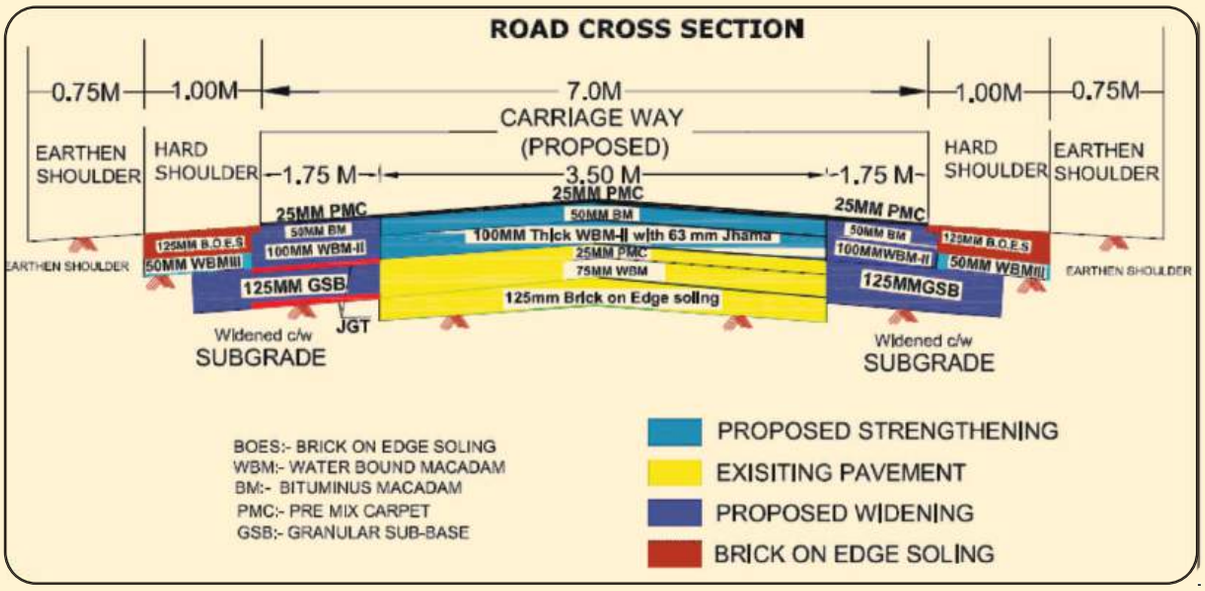
PRE-WORK TRAFFIC STATUS

- The road was designed on Cumulative ESAL over 10 years of design life period @ 7.5% growth rate conforming to 1 msaas per specifications of IRC:SP:37 – 200, Plate – 1.

15 The performance evaluation is carried out by Civil Engineering Consultancy Services Pvt. Ltd. Kolkata).

VIEW OF CONDITION OF ROAD BEFORE CONSTRUCTION

CROSS-SECTIONAL DETAILS OF PAVEMENT WITH JUTE GEOTEXTILE



PROPERTIES OF JUTE GEOTEXTILE USED

Type of JGT	Woven
Weight at 20% MR	790 gsm
Thickness	1.72 mm
Wide Width Tensile Strength (MD x CD)	45.1 x 21.3 kN/m
Pore Size (O_{90})	180 micron
Elongation at break (MD x CD)	5.74 x 4.69
Bursting Strength	679 kN/m^2
Puncture Resistance	0.62 kN
Permittivity	0.18 /sec

RESULTS AND DISCUSSION

(a) Benkelman Beam Deflection Tests have been conducted as per IRC:81-1997 on both control & JGT treated sections

Table 1 - Comparative Study of Deflection in the Pavement after 32 (Thirty Two) Days of Carpeting

Stretch	Characteristic Deflection (mm)		Percent of Reduction Of Deflection In LHS Than RHS (%)
	LHS	RHS	
I	0.624	3.175	80.34
II	0.617	3.208	80.76
III	0.636	0.146	-

NR-Not Required, RHS is control section and LHS is JGT treated portion

Table 2 - Comparative Study of Deflection in the Pavement after 60 (Sixty) Days of Carpeting

Stretch	Characteristic Deflection (mm)		Percent of Reduction Of Deflection In LHS Than RHS (%)
	LHS	RHS	
I	0.646	3.197	79.78
II	0.628	3.253	80.68
III	0.635	0.164	-

NR-Not Required, RHS is control section and LHS is JGT treated portion

Table 3 - Determination of Overlay Thickness after 32 (Thirty Two) Days of Carpeting

Stretch	Road Side	Characteristic Deflection (mm)	Design Overlay Thickness (mm)(Ref. IRC 81,1997, Fig.9)
			For 1.0 msa
I	LHS	0.624	NR
	RHS	3.175	145
II	LHS	0.617	NR
	RHS	3.208	145
II	LHS	0.636	NR
	RHS	0.146	NR

NR-Not Required,RHS is control section and LHS is JGT treated portion

Table 4 - Determination of Overlay Thickness after 60 (Sixty) Days of Carpeting

Stretch	Road Side	Characteristic Deflection (mm)	Design Overlay Thickness (mm)(Ref. IRC 81,1997, Fig.9)
			For 1.0 msa
I	LHS	0.646	NR
	RHS	3.197	145
II	LHS	0.628	NR
	RHS	3.253	150
II	LHS	0.635	NR
	RHS	0.164	NR

NR-Not Required, RHS is control section and LHS is JGT treated portion

(b) Determination of FDD & FMC after two years of carpeting

Stretch Designation	JGT treated section				Control section			
	FDD Just Before Construction	FDD Just After Two years of Construction	FMC Just Before Construction	FMC Just After Two years of Construction	FDD Just Before Construction	FDD Just After Two years of Construction	FMC Just Before Construction	FMC Just After Two years of Construction
Stretch I	1.67	1.79	16.49	13.91	1.67	1.69	22.00	20.48
Stretch II	1.65	1.79	21.14	17.05	1.67	1.70	18.12	17.56
Stretch III	1.66	1.73	13.09	12.14	1.96	1.98	11.75	10.97

Stretch Designation	**JGT treated section**		**Control section**		**Net % Increment of FDD Due to Contribution of JGT**	**Net % Decrease of FMC Due to Contribution of JGT**
	Net % Increment of FDD	**Net % Decrease of FMC**	**Net % Increment of FDD**	**Net % Decrease of FMC**		
Stretch I	6.70	15.60	1.18	6.90	5.52	8.70
Stretch II	7.80	19.34	1.76	3.00	6.04	16.34
Stretch III	4.04	7.30	1.01	6.60	3.03	0.70

FMC* is Field Moisture content & FDD** is Field Dry Density

VIEW OF LAYING OF JGT & FINISHED CONDITION ROAD

Laying of JGT in widened portion

Finished Condition of road after 2 years (2010)

CASE STUDY 16

CONSTRUCTION OF PAVED ROAD IN SATKHIRA DISTRICT,BANGLADESH[16]

NAME OF THE ROAD - Noabenki-Gazerhat-Harihajanhat Road

LOCATION - Shymangar Upzilla ,Satkhira District, Bangladesh

YEAR OF APPLICATION - 2012

NAME OF THE CLIENT - Roads & Highways Department (RHD), Bangladesh

ROAD LENGTH - 1 Km

SITE CONDITION

This was an earthen road in plain terrain. Average annual rainfall observed as above 2000 mm.

PROPERTIES OF SUB-GRADE SOIL

Test Results as mentioned in DPR	
Soaked CBR	0.3 – 1.1%
Soil type	CH
Max Dry Density	15.76 kN/m^3
Optimum Moisture Content	20.1 %
Liquid Limit	58 %
Plastic Limit	36%
Sand	3 %
Silt	57 %
Clay	40 %
% Finer 0.075 mm sieve	97.8 %

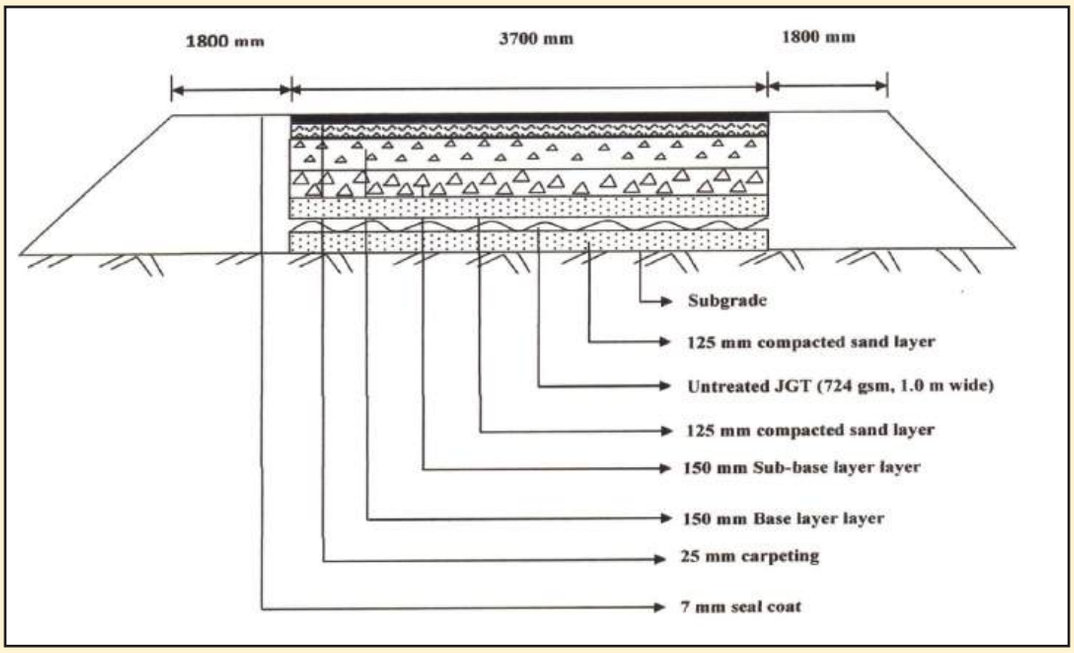
PRE-WORK TRAFFIC STATUS

- Annual Average Daily Traffic (AADT) - 450

VIEW OF CONDITION OF ROAD BEFORE CONSTRUCTION

16 The performance evaluation is carried out by Bangladesh University of Engineering and Technology (BUET)under CFC/IJSG/21 International Project.

CROSS-SECTIONAL DETAILS OF PAVEMENT WITH JUTE GEOTEXTILE



PROPERTIES OF JUTE GEOTEXTILE USED

Type of JGT	Woven
Weight at 20% MR	830 gsm
Thickness	2.43 mm
Wide Width Tensile Strength (MD x CD)	34 x 27 kN/m
Pore Size (O_{90})	100 micron
Elongation at break (MD x CD)	10.0 x 16.0
Bursting Strength	25.60 kg/cm^2
Puncture Resistance	0.43 kN
Vertical Permeability (2 kN/m^2)	2.3 x 10^{-3} m/sec

RESULTS AND DISCUSSION

(a) **CBR values of sub-grade soil before and after 6monthsfrom end of construction**

CBR (%) before laying JGT	Improved soil after 6 months (2013) in JGT treated section
Field CBR :**2.6 %** **Soaked CBR : 2.1 %**	Field CBR :**3.6 %** **Soaked CBR : 2.7 %**

(b) **Visual observations (after 6 months)**

- The riding surface is in good condition with no sign of distresses
- No pot holes or rutting observed.
- Shoulders as well as side slope condition is in good condition without any rain-cuts or settlement at the slope.

VIEW OF LAYING OF JGT & FINISHED CONDITION ROAD

ROAD SITE-NOABENKI-GAZERHAT-HARIHAJHANHAT ROAD

Construction Started in July, 2012

Construction Completed in July, 2013

Fig: Pre-work Condition of the road

Fig: Laying of JGT

Fig: Conducting field CBR test during 1st monitoring

Fig: Condition of JGT during 1st monitoring

Fig: Performing Field density test during 2nd monitoring

Fig: Condition of JGT during 2nd monitoring

CASE STUDY 17

CONSTRUCTION OF PAVED ROAD IN NARAIL DISTRICT, BANGLADESH[17]

NAME OF THE ROAD - Sairbor GC to Mithapur GC via Lahuria Bazar Road

LOCATION - Lohagara Upzilla, Narail District, Bangladesh

YEAR OF APPLICATION - 2012

NAME OF THE CLIENT - Local Government Engineering Department (LGED), Bangladesh

ROAD LENGTH - 1 Km

SITE CONDITION

This was an earthen road in plain terrain. Average annual rainfall observed as above 1567mm.

PROPERTIES OF SUB-GRADE SOIL

Test Results as mentioned in DPR	
Soaked CBR	**0.8 – 1.7%**
Soil type	**CH**
Max Dry Density	14.37 kN/m^3
Optimum Moisture Content	23.4 %
Liquid Limit	69 %
Plastic Limit	43%
Sand	1 %
Silt	44 %
Clay	55 %
% Finer 0.075 mm sieve	99.3%

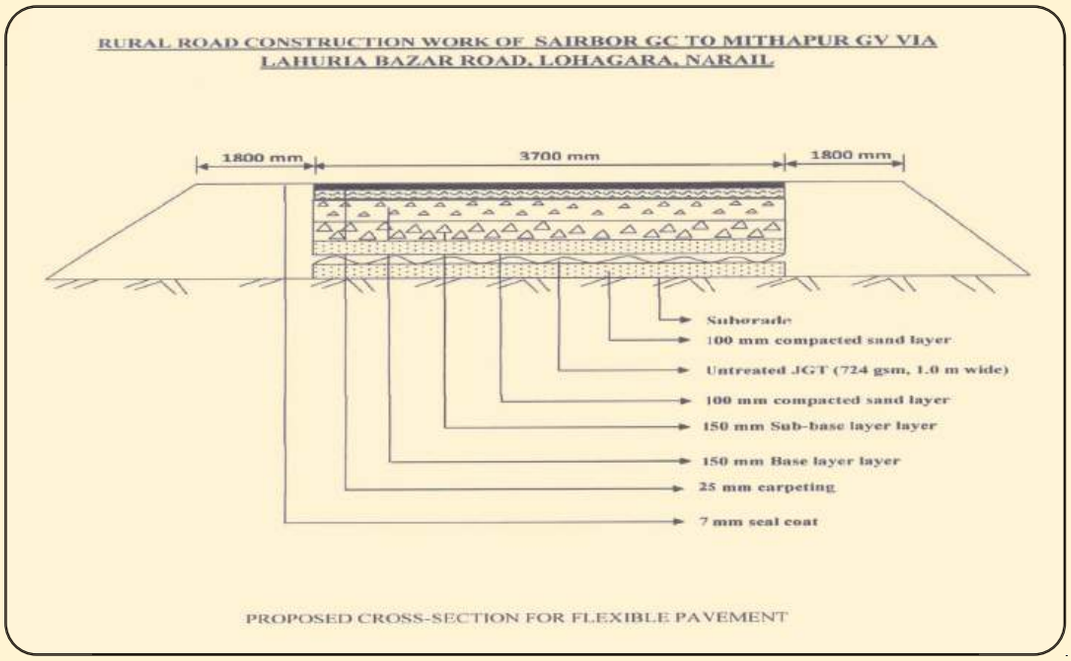
PRE-WORK TRAFFIC STATUS

- Annual Average Daily Traffic (AADT) - 475

VIEW OF CONDITION OF ROAD BEFORE CONSTRUCTION

17 The performance evaluation is carried out by Bangladesh University of Engineering and Technology (BUET)under CFC/IJSG/21 International Project.

CROSS-SECTIONAL DETAILS OF PAVEMENT WITH JUTE GEOTEXTILE



PROPERTIES OF JUTE GEOTEXTILE USED

Type of JGT	Woven
Weight at 20% MR	830 gsm
Thickness	2.43 mm
Wide Width Tensile Strength (MD x CD)	34 x 27 kN/m
Pore Size (O_{90})	100 micron
Elongation at break (MD x CD)	10.0 x 16.0
Bursting Strength	25.60 kg/cm^2
Puncture Resistance	0.43 kN
Vertical Permeability (2 kN/m^2)	2.3 x 10^{-3} m/sec

RESULTS AND DISCUSSION

(a) **CBR values of sub-grade soil before and after 1month from end of construction**

CBR (%) before laying JGT	Improved soil after 1 month (2014)	
	Control section	JGT treated section
Soaked CBR : **0.8 – 1.7%**	Soaked CBR : **1.5 %** OMC : **15.09 %** MDD : **16.66 kN/m^3**	Soaked CBR : **3.5 %** OMC : **15.09 %** MDD : **16.66 kN/m^3**

(b) **Visual observations (after 6 months)**

- The riding surface is in good condition with no sign of distresses
- No pot holes or rutting observed.
- Shoulders as well as side slope condition is in good condition without any rain-cuts or settlement at the slope.

VIEW OF LAYING OF JGT & FINISHED CONDITION ROAD

ROAD SITE-NOABENKI-GAZERHAT-HARIHAJHANHAT ROAD

Construction Started in July, 2012

Construction Completed in July, 2013

Fig: Pre-work Condition of the road

Fig: Laying of JGT

Fig: Conducting field CBR test during 1st monitoring

Fig: Condition of JGT during 1st monitoring

Fig: Performing Field density test during 2nd monitoring

Fig: Condition of JGT during 2nd monitoring

ROAD SITE-SAIRBOR GC TO MITHAPUR GV VIA LAHURIA BAZAR ROAD, LOHAGARA, NARAIL

Construction started in February, 2013
Construction completed in March, 2014

Fig : Finished subgrade

Fig: Condition of road during 1st monitoring

Fig: Field Density test during 1st monitoring

Fig: Condition of road during 2nd monitoring

Fig: Field density test during 2nd monitoring

Fig: Condition of JGT during 2nd monitoring

CASE STUDY 18

CONSTRUCTION OF PAVED ROAD IN DHAKA DISTRICT, BANGLADESH[18]

NAME OF THE ROAD - Turag – Rohitpur – Baurvita Road

LOCATION - Keraniganj Upzilla , Dhaka District, Bangladesh

YEAR OF APPLICATION - 2011

NAME OF THE CLIENT - Roads & Highways Department (RHD), Bangladesh

ROAD LENGTH - 487 metre

SITE CONDITION

This was an earthen road in plain terrain. Average annual rainfall observed as above 2098 mm.

PROPERTIES OF SUB-GRADE SOIL

Test Results as mentioned in DPR	
Soaked CBR	**4.5 – 6.0 %**
Soil type	**SP**
Max Dry Density	15.50 kN/m^3
Optimum Moisture Content	19.1 %
Liquid Limit	NP
Plastic Limit	NP
Sand	-
Silt	-
Clay	-
% Finer 0.075 mm sieve	13.9%

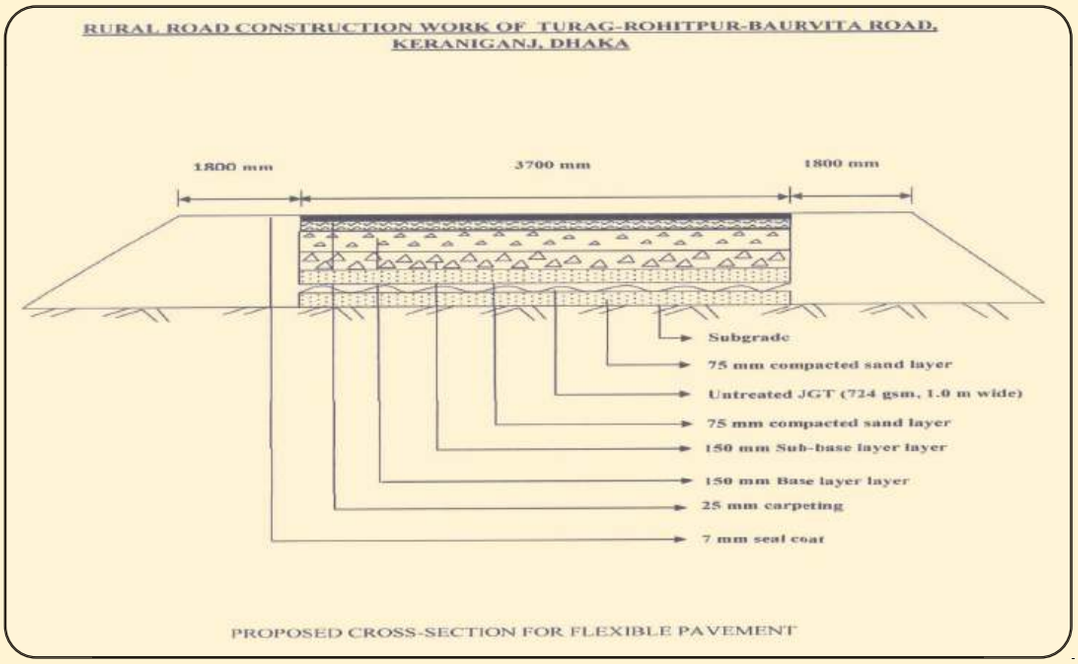
PRE-WORK TRAFFIC STATUS –

- Annual Average Daily Traffic (AADT) - 10970

VIEW OF CONDITION OF ROAD BEFORE CONSTRUCTION

18 The performance evaluation is carried out by Bangladesh University of Engineering and Technology (BUET)under CFC/IJSG/21 International Project.

CROSS-SECTIONAL DETAILS OF PAVEMENT WITH JUTE GEOTEXTILE



PROPERTIES OF JUTE GEOTEXTILE USED

Type of JGT	Woven
Weight at 20% MR	830 gsm
Thickness	2.43 mm
Wide Width Tensile Strength (MD x CD)	34 x 27 kN/m
Pore Size (O_{90})	100 micron
Elongation at break (MD x CD)	10.0 x 16.0
Bursting Strength	25.60 kg/cm^2
Puncture Resistance	0.43 kN
Vertical Permeability (2 kN/m^2)	2.3 x 10^{-3} m/sec

RESULTS AND DISCUSSION

(a) **CBR values of sub-grade soil before and after 2 years from end of construction**

CBR (%) before laying JGT	Improved soil after2 years(2013)
	JGT treated section
Soaked CBR **: 2.1 %** Field CBR **: 3 %**	Soaked CBR **: 4.1 %** Field CBR : **12.0** %

(b) **Visual observations (after 2 years)**

- The riding surface is in good condition with no sign of distresses
- No pot holes or rutting observed.
- Shoulders as well as side slope condition is in good condition without any rain-cuts or settlement at the slope.

VIEW OF DURING CONSTRUCTION & FINISHED CONDITION ROAD

CASE STUDY 19

CONSTRUCTION OF PAVED ROAD IN BRAHMANBARIA DISTRICT, BANGLADESH[19]

NAME OF THE ROAD - Bishnurampur-Tezkhali-Titas River Ghat Road

LOCATION - Bancharampur Upzilla , Brahmanbaria District, Bangladesh

YEAR OF APPLICATION - 2012

NAME OF THE CLIENT - Local Government Engineering Department (LGED), Bangladesh

ROAD LENGTH - 405metre

SITE CONDITION

This was an earthen road in plain terrain. Average annual rainfall observed as above 2551mm.

PROPERTIES OF SUB-GRADE SOIL

Test Results as mentioned in DPR	
Soaked CBR	**1.7 – 3.7%**
Soil type	**ML**
Max Dry Density	15.590 kN/m^3
Optimum Moisture Content	18.7 %
Liquid Limit	41 %
Plastic Limit	14 %
Sand	11 %
Silt	75 %
Clay	14 %
% Finer 0.075 mm sieve	95%

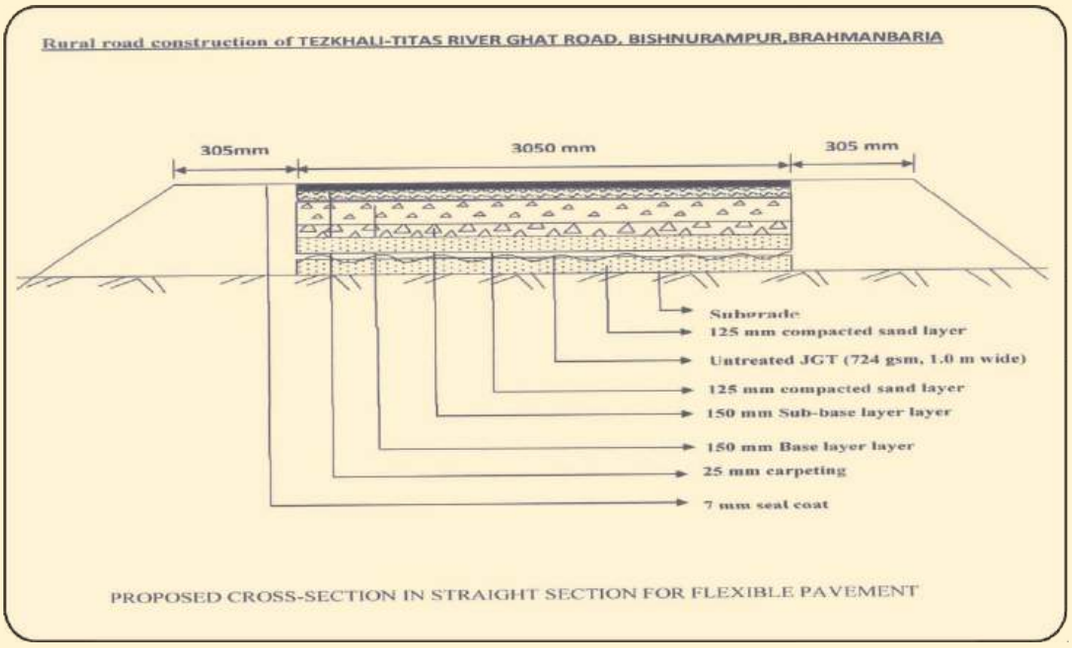
PRE-WORK TRAFFIC STATUS

- Annual Average Daily Traffic (AADT) :>450

VIEW OF CONDITION OF ROAD BEFORE CONSTRUCTION

19 The performance evaluation is carried out by Bangladesh University of Engineering and Technology (BUET)under CFC/IJSG/21 International Project.

CROSS-SECTIONAL DETAILS OF PAVEMENT WITH JUTE GEOTEXTILE



PROPERTIES OF JUTE GEOTEXTILE USED

Type of JGT	Woven
Weight at 20% MR	830 gsm
Thickness	2.43 mm
Wide Width Tensile Strength (MD x CD)	34 x 27 kN/m
Pore Size (O_{90})	100 micron
Elongation at break (MD x CD)	10.0 x 16.0
Bursting Strength	25.60 kg/cm^2
Puncture Resistance	0.43 kN
Vertical Permeability (2 kN/m^2)	2.3 x 10^{-3} m/sec

RESULTS AND DISCUSSION

(a) **CBR values of sub-grade soil before and after 1 year from end of construction**

CBR (%) before laying JGT	Improved soil after1 year(2013)
	JGT treated section
Soaked CBR : **2.5 %** Field CBR : **3.3 %**	Soaked CBR : **8.1 %** Field CBR : **14.0** %

(b) **Visual observations (after 1 year)**

- The riding surface is in good condition with no sign of distresses
- No pot holes or rutting observed.
- Shoulders as well as side slope condition is in good condition without any rain-cuts or settlement at the slope.

VIEW OF LAYING OF JGT & FINISHED CONDITION ROAD

CASE STUDY 20

CONSTRUCTION OF PAVED ROAD IN DHAKA DISTRICT, BANGLADESH[20]

NAME OF THE ROAD - Circular Road at Savar Cantonment

LOCATION - Savar Upzilla , Dhaka District, Bangladesh

YEAR OF APPLICATION - 2012

NAME OF THE CLIENT - Local Government Engineering Department (LGED), Bangladesh

ROAD LENGTH - 1000 metre

SITE CONDITION

This was an earthen road in plain terrain. Average annual rainfall observed as above 2540 mm.

PROPERTIES OF SUB-GRADE SOIL

Test Results as mentioned in DPR	
Soaked CBR	**0.6 – 3.3%**
Soil type	**CH**
Max Dry Density	16.22 kN/m^3
Optimum Moisture Content	20.8 %
Liquid Limit	57 %
Plastic Limit	38 %
Sand	9 %
Silt	50 %
Clay	41 %
% Finer 0.075 mm sieve	95.4%

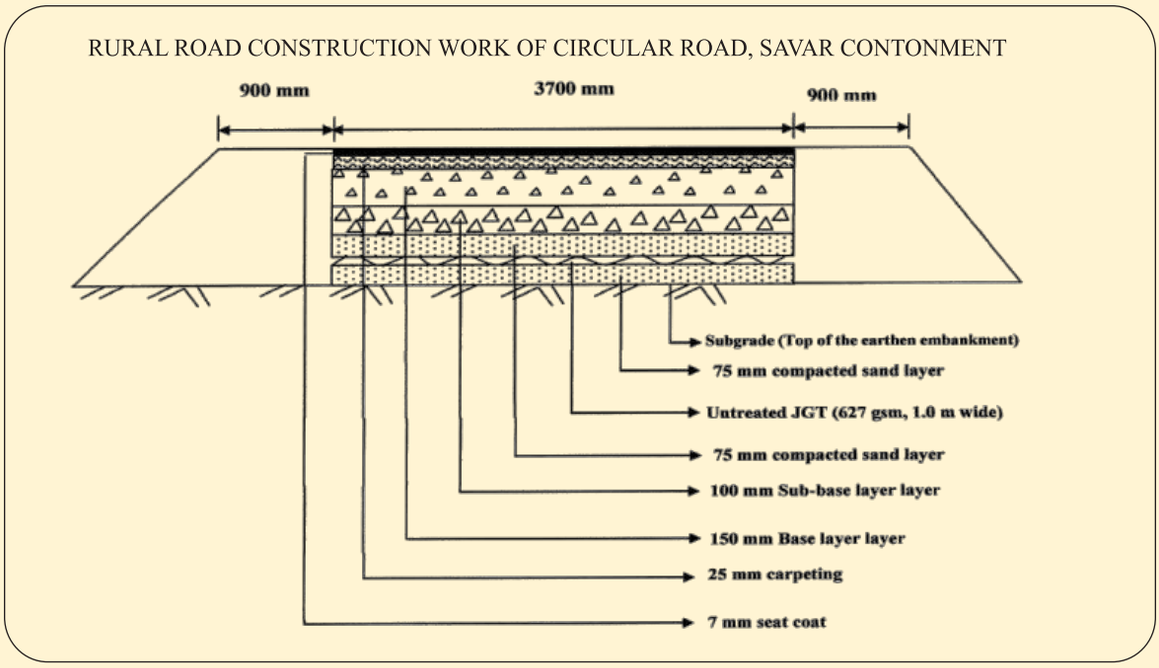
PRE-WORK TRAFFIC STATUS

- Annual Average Daily Traffic (AADT) : >450

VIEW OF CONDITION OF ROAD BEFORE CONSTRUCTION

20 The performance evaluation is carried out by Bangladesh University of Engineering and Technology (BUET) under CFC/IJSG/21 International Project.

CROSS-SECTIONAL DETAILS OF PAVEMENT WITH JUTE GEOTEXTILE



PROPERTIES OF JUTE GEOTEXTILE USED

Type of JGT	Woven
Weight at 20% MR	830 gsm
Thickness	2.43 mm
Wide Width Tensile Strength (MD x CD)	34 x 27 kN/m
Pore Size (O_{90})	100 micron
Elongation at break (MD x CD)	10.0 x 16.0
Bursting Strength	25.60 kg/cm^2
Puncture Resistance	0.43 kN
Vertical Permeability (2 kN/m^2)	2.3 x 10^{-3} m/sec

RESULTS AND DISCUSSION

(a) **CBR values of sub-grade soil before and after 1 year from end of construction**

CBR (%) before laying JGT	Improved soil after1 year(2014)
	JGT treated section
Soaked CBR **: 0.3 – 3.3%**	Soaked CBR **: 8.1 %**
	Field CBR : **14.0** %

(b) **Visual observations (after 1 year)**

- The riding surface is in good condition with no sign of distresses
- No pot holes or rutting observed.
- Shoulders as well as side slope condition is in good condition without any rain-cuts or settlement at the slope.

VIEW OF LAYING OF JGT & FINISHED CONDITION ROAD

CASE STUDY 21

ARRESTING CRACK & POTHOLES OF RURAL ROAD UNDER PMGSY WITH USE OF JGT AT NADIA, WEST BENGAL[21]

NAME OF THE ROAD - Thansara to Bhandarkona Road, Haringhata Block, Nadia

LOCATION - Haringhata Block, Kalyani, Nadia, West Bengal

YEAR OF APPLICATION - 2023

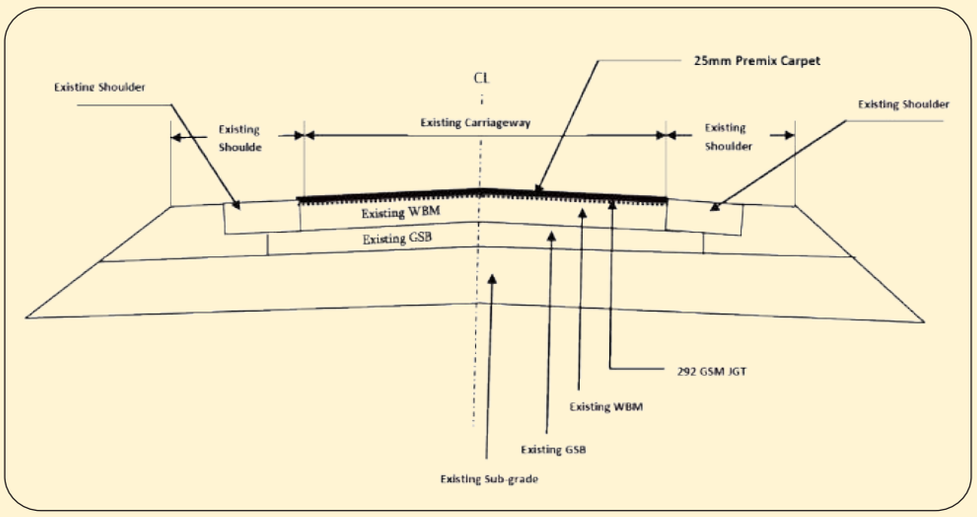
NAME OF THE CLIENT - West Bengal State Rural Development Agency (WBSRDA), Nadia District, West Bengal

ROAD LENGTH - **2.76** Km

SITE CONDITION

The road had shown endless potholes, reflective cracks, distress, eroded flank on either side etc. Average annual rainfall observed as above 1300 mm.

CROSS-SECTIONAL DETAILS OF PAVEMENT WITH JUTE GEOTEXTILE



VIEW OF CONDITION OF ROAD BEFORE CONSTRUCTION

21 Prework and postwork observations were conducted by West Bengal State Rural Development Agency, Govt. of West Bengal

PROPERTIES OF JUTE GEOTEXTILE USED

Type of JGT	Open weave JGT
Weight (g/m2) at 20% M.R.	292
Ends x Picks / dm (MD x CD)	12 x 12
Thickness (mm)	3
Width (cm)	132
Aperture size (mm)	8 x 7
Tensile Strength, min. (kN/m) [MD x CD]	10 x 10
Elongation at break, max.(%) [MD x CD]	12 x 12

WORK DONE:

- The existing pot holes were made good and cracks were sealed by stone materials.
- Earth filling were done on the damaged shoulders and rammed. Dust and dirt present on the existing surface was cleaned by blowing air.
- Then a layer of prime coat @ 0.250 kg/ sq.m. was spread on the road surface followed by spreading of tack coat 0.225 @ kg/sq.m.
- The 132 cm wide JGT was then laid along the length of the road and the 2nd length cloth was laid parallel to the 1st cloth with an overlapping of 10 cm. The 3rd length of cloth would be laid in similar way to cover the entire width of road (carriage way).
- The fabrics were fixed on the road surface by pegging with 2" iron nail at an interval of 1m along and across the fabric.
- 2nd dose of prime coat followed by tack coat at similar rate was applied on JGT.
- Then a hot mix bituminized pre- mix carpet was spread in order to achieve 20 mm compacted thicknesses. Temp. of the premix carpet material was checked to be 110 degree centigrade.
- The PMC laid was then compacted with 10 MT roller to get required compaction and thickness.
- The road surface was finished by spreading hot stone grits.

VIEW OF LAYING OF JGT & FINISHED CONDITION ROAD

Repaired surface of damaged road

Road Signage

Laying of JGT

Spreading Prime & Tack Coat on JGT

Premix Carpeting on one side of carriage way

Spreading Prime & Tack Coat on JGT

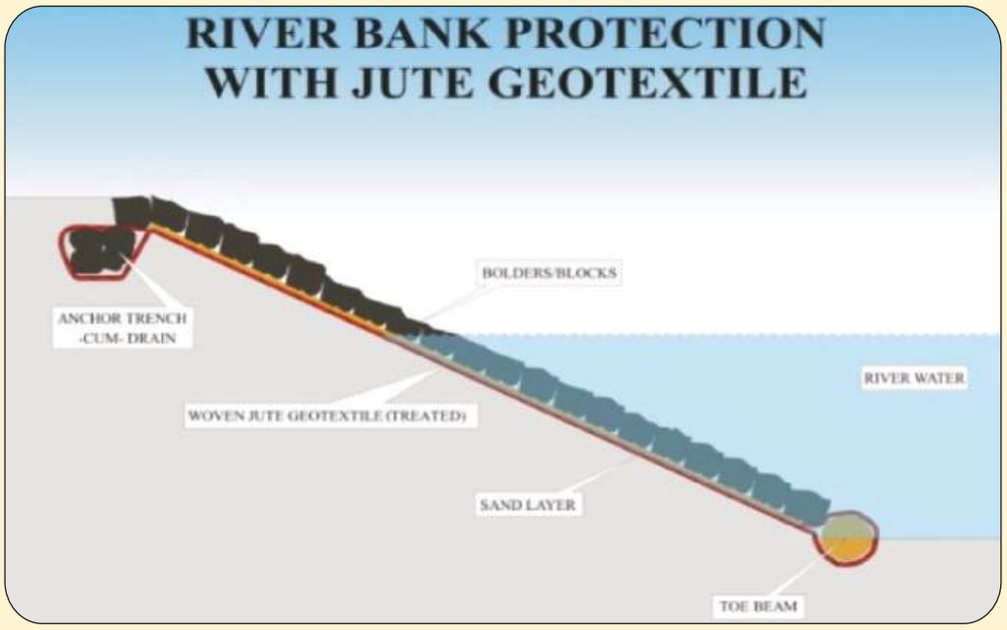
Pre-mix Carpeting

Finished Road

RESULTS AND DISCUSSION

The riding surface is in good condition with no sign of distresses observed after 3 months of application. The same type of JGT applications had already been successfully carried out in 7 Roads under Uttar Pradesh Rural Road Development Agency (UPRRDA) in past. Use of JGT helps to enhance durability of roads as well as reduce maintenance cost of the road in the long run. JGT is found to be effective in arresting reflection cracks and potholes on the riding surface of the road. JGT will provide additional tension capacity which will be effective in reducing rutting of the surface as well as JGT layer will perform as crack relief layer and act as stress reliever through stress distribution.

APPLICATION IN RIVER BANK EROSION CONTROL



CASE STUDY 1

RIVER BANK EROSION CONTROL AT RIVER HUGLI[22]

NAME OF THE RIVER - River Hugli

LOCATION - Nayachara Island (21 miles away from face of Bay of Bengal), East Medinipur, West Bengal

AFFECTED BANK - Eroded Western Bank of Nayachara Island

YEAR OF APPLICATION - 1990

NAME OF THE CLIENT - Kolkata Port Trust, WB

PROBLEM - Fast deteriorating Haldia channel on account of spatial advancement of Jiggerkhali flat inside the channel together with erosion of the western bank of the island upto a stretch of 2 km from north.

AREAOF AFFECTED PORTION TREATED - 3000 m^2

SITE CONDITION - In this region, erosion is most pronounced just after freshnets when upland discharge is its peak, especially in the months of August and September. Bank erosion during this period caused due to wind-induced waves.

TYPE OF FLOW - Two-way flow / Tidal (Semi-diurnal)

GEOHYDROLOGICAL DATA

Highest Flood level	6.50m
Lowest Low water level	(-) 0.71m
Velocity (average) of flow	3m/sec
Waves	Wind generated waves of maximum 1.6m high of periodicity 6 – 8 secs.
Water quality	Saline (Salinity ranges from 6ppt during fresh-nets to 18 ppt in post-freshnet season)
Tides	Semi diurnal with periodicity of 12.42 hours. Avg flood period – 5 hours
Rate of erosion	150 m in the course of 7 years

TYPE OF BANK SOIL - Silty-clay with organic matter content within range of 0.5 % - 2 % .

22 Post work observations were conducted by Hydraulic Study Department, Kolkata Port Trust, West Bengal.
NB: Bituminized JGT was supplied by IJIRA free of cost under UNDP Project

VIEW OF ERODED RIVER BANK

REMEDIAL MEASURE

For preventing of migration of soil particles from the bank and also for providing escape routes for 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 tried.

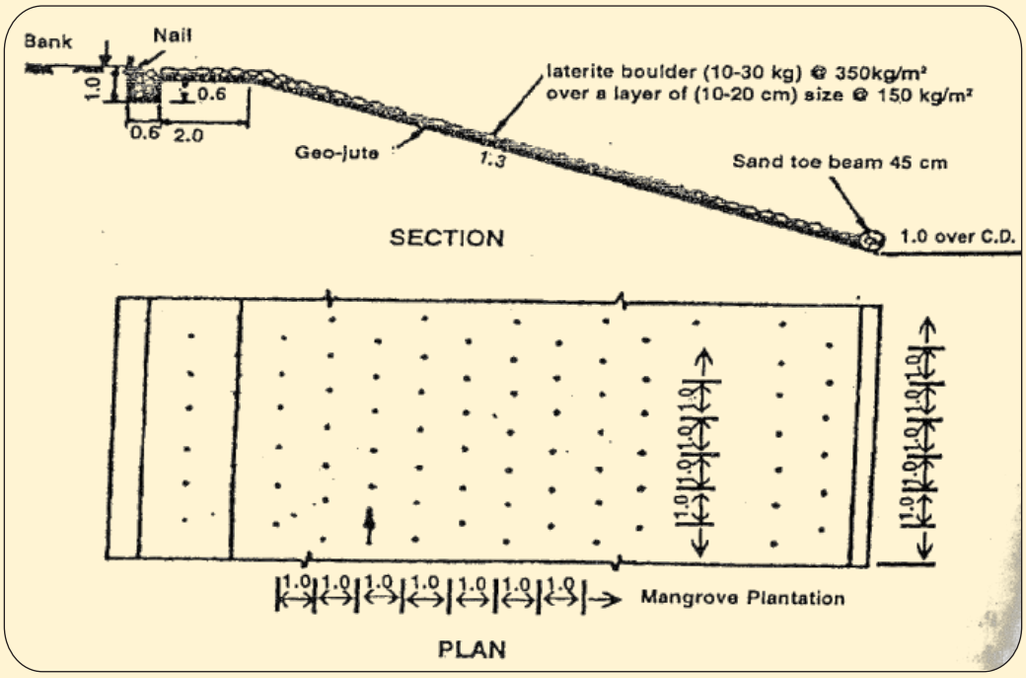
PROPERTIES OF JUTE GEOTEXTILE USED

Weight of grey JGT (gm/sqm)	850
Weight of bituminized JGT (gm/sqm)	1538
Thickness (mm)	2.83
Breaking Strength (kN/m) (MD x CD)	33.08 x 28.21
Elongation at break (%) (MD x CD)	11.8 x 13.5
Pore size (O_{90}) (micron)	150
Threads/dm (MD x CD)	102 x 39
Puncture resistance (kgf/sq.cm)	37.9
Air permeability ($m^3/m^2/min$)	16.2
Water permeability at 10 cm water column ($l/m^2/sec$)	20.4

DETAILS OF ARMOUR USED

Bituminized Woven Jute Geotextile (JGT) overlain by different varieties of mangrove plantation as the outer protective cover.

CROSS-SECTIONAL ELEVATION & PLAN FOR BANK WITH JUTE GEOTEXTILE



VIEW DURING LAYING OF JGT

RESULTS AND DISCUSSION

- Entire stretch of JGT treated portion is in good shape with no distresses observed even after 2 decades.
- Even in high tidal fluctuations and high salinity, JGT worked satisfactorily.
- Submerged granular spurs were constructed at some places for neutralizing effects of eddies at the bank toe.
- The growth of mangrove seedlings planted through JGT could not rise above the thickness of sediment deposited on the bank implying that the rate of growth of mangrove seedlings was less than siltation rate at the particular location.

VIEW OF CONDITION RIVERBANK AFTER TWO DECADES OF JGT APPLICATION

CASE STUDY 2

RIVER BANK EROSION CONTROL AT RIVER BIDYA[23]

RIVERNAME - River Bidya

LOCATION - Rangabelia in South 24-Paraganas District, West Bengal

AFFECTED BANK - Eroded Right Bank of River Bidya

PROBLEM - Bank soil erosion due to tidal effect, fluctuations & high salinity.

YEAR OF APPLICATION - 2007

NAME OF THE CLIENT - Joynagar Irrigation Division (under Eastern Circle), I & WD, WB

COST OF JGT - Rs. 3, 28,400.00 (Rs. 82.10/ sq. m)

LENGTH OF AFFECTED PORTION TREATED - 500 m

SITE CONDITION

The average ground level of the adjacent area varies between 1.20 m to 2.00 m above Mean Sea Level (MSL) against a mean high water level of 3.50 m GTS. The annual rainfall in the area generally varies between 1300 mm to 1625 mm approx. The tides are semi-diurnal.

TYPE OF FLOW - Two-way flow / Tidal (Semi-diurnal)

GEOHYDROLOGICAL DATA

Highest High water level	4.50 m GTS
Lowest Low water level	(-)1.20 m GTS
Mean High water level	3.50 m GTS
Velocity (average) of flow	1 m/sec
Width of River	1000 metre
Water quality	Saline (>18 ppt)

SALIENT FEATURES OF WORK- SITE

Crest level of Embankment	6.70 m GTS
Top width of Embankment	3.00 metre
River side slope of bank	4:1
Country side slope of bank	2:1
Total slope length(r/s)	27.50 m

TYPE OF BANK SOIL - Silty-clay with fine sand

REMEDIAL MEASURE - Bank protection with bituminized JGT overlain by two layers of brick pitching.

23 Post work observations collected by I&WD Department and National Jute Board together.

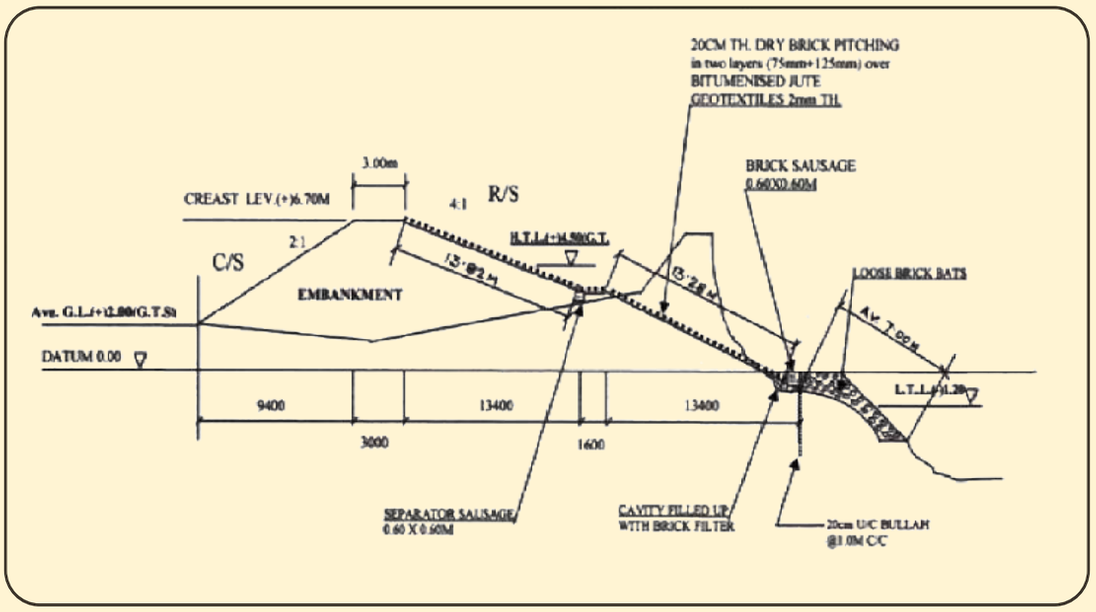
PROPERTIES OF JUTE GEOTEXTILE USED

Width of JGT (mm)	2000
Weight of grey JGT (gm/sqm)	760
Weight of bituminized JGT (gm/sqm)	1200
Thickness (mm)	2
Tensile Strength (kN/m) (MD x CD)	21
Elongation at break (%)	10
Pore size (O_{90}) (micron)	150 (min)
Threads/dm (MD x CD)	102 x 39
Puncture resistance (kN)	0.400
Horizontal lapping (mm)	250
Side lapping (mm)	150

DETAILS OF ARMOUR USED

Bituminized Woven Jute Geotextile (JGT) overlain by 200 mm thick dry brick pitching in two layers (75 mm+125 mm) as the outer protective cover.

CROSS-SECTIONAL DETAILS OF PROTECTION WORK WITH JGT



RESULTS AND DISCUSSION

- Entire portion of JGT treated portion of bank is stabilized and in good shape with no distresses observed even after two and half years.
- Even in high tidal fluctuations and high salinity JGT worked satisfactorily in the eroded bank section treated with JGT.

VIEW OF CONDITION RIVERBANK AFTER TWO AND HALF YEARS OF JGT APPLICATION

CASE STUDY 3

RIVER BANK EROSION CONTROL AT RIVER PUNARBHAVA

NAME OF THE RIVER - River Punarbhava

LOCATION - Bamongola Block of Malda District, West Bengal.

AFFECTED BANK - Right Bank of River Punarbhava

YEAR OF APPLICATION - 2011

PROBLEM - Since 1997, 140 m land width has been eroded away on right concave side undermining of high bank side and subsequent slip caused by washing away of sandy stratum of the bank

NAME OF THE CLIENT - Malda Irrigation Division, I &WD, Govt. of West Bengal

COST OF JGT - 13.86 Lakh (Rs. 81.50/ sq. m)

LENGTH OF AFFECTED PORTION TREATED - 1000 m

SITE CONDITION

The river is not a perennial river is fed through surface runoff of catchment area.

TYPE OF FLOW - One-way flow / Unidirectional

GEOHYDROLOGICAL DATA

Highest Flood level	23.650 M GTS
Lowest Low water level	17.450 M GTS
Average Ground Level of the area	23.670 M GTS
Velocity (average) of flow	2m/sec
Max Discharge during flood	1474 cumec
Bank Slope	2:1
Flood Slope	1 in 5000
Scour depth	6.062 M
Rate of erosion	140 m since 1997

TYPE OF BANK SOIL - Clayey-silt with certain percentage of fine sand.

REMEDIAL MEASURE

For preventing of migration of soil particles from concave side of the bank and also for providing escape routes for confined water to neutralize the differential over pressure Jute Geotextile smeared with bitumen was used on the embankment with apron of cement concrete blocks as apron of size 0.25m x 0.25m 0.25m laid over Tarza mat up to 13 m from toe wall with Pitching of 0.2 m thick CC blocks over JGT.

VIEW OF ERODED RIVER BANK

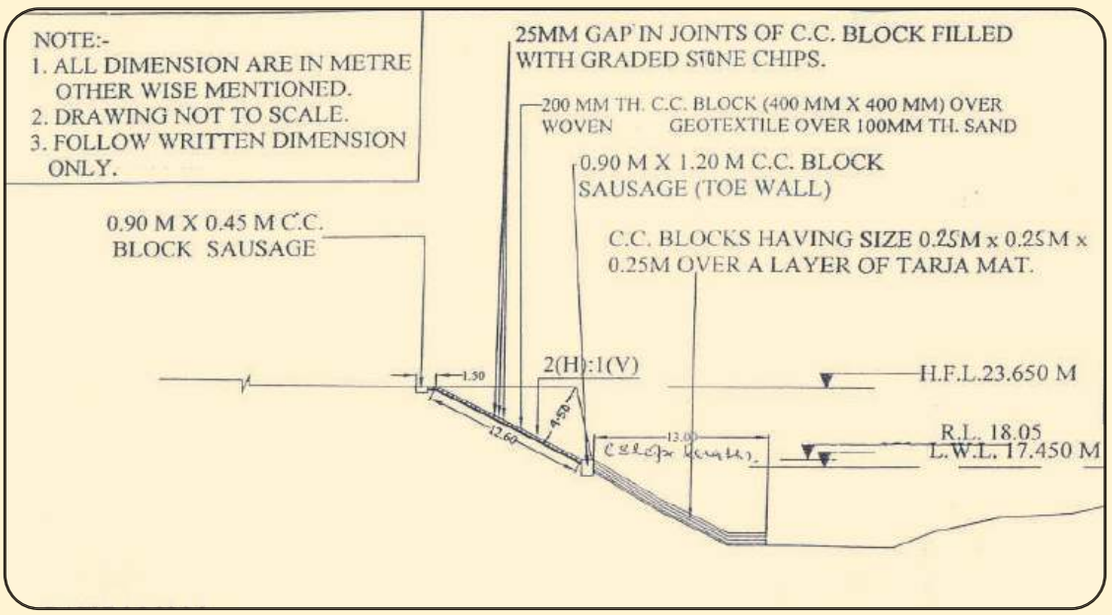
PROPERTIES OF JUTE GEOTEXTILE USED

Weight of grey JGT (gm/sqm)	705
Weight of bituminized JGT (gm/sqm)	1075
Thickness (mm)	1.86
Tensile Strength (kN/m) (MD x CD)	26.98 x 22.63
Elongation at break (%) (MD x CD)	12.9 x 11.8
Pore size (O_{90}) (micron)	150
Threads/dm (MD x CD)	95.0 x 38.3
Static Puncture resistance (N/cm^2)	468.1
Water permeability at 10 cm water column (l/m^2/sec)	25.5

DETAILS OF ARMOUR USED

Bituminized Woven Jute Geotextile (JGT) overlain by 0.2 m thick CC blocks as the outer protective cover.

CROSS-SECTIONAL VIEW OF TREATED BANK WITH JUTE GEOTEXTILE



VIEW DURING LAYING OF JGT

RESULTS AND DISCUSSION

- Entire stretch of JGT treated portion is in good shape with no distresses observed even after more than 3 years.
- Dense growth of vegetation is observed in entire stretch of bank treated with JGT.
- Even in concavity portion of bank where the impact of flood water is higher, JGT worked satisfactorily.

VIEW OF CONDITION RIVER BANK AFTER THREE YEARS OF JGT APPLICATION

CASE STUDY 4

RIVERBANK EROSION CONTROL AT RIVER KALJANI

NAME OF THE RIVER - River Kaljani

LOCATION - Jhaukuthi, Tufanganj Block, Coochbehar District, West Bengal

AFFECTED BANK - Left Bank of River Kaljani

PROBLEM - The river Kaljani with combined four other rivers flows laden with fine sand. The upper layer of the bank soil which is a combination of sandy silt (with sand ranging between 36% to 44% & silt 50% to 60%) shears off and falls into the river when the water level recedes after the floods. This phenomenon is a feature in Jhaukuthi area of the river course and was reportedly occurring for the last few years.

YEAR OF APPLICATION - 2012

NAME OF THE CLIENT - North Bengal Flood Control Commission, Coochbehar Irrigation & Waterways Directorate, Govt. of West Bengal

COST OF JGT - Rs. 4.43 Lakh (Rs. 94.00/sq. m)

LENGTH OF AFFECTED PORTION TREATED - 520 m

SITE CONDITION

River carries huge discharge during the monsoon. It gets its feed from the river Torsa which is a trans-boundary river rising in Tibet and flowing through the hilly terrains of Bhutan before entering Coochbehar district in West Bengal. The combined flow of Torsa and Kaljani together with three others river Ghargharia, Gadadhar and Raidak – I spews into the river Brahmaputra in Bangladesh. The combined flow is known as the river Kaljani. Average annual rainfall in the area is about 3600 mm.

TYPE OF FLOW - One-way flow / Unidirectional

GEOHYDROLOGICAL DATA

Highest Flood level	99.870 M
Lowest Low water level	95.765 M
Average Ground Level of the area	99.36 M
Velocity (average) of flow	2.52 m/sec
Max Discharge during flood	19756 cumec
Bank Slope	2:1
Scour depth	13.45 M

TYPE OF BANK SOIL - Sandy silt.

VIEW OF ERODED RIVER BANK

REMEDIAL MEASURE

For preventing of migration of soil particles from concave side of the bank and also for providing escape routes for confined water to neutralize the differential over pressure Jute Geotextile smeared with bitumen was used on the embankment with Launching apron of dimensions 15.0m x 0.9m by placing cement concrete blocks of size 0.3m x 0.3m 0.3m laid over Durma mat from toe wall with Pitching of 0.4m x 0.4m x 0.25m dimensions of CC blocks over JGT over 100mm thick sand cushion.

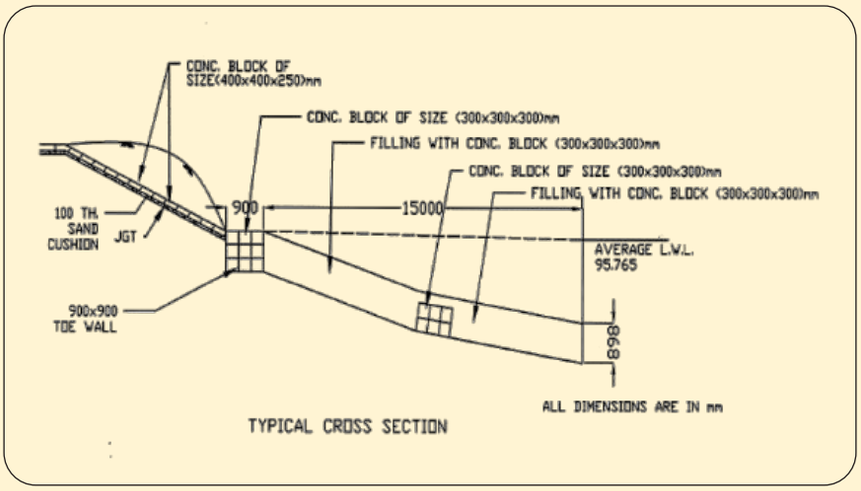
PROPERTIES OF JUTE GEOTEXTILE USED

Weight of grey JGT (gm/sqm)	800
Weight of bituminized JGT (gm/sqm)	1300
Thickness (mm)	1.84
Tensile Strength (kN/m) (MD x CD)	36.62 x 45.45
Elongation at break (%) (MD x CD)	17.84 x 8.03
Pore size (O_{90}) (micron)	178
Threads/dm (MD x CD)	90.2 x 38.0
Puncture resistance (kN)	0.52
Permittivity (/sec)	0.442
Water permeability at 10 cm water column (l/m^2/sec)	22.1

DETAILS OF ARMOUR USED

Bituminized Woven Jute Geotextile (JGT) overlain by 0.4m x 0.4m x 0.25m thick CC blocks as the outer protective cover.

CROSS-SECTIONAL VIEW OF TREATED BANK WITH JUTE GEOTEXTILE



VIEW DURING LAYING OF JGT

RESULTS AND DISCUSSION

- Entire stretch of JGT treated portion is in good shape with no distresses observed even after 3 years.
- Even in such high discharge of five rivers together, bank treated with JGT worked satisfactorily.

Fineness Modulus				
Depth below JGT (mm)	April,2012		December,2013	
	Bore hole. 1	Bore hole. 2	Bore hole. 1	Bore hole. 2
1. 0-300mm	0.35	0.40	0.50	0.48
2. 300- 600mm	0.38	0.41	0.44	0.16
3. 600-1200mm	0.88	0.87	0.17	0.18

- Determination of Fineness Modulus (FM) can indicate the status of soil consolidation in river bank.
- F M on soil samples is a surer indicator of consolidation

VIEW OF CONDITION RIVER BANK AFTER THREE YEARS OF JGT APPLICATION

CASE STUDY 5

RIVER BANK EROSION CONTROL AT RIVER PHULAHAR

NAME OF THE RIVER - River Phulahar

LOCATION - Shankaritola Ghat, Malda District, West Bengal.

AFFECTED BANK - Left Bank of River Phulahar

PROBLEM - Continued erosion of left concave bank during and after monsoon floods for several years.

YEAR OF APPLICATION - 2003-04

NAME OF THE CLIENT - Malda Irrigation Division, I & WD, Govt. of West Bengal

COST OF JGT - Rs. 53.00 per sq. meter.

LENGTH OF AFFECTED PORTION TREATED - Around 2 km

SITE CONDITION

Flood during monsoon as a result of high precipitation caused rise in water level both in the Ganga and the Phulahar connected with it. There was a heave-up of the excess water at the mouth of the narrower Phulahar that takes a bend at a distance of one and half kilometers from its outfall in the Ganga. The concave bank was subjected to heavy erosion that was accentuated due to strong protective measures undertaken on the opposite end for the stability of a big land-form (Bhutni Diara) that has emerged within the Ganga.

TYPE OF FLOW - One-way flow / Unidirectional

GEOHYDROLOGICAL DATA

Maximum Velocity	2 m/sec
Monsoon Discharge	9330 cumec
Bank Slope	2:1

TYPE OF BANK SOIL - Fine sand (0.175 mm)

REMEDIAL MEASURE

Erosion at the toe of the bank can be controlled by construction of submerged repelling spurs or by construction of a toe wall. Irrigation & Waterways Department adopted the second option, presumably for avoiding flow repulsion to the opposite end that could destabilize the protective work around Bhutni Diara. The bank slope measuring 12 meters in length was given a 'break' after 5 meters from the bank top, forming a berm of a 1 meter.

VIEW OF ERODED RIVER BANK

PROPERTIES OF JUTE GEOTEXTILE USED

Weight of grey JGT (gm/sqm)	760
Weight of **bituminized JGT** (gm/sqm)	**1200**
Thickness (mm)	1.86
Tensile Strength (kN/m) (MD x CD)	21x 21
Elongation at break (%) (MD x CD)	10 x 10
Pore size (O_{90}) (micron)	150
Threads/dm (MD x CD)	95.0 x 38.3
Static Puncture resistance (N/cm^2)	400
Permittivity at 50mm constant water head (/sec)	350×10^{-5}
Flow rate at 50mm constant water head ($l/m^2/sec$)	14

DETAILS OF ARMOUR USED

Bituminized Woven Jute Geotextile (JGT) overlain by 450 mm thick loose granite boulders (Rajmahal trap).

VIEW DURING LAYING OF JGT

RESULTS AND DISCUSSION

- Entire stretch of JGT treated portion is in good shape with no distresses observed even after more than 3 years.
- Dense growth of vegetation is observed in entire stretch of bank treated with JGT.
- Even in concavity portion of bank where the impact of flood water is higher, JGT worked satisfactorily.
- Based on excellent performance of JGT, I & WD Deptt. has undertaken the bank protection work with JGT in other stretches of the same river.

VIEW OF CONDITION RIVER BANK AFTER THREE YEARS OF JGT APPLICATION

CASE STUDY 6

RIVER BANK EROSION CONTROL AT RIVER JAGADDAL

NAME OF THE RIVER - River Jagaddal

LOCATION - River Jagaddal a tidal river in sundarban in Pathar Pratima Block of South 24 Parganas in West Bengal..

AFFECTED BANK - Right bank of river Jagaddal lying near the confluence of river Jagaddal and Bay of Bengal.

PROBLEM - Bank soil erosion due to tidal effect, fluctuations & high salinity..

YEAR OF APPLICATION - 2010-11

NAME OF THE CLIENT - Kakdwip Irrigation Division, South 24 parganas, Govt. of W.B

LENGTH OF AFFECTED PORTION TREATED - 400 meter

SITE CONDITION

The sundarban (Gangetic Delta) area comprising of islands reclaimed by putting marginal embankment for rehabilitation through cultivation severe wind and resultant wave thrust causes massive damages with embankments as routine basis. The area around Buraburirtat (East) section is one of the most vulnerable section with the direct effect of sea is one of the factors due to change in configuration of Delta.

TYPE OF FLOW - Two way flow (Tidal)

GEOHYDROLOGICAL DATA

Maximum Velocity	1.02 m/s
Mean Velocity	0.13 m/s
Mean Discharge	601 m3/s
Bank Slope	4:1

TYPE OF BANK SOIL

Soil Type	CH
Sand Content (%)	5 – 7
Silt Content (%)	59 – 65
Clay Content (%)	30 – 34
Moisture Content (%)	32
Liquid Limit (%)	52 – 55
Plasticity Limit (%)	20 – 24

REMEDIAL MEASURE

Jute Geotextile treated with bitumen (90/15 grade) was used as filter material replacing granular filter as a cost effective and eco friendly material. Considering the grain size distribution of bank soil (D50) the pore size (O90) of Jute Geotextile was designed. (even after bituminized treatment of JGT), Properties like retention, filtration & tensile strength was being ensured)

VIEW OF ERODED RIVER BANK

PROPERTIES OF JUTE GEOTEXTILE USED

Nomenclature	Gray (untreated)	Bituminized
Width (cm)	76- 200	76- 200
Weight (gsm at 20% M.R.)	760	1200
Ends /dm X Picks / dm	102 x 39	102 x 39
Thickness (mm) at 2 kPa	2	2
Tensile Strength (kN/m) (MD x CD	20 x 20	21 x 21
Elongation at break (%) (MD x CD)	10 x 10	8 x 8
Permittivity (/sec)	0.45	0.0035
Apparent Opening Size (O95) (µm)	275	180

DETAILS OF ARMOUR USED

32.5 cm thick dry brick pitching over a layer of Bituminized Woven Jute Geotextile (JGT) filter.

VIEW DURING LAYING OF JGT

RESULTS AND DISCUSSION

- Entire stretch of JGT treated portion is in good shape with no distresses observed even after more than 3 years.
- Dense growth of vegetation is observed in entire stretch of bank treated with JGT.
- JGT have served its purpose as an effective filter material for river bank erosion control.

VIEW OF CONDITION RIVER BANK AFTER JGT APPLICATION

Nov. 2012

August 2013

March 2014

Nov. 2014

March 2015

Dec. 2015

CASE STUDY 7

RIVER BANK EROSION CONTROL AT RIVER DHARALA

NAME OF THE RIVER - River Dharala

LOCATION - The proposed bank is situated at IBB Road, Fencing, bridge and gate near village Mahismari, BOP Tetulchhara, B.P. No. 879/9S IBBR No. 62/21.20 Km & B.P No. 879/14S IBBR No. 62/22/70 km along with R/B of river Dharala at Suktabari (Tetulchara), B.P No. 879/9S along L/B od river Dharala in P.S Sitalkuchi, Dist Coochbehar

AFFECTED BANK - Left bank of river Dharala

PROBLEM - River Dharala has a tortuous course with frequent meanders.

YEAR OF APPLICATION - 2011-12

NAME OF THE CLIENT - Cooch Behar Irrigation Division, Govt. of West Bengal

LENGTH OF AFFECTED PORTION TREATED - 1320 meter

SITE CONDITION

River Dharala originates from River Ramsai in Jalpaiguri district West Bengal. The river enters Bangladesh territory and again it enters the Indian territory bordering some area in Bangladesh outfalls into the river Mansai (Jaldhaka). River Dharala has a tortuous course with frequent meanders. The unstable regime is one of the prime reasons for the course shift. If the process of bank erosion continues unabated it may have larger manifestation with the main river flow close to the bank eating away the bottom of the eroded bank and destabilizing the upper portion of the eroded bank. Large chunks of land mass may get detached from the main land in course of time as a result. It was thus necessary to control the erosion before it could magnified.

TYPE OF FLOW - One way river (meandering river)

GEOHYDROLOGICAL DATA

HFL	99.433 m
LWL	94.524 m
Maximum Discharge	1846 cumec
Flow velocity near the affected bank	2.25 m/sec

TYPE OF BANK SOIL

Soil Type	SM
Sand Content (%)	85 – 95
Silt & Clay Content (%)	5 – 15
Moisture Content (%)	36%
Void ratio	0.88

REMEDIAL MEASURE

Jute Geotextile treated with bitumen (90/15 grade) was used as filter material replacing granular filter as a cost effective and ecofriendly material. Considering the grain size distribution of bank soil (D50) the pore size (O90) of Jute Geotextile was designed. (even after bituminized treatment of JGT), Properties like retention, filtration & tensile strength was being ensured)

VIEW OF ERODED RIVER BANK

PROPERTIES OF JUTE GEOTEXTILE USED

Nomenclature	Bituminized
Width (cm)	201.0
Weight (gsm at 20% M.R.)	1300.0
Ends /dm X Picks / dm	90.6 x 37.0
Thickness (mm) at 2 kPa	1.84
Tensile Strength (kN/m) (MD x CD	36.62 x 45.50
Elongation at break (%) (MD x CD)	17.84 x 8.03
Permittivity (/sec)	0.442
Apparent Opening Size (O_{95}) (μm)	178

DETAILS OF ARMOUR USED

400 mm x 400 mm x 200 mm C.C. blocks (1:3:6) in pitching over a layer of woven Jute Geotextile filter in slope pitching. The minimum weight of each block comes 73.60kg.

VIEW DURING LAYING OF JGT

RESULTS AND DISCUSSION

- Entire stretch of JGT treated portion is in good shape with no distresses observed even after more than 3 years.
- Dense growth of vegetation is observed in entire stretch of bank treated with JGT.
- JGT have served its purpose as an effective filter material for river bank erosion control.

VIEW OF CONDITION RIVER BANK AFTER JGT APPLICATION

March 2013

Nov. 2013

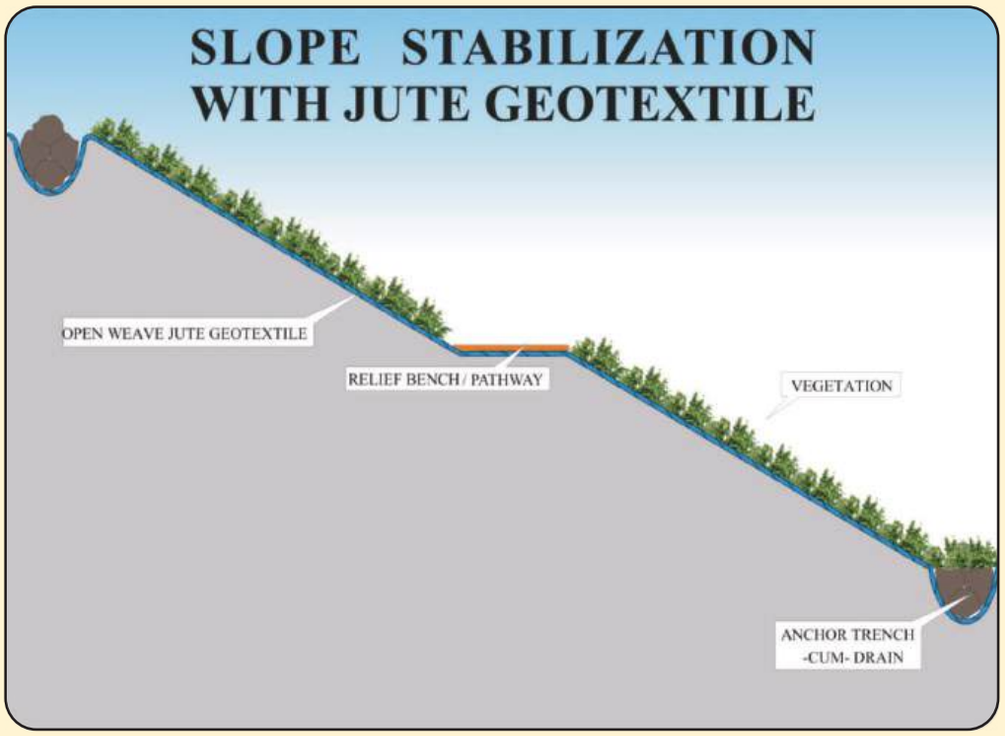
April 2014

August 2014

February 2015

November 2015

APPLICATION IN HILL SLOPE MANAGEMENT



CASE STUDY 1

MINE SPOIL STABILIZATION IN UTTARANCHAL[24]

NAME OF THE QUARRY - Dhandaula Kharawan (Lime Stone Quarry)

LOCATION - Sahastradhara, 18 Km away from Dehradun, Uttranchal (erstwhile Uttarakhand) in lesser Himalayan zone of Doon valley.

PROBLEM - Frequent landslides due to Rain – induced erosion

YEAR OF APPLICATION - 1987

NAME OF THE CLIENT - ICAR – Indian Institute of Soil and Water Conservation (IISWC) erstwhile Central Soil and Water Conservation Research and Training Institute (CSWCRTI), Dehradun

AREAOF AFFECTED PORTION TREATED - 8600 sq. metre

ELEVATION OF SLOPE - Ranging between 842 m to 1310 m

ESTIMATED COST - The cost of OW (open weave) JGT used in the project was of the order of Rs. 8/- per sq.m.(comprising of cost of fabric, labour, plantation and installation) and quantity of JGT required was 10000 sq. m.

SITE CONDITION

Slopes are steep with an average slope of about 50%, at some points the slopes are exceeding even 100% and steepness increased due to mining activity. It was observed that nearly 35000 tonnes of debris used to come down annually from 64 hectares degraded watershed on road that led to frequent vehicular disruption and huge maintenance cost. The mine spoil flows directly into the river Baldi, a tributary of Ganga. Average annual rainfall of the site is 3000 mm in which 80% received during monsoon months (mid June to mid September). The area receives high intensity storm of 240 mm/hr (5 minute duration).

ECOLOGICAL AND PHYSIOGRAPHY CHARACTERISTICS

Ecologically, in this region vegetation changes with modifications in soil composition and the area is characterized by Krol belt comprising of limestone, gypsum, marble, slates, dolomite etc. the mine spoil is sandy loam in texture with high gravel content (60% of material is greater than 16 mm size). The soil is poor in fertility and poor water holding capacity. The poor fertility of mine spoil inhibits the growth of vegetation.

VIEW OF DESTABILIZED MINE SPOIL HEAP

24 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.

REMEDIAL MEASURES UNDERTAKEN

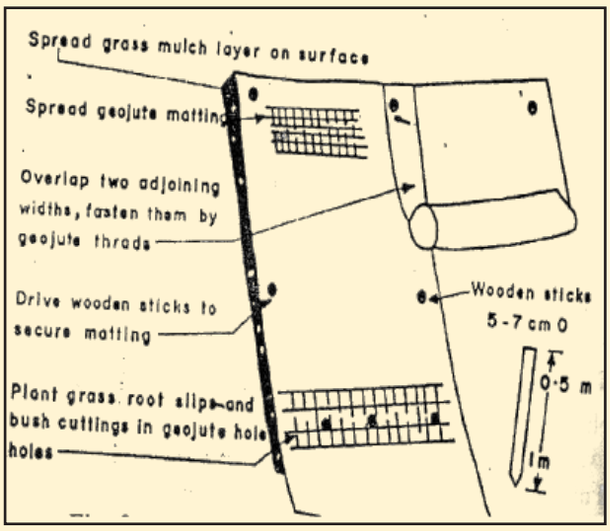
The following remedial measures were undertaken –

- Based on the topographical and soil surveys, a corrective plan consisting of a combination of engineering and vegetative measures was implemented.
- Easing of the existing slope to the extent possible
- Installation of JGT of 500 gsm Open Weave
- Rooted slips of grasses were planted in openings 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

Construction	Open weave Jute Geotextiles (soil saver)
Width (cm)	122 cm
Weight (gsm) at 20% MR	500
Ends X Picks / dm	6.5 X 4.5
Thickness (mm)	4.00
Wide width Tensile strength (kN/m) MD X CD	≥ 6.5 X 6
Elongation-at-break (%) MD X CD	≤ 10 X 10
Open Area (%)	50
Water Holding Capacity (%) on dry weight	500

VIEW AFTER LAYING OF JGT & SPROUTING OF SEEDLINGS THROUGH JGT



RESULTS

(a) JGT degraded in about 2 years, by then vegetation cover had established itself providing good anchorage to soil.

(b) 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.

(c) 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

(d) 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).

(e) 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

(f) 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%
- pH value reduced from 8.1 to 7.7 over a period of 7 years

VIEW OF STABILIZED MINE SPOIL TREATED WITH JGT AFTER 9 YEARS

CASE STUDY 2

HILL SLOPE STABILIZATION IN LEH IN ADVERSE CLIMATIC CONDITIONS[25]

LOCATION - Rumtse, Upshi-Sarhu-Manali Road about 90.4 km away from Leh, Jammu & Kashmir.

PROBLEM - Non-cohesive material like sand mixed with pebbles migrates and rolls down the slope triggered mainly by high wind thus affecting road communication, fluvial characteristics of waterways and vegetative growth. Transportation of artilleries, materials related to defence and movement of army officers to the border areas like Kargil and others are thus severely hampered due to wind-induced erosion.

RANGE - Karakoram in north and the Great Himalayas in south.

YEAR OF APPLICATION - 2013

NAME OF THE CLIENT - Project HEMANK, 16th Border Road Task Force (BRTF), Border Roads Organization, Jammu & Kashmir

AREA OF AFFECTED PORTION TREATED - 3600 sq. metre

ELEVATION OF SLOPE - 4900 metres above MSL.

ESTIMATED COST - The cost of OW JGT used in the project was of the order of Rs. 40/- per sq.m. and quantity of JGT required was 4000 sq. m.

SITE CONDITION

Slopes are steep with an average angle of inclination of about $30^0 - 45^0$. The temperature varies between -35^0 C to $+35^0$ C, Relative Humidity varies in the range of 2 to 25%. Wind velocity is about 90 km/hr and annual snow fall of 150 cm is observed in this region. Due to its high altitude, it experiences temperature extremes – a very cold climate in winter (-30°C) and heat in summer. It usually receives rainfall twice a year i.e., during June to September and October to May. Glacier-melted water is the major source of surface water. The area experiences both arctic and desert climate.

(Source:- Defence Institute of High Altitude Research, C/o 56 APO)

ECOLOGICAL AND PHYSIOGRAPHY CHARACTERISTICS

Non-cohesive material like **sand mixed with pebbles** migrates and rolls down the slope triggered mainly by high wind thus affecting road communication, fluvial characteristics of waterways and vegetative growth. Large temperature variation results in mechanical breaking of rocks that gives rise to unconsolidated material over the hill range and along hill slopes. Pebbly-gravely material, boulders, fragmented shells etc. creep down along the unstable slopes or is carried down by the glacier or glacier-melt water. This valley was formed as a result of diverse erosive process.

25 Published in Proceedings of International Symposium "Geosynthetics India 2013" organized by CBIP, New Delhi, October 2013 authored by T Sanyal, P K Choudhury and Sunil Verma

VIEW OF DESTABILIZED MINE SPOIL HEAP

REMEDIAL MEASURES UNDERTAKEN

The following remedial measures were undertaken –

- Wire crate toe wall was constructed as lateral restraint
- 4000 sq. mtrs of 500 gsm Open Weave JGT was in this adverse climatic condition
- Open Weave JGT in the area with the object of providing cover over the area for arresting detachment and migration of top slope fill and binding the top soil by confining it, followed by growth of vegetation mulching and nutritional effects of jute at different stages of its life.

PROPERTIES OF JUTE GEOTEXTILE USED

Construction	Open weave Jute Geotextiles (Soil Saver)
Width (cm)	122 cm
Weight (gsm) at 20% MR	**500**
Ends X Picks / dm	6.5 X 4.5
Thickness (mm)	4.00
Wide width Tensile strength (kN/m) MD X CD	≥ 6.5 X 6
Elongation-at-break (%) MD X CD	≤ 10 X 10
Open Area (%)	50
Water Holding Capacity (%) on dry weight	500

RESULTS & DISCUSSION

- The entire JGT treated area was observed to be stable within 2 months of installation of JGT and no sign of erosion was observed.
- Interestingly, formation of ice was observed only on the surface of JGT and no where else in the surrounding which may be due to hygroscopic character of JGT appeared to have contributed to the phenomenon providing a cover over soil. Additionally durability of JGT was also seen to have increased.
- Sprouting of vegetation was also observed in the treated area.
- Any way the initiative taken by BRO has proved successful confirming suitability of JGT even in freezing zones.

VIEW AFTER LAYING OF JGT & FORMATION OF SNOW OVER JGT

CASE STUDY 3

STABILIZATION OF SLIDE – PRONE HILL SLOPE IN SILIGURI[26]

LOCATION - Paglajhora on NH-55 off Siliguri, Northern part of West Bengal in India, (Locally known as "14th Mile Hill slide"

PROBLEM - Frequent land slips and erosion of top soil layers due to Rain – induced erosion.

RANGE - Eastern Himalayan Range.

YEAR OF APPLICATION - 2011

NAME OF THE CLIENT - PW(Roads) Department, Govt. of West Bengal

WIDTH OF AFFECTED PORTION OF SLOPE TREATED - 500 metre (both uphill and downhill)

ESTIMATED COST - The cost of OW JGT used in the project was of the order of Rs. 32/- per sq.m. and quantity of JGT required was 52000 sq. m.

SITE CONDITION

Slopes are steep with an average angle of inclination of about 30^0 – 50^0. There are '550 jhora' (natural falls) in the area and also falls under seismic zone. Annual rainfall varies between 4200 mm to 2800 mm with rainfall intensity of ranges about 400 mm/hr to 100 mm/hr. Slide zones are located within the upper catchment of Shivokhola of small tributary. The stream possesses high erosion potential that runs close to the toe of the slide. Initialization of slope destabilization started due to shift of river course towards the toe of down slope.

ECOLOGICAL AND PHYSIOGRAPHY CHARACTERISTICS

The affected site locally known as '14th Mile Slide' comes under an extremely geologically fragile zone. The top soil consisted of debris that had been eroded exposing the bare rock surface. Such type of erosion is common in Eastern Himalayas. The soil is mainly consists of clayey dark soils with high sand content having less cohesion.

VIEW OF LAND SLIDE

26 Published in proceedings of Indian Geotechnical Conference, December 15 – 17, 2011, Kochi (Paper No. Q – 381) authored by T Sanyal, P K Choudhury and Nirmal Mondal .

REMEDIAL MEASURES UNDERTAKEN

The following remedial measures were undertaken listed below –

Several structural measures like

- Strong toe wall to prevent lateral dispersion
- Cross drainage works
- Channeling of discharge from top of uphill and their convergence at a lower level
- Easing the existing slope to the extent possible
- Some other measures (alternate route in place of existing road alignment)
- Installation of Jute Geotextiles of 730 gsm Open Weave (Dense and heavy weight) type was implemented of vegetative measures as follows –
  a) locally available grass seeds were thrown directly on the prepared slope
  b) JGT was placed to top down and anchor at top and stapled with suitable pegs
  c) A second dose of seeds of hydro-seeding was also sprayed (emulsified mixture of seeds, fertilizer, growth hormone, enzymes and soil bacteria) over installed JGT

PROPERTIES OF JUTE GEOTEXTILE USED

Construction	Open weave Jute Geotextiles (Soil Saver)
Width (cm)	122 cm
Weight (gsm) at 20% MR	730
Ends X Picks / dm	7 X 7
Thickness (mm)	7.00
Wide width Tensile strength (kN/m) {MD X CD}	12 X 12
Elongation-at-break (%) {MD X CD}	10 X 12

VIEW AFTER LAYING OF JGT

RESULTS & DISCUSSION

Vegetation Establishment – The area treated with JGT was seen to have well stabilized with vegetation growth all over the treated area arresting landslides and erosion of soils.

Open weave JGT was found to be effective to re-vegetate and stabilizes the highly erodible slopes.

Even after recent slides occurred in June, 2015 no damage has been caused over JGT treated area.

VIEW AFTER SLOPE STABILIZATION AND GROWTH OF VEGETATION

CASE STUDY 4

SLOPE STABILIZATION IN SHIVALIK HILLS, PUNJAB[27]

NAME OF THE HILL - Shivalik Hills

LOCATION - Along the Ropar-Noorpur Bedi Road, Roopnagar District, Punjab

PROBLEM - Shivaliks experiences massive soil erosion due to various forms of degradation, including deforestation, high intensity rainfall with long duration in monsoon.

RANGE - Lower Shivalik range of lesser Himalayas

YEAR OF APPLICATION - 2012

NAME OF CLIENT - ICAR - Indian Institute of Soil and Water Conservation (IISWC) erstwhile Central Soil and Water Conservation Research and Training Institute (CSWCRTI), Chandigarh

AREA OF AFFECTED PORTION TREATED - JGT of 500,600 and 700 gsm were laid in area of 800, 1200 and 1200 sq. m respectively.

ESTIMATED COST - Total cost of JGT Rs. 202500.00

ANGLE OF SLOPE - 10^0 to 60^0

SITE CONDITION

- Average annual rainfall of the region is 656 mm
- 90% of which received from June to September and rest in winter rains. Monsoon normally starts by the end of June and withdraws by middle of September.
- Rainfall events of high intensity and long duration are common feature of the region.
- Winter rains occurs in January-February.
- Maximum rainfall of 1092 mm occurred in 1990 and minimum rainfall of 444 mm in 2005.
- Extreme hot and cold conditions during summer and winter.
- Mean maximum temperature is 38.5^0C during May.
- Mean minimum temperature recorded is 6.4^0C.

ECOLOGICAL AND PHYSIOGRAPHY CHARACTERISTICS

Natural resources in mountainous terrain are profoundly affected by land degradation due to anthropogenic pressure. Shivaliks are one of the most important and integral part of Himalayas representing most fragile ecosystem of Himalayan mountainous range threatened by massive soil erosion hazards. On account of various forms of degradation, it has been estimated that the loss of 5.334 million tonnes of top soil occurs annually, which is equivalent to 5.37 to 8.4 million tonnes of plant nutrients (Dharuyanarayana and Ram babu, 1983). In some cases the soil loss in Shiwaliks due to erosion up to 400 t ha^{-1} yr^{-1} has been reported (Sidhu et al. 2007).

- The area falls under seismically active zone
- Existence of litho logical weak zones along sand clay contact promotes frequent land slides
- Deforestation, excessive grazing add to the menace of soil erosion & land slips

27 The performance evaluation and study is carried by ICAR - IISWC (erstwhile CSWCRTI), Chandigarh

- Water holding capacity of soil is poor
- Average texture of top soil in study area is as follows

  Sand- 57%,
  Silt- 28.7%,
  Clay- 14.2%

VIEW OF DESTABILIZED HILL SLOPE

REMEDIAL MEASURES UNDERTAKEN

The following remedial measures were undertaken –

- Dressing of slopes, installation of JGT (3 varieties) with control section (without any treatment)
- Control through insecticide at frequent intervals
- Watch and ward was posted at initial stages.
- Automatic machine was installed for measurement of runoff from area treated with JGT and from control.
- Vegetation planted during monsoon for better establishment.

PROPERTIES OF JUTE GEOTEXTILE USED

Construction	500gsm Open weave JGT	600gsm Open weave JGT	700gsm Open weave JGT
Width (cm)	≥122 cm	≥122 cm	≥122 cm
Ends X Picks / dm	6.5 X 4.5	8 X 7	8 X 8
Thickness (mm)	4.50	5.25	5.50
Wide width Tensile strength (kN/m) MD X CD	≥ 6.5 X 6	≥ 12 X 6	≥ 14 X 7
Elongation-at-break (%) MD X CD	≤ 10 X 10	≤ 10 X 10	≤ 10 X 10
Open Area (%)	50-65	45-50	40-45
Water Holding Capacity (%) on dry weight	450-500	450-500	550-600

VIEW AFTER LAYING OF JGT

RESULTS AND DISCUSSION

- Performance of the treatments was monitored in the monsoon season.
- Gross soil erosion reduced in the JGT treated area by up to 75% over untreated area.
- Land slide was completely checked by use of JGT and soil surface also became stable.
- In all the application of JGT, plants further reduced the soil loss.
- Wherever possible grass/vegetation has been planted particularly in newly constructed slopes/ embankments and JGT arrested soil erosion.

Comparative performance of 3 types of OW JGT may be seen in the table below -

Material	Rainfall (mm)	Soil loss (t/ha)	Soil moisture (%)
Control Section	727.4 mm	626	3.85
500 gsm JGT Section	727.4 mm	263	9.63
600 gsm JGT Section	727.4 mm	160	11.27
700 gsm JGT Section	727.4 mm	380	5.20

VIEW OF COMPARATIVE CONDITION OF SLOPE (WITHOUT & WITH JGT)

Control Section (without JGT)

Plantation through JGT laid on slop

CASE STUDY 5

SLOPE STABILIZATION IN CHAKRATA HILL, UTTARAKHAND[28]

NAME OF THE HILL - Chakrata Hill, Dehradun, Uttarakhand

LOCATION - Downhill side along Phedulani to Maletha PMGSY road, Dehradun, Uttarakhand

PROBLEM - The area is under open grazing by goats and other animals. The area is having scrub vegetation at places generally in the depressions of gullied portion due to better moisture and is by and large in degraded condition. The debris coming from road construction has further added to soil erosion and degradation.

YEAR OF APPLICATION - 2012

NAME OF CLIENT - Indian Institute of Soil and Water Conservation (IISWC) formerly, Central Soil and Water Conservation Research and Training Institute (CSWCRTI), Dehradun

AREA OF AFFECTED PORTION TREATED - OW JGT of 500, 600 and 700 gsm covered and area 0.10 ha., 0.20 ha. & 0.35 ha respectively and total area covered is 0.65 ha.

ESTIMATED COST - Total cost of OW JGT Rs. 202500.00

ANGLE OF SLOPE - 35^0(70%)

SITE CONDITION

Average annual rainfall is about 1400 mm out of which 80% is received during monsoon season i.e. from June to September and rest in winter rains. Rainfall events of high intensity and short duration (1hr) and low intensity and long duration (3 days) were observed. Normally October to December months go dry and winter rains occur in the month of Jan. and Feb. The maximum one day rainfall observed on 9th September 2010 was 203 mm. Maximum temperature goes upto 34° during the month of May and upto mid June. The area experiences very cold in winter. The minimum temperature is experienced in the month of January (-1°).

ECOLOGICAL AND PHYSIOGRAPHY CHARACTERISTICS

The area is a mountainous terrain heaving steep and precipitous slopes (about 70%). Soil of the area is characterized by evidence of juvenile weathering of rocks, manifested by low soil depth and apparent removal of the soil through water erosion from precipitous sloping terrain. The lithological diversity composed of shale schist, slate, limestone, sand stone conglomerates is largely responsible for fragile nature of the area. Soil consists of Clayey sand.

VIEW OF DESTABILIZED HILL SLOPE

28 The performance evaluation and study is carried by ICAR - IISWC (formerly CSWCRTI), Dehradun

REMEDIAL MEASURES UNDERTAKEN

Initially the area was scraped to remove the protruding undulations. A trench (30 cm x 30 cm) was dug in the upper portion on contour. Starting portion of JGT material was embedded in the trench and backfilled to make it secure. Locally made wooden pegs (about 1 m length and 4 to 5 cm dia) were inserted below ground (about 50 cm) to keep the JGT rolls in proper position by fixing them at suitable interval. The whole area was covered from top to bottom of the hillock. This was done to prevent its displacement by wind or animal movement.

PROPERTIES OF JUTE GEOTEXTILE USED

Construction	500 gsm Open weave JGT	600 gsm Open weave JGT	700 gsm Open weave JGT
Width (cm)	≥122 cm	≥122 cm	≥122 cm
Ends X Picks / dm	6.5 X 4.5	8 X 7	8 X 8
Thickness (mm)	4.50	5.25	5.50
Wide width Tensile strength (kN/m) MD X CD	≥ 6.5 X 6	≥ 12 X 6	≥ 14 X 7
Elongation-at-break (%) MD X CD	≤ 10 X 10	≤ 10 X 10	≤ 10 X 10
Open Area (%)	50-65	45-50	40-45
Water Holding Capacity (%) on dry weight	450-500	450-500	550-600

VIEW AFTER LAYING OF JGT

RESULTS AND DISCUSSION

- No visible erosion taking place in the JGT area and no rills were observed.
- The JGT material was intact after one year of installation, though degradation in strength had taken place.
- The observations recorded so far indicate that JGT is effective in controlling soil erosion and help in growth of vegetation on degraded steep slopes even under open grazing conditions.
- Soil moisture (%) is more in OW JGT (700 GSM) by about 7.5 % compared to control
- Regeneration of vegetation and vegetation cover was more in JGT treated sites (700, 600,500 GSM in order) in comparison to Control section.
- JGT reinforced retaining/toe walls were intact at the lower portion.

VIEW OF STABILIZED SLOPE & GROWTH OF VEGETATION AFTER 1 YEAR

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