JUTE GEOTEXTILE APPLICATION IN KAKINADA PORT AREA

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INTRODUCTION

Kakinada town is situated on the East Coast of India at a latitude of 16°56' North and longitude of 82°15' East. The location of the Kakinada Port at the head of the fertile delta of East Godavari District, Andhra Pradesh, places it in a commanding position in the development of marine commerce. Major cargo handled by the port required transit shed accommodation to transport cargo from the transit shed to the main port. The average soil profile at the site, where the improvement of the road was taken up, consists of soft clay about 8.5 in thick, followed by 3.0m thick sandy silt. This, in turn, is underlain by a 6.0m in thick clayey silt layer. The water table fluctuates from 0.2m to 1.0m. The soft clay, with its liquid limit and natural water content at 78% and 75% respectively, is highly unsuitable for construction of a road pavement, Hence, the need to improve the engineering behavior of the soil and to render it suitable for use.

USE OF GEOTEXTILES

The use of geotextiles in ground improvement is too well known to be emphasized here. One of the most common uses of geotextiles has been in the construction and rehabilitation of both permanent and temporary roadways. Geotextiles are particularly effective where roads are constructed over weak subgrade soils, having CBR value less than 2.0. Unpaved roads, in particular, are subjected to severe rutting and loss of aggregate, resulting in heavy maintenance cost.

Use of Jute geotextiles has also become very popular in recent years. According to one estimate, about 100 million square kilometers of jute geotextiles will be used every year as a soil saver, if proper marketing strategy is adopted by the appropriate authorities. With IJMA and IJIRA taking a proactive role, jute geotextiles are finding their way into almost every sphere of application in civil engineering. Being produced from natural resources, jute geotextiles are eco-friendly. Since synthetic geotextiles are expensive in India, cheaper substitutes like jute have become more popular. The broad application and uses of geotextiles have been fairly identified (Palit et al, 1988). Kabir et al (1988) have given analysis and design approach for an unpaved road reinforced with jute fabric. The following sections present a case study in which jute geotextile was used to strengthen a weak subgrade in Kakinada port area.

LAYING OF GEOJUTE-REINFORCED PAVEMENT AND TESTS DONE

Fig. 1 shows the plan of the area where jute geotextile was used for improving the quality of the riding surface of a road on which heavily laden trucks move. A test section, 360m long, was chosen. The formation width of the road is 21.6m. On either side of the road, lm deep trenches were excavated to a width of 1.2m to anchor the jute geotextiles. Rolls of jute geotextiles were sewn to make a width of 28m with an overlap of 150mm. The unit weight of the geotextiles is 600g/m^2. The rolls were folded in the weft direction along the width, and then, a second fold is made in the ward direction in the length stretch. The jute geotextile was spread over the road and the trench. After the laying of the geotextile, trenches were backfilled with the clay excavated for the formation of trenches. Sand was laid on the jute geotextile and compacted with smooth-wheeled rollers. Thickness of compacted sand bed was 1.2m. This constituted the base course. A layer of compacted gravel was placed on the sand layer to a compacted thickness of 100mm. The top width of the embankment thus formed was 18m. The slopes of the embankment were protected with revetment (quarry rubble) of 300mm thickness. Here the jute geotextile serves the purpose of a separator as well as reinforcement. The cross-section of the road is shown in Fig. 2. Disturbed and undisturbed samples were collected from different boreholes across the section for studying the improvement in the engineering behavior that the introduction of jute geotextile might have resulted in.

Fig. 1 shows the location of the bore holes numbered 1, 2 and 3. Both disturbed and undisturbed samples were collected from a depth of 2.5m below the ground level, from the nalla, the spot just before a nalla and at a distance of 26m from the nalla before placing the geojute. Samples were also collected at elapsed times of 3, 7, 21 and 30 months afer the laying of the geotextiles. Index property tests were conducted on disturbed samples, while consolidation and CBR tests were performed on undisturbed samples.

DISCUSSION

Table 1 shows the index properties and classification of the soil.

Table - 1 : INDEX PROPERTIES

Location	**1**	**2**	**3**
Specific Gravity	2.75	2.75	2.75
Liquid limit	78.0	80.0	81.4
Plastic limit	25.4	28.0	30.8
Plasticity Index	52.6	52.0	50.6
U.S.C.S. Classification	CH	CH	CH

The soil is a clay of high plasticity. Table 2 shows, by comparison, water content of soil before and after the laying of geotextile. The high initial water content of the soil indicated that the soil was very soft. Water content decreased after the laying of geotextiles over a period of time, indicating the increase in the effective stress. The corresponding gain in the dry density of the soil is given in Table 3. The reduction in water content, increase in effective stress and decrease in dry density show that, following introduction of jute geotextile, water was drained out of the soil, indicating that the geotextile served as a drainage medium also.

Table - 2 WATER CONTENT OF SOIL BEFORE AND AFTER LAYING OF GEOJUTE

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

Table - 3 DRY DENSITY OF SOIL BEFORE AND AFTER LAYING OF GEOJUTE

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

Table 4 shows the changes in the void ratio and the compression index of the soil at different elapsed times.

Table - 4 RESULTS SHOWING THE PROGRESS OF CONSOLIDATION OF THE SUBGRADE SOIL FOLLOWING LAYING OF GEOTEXTILE

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

The percentage reduction in the compression index at an elapsed time of 30 months after placing the jute geotextile at different locations is 30.8, 37.7 and 34.4 respectively. Table 5 shows the CBR values obtained on the suograde soil before laying the geotextile and 30 months after laying. The CBR values were determined on the sample collected from location 3. The increase in CBR is as high as three times that of the natural soil, which ensures that the thickness of the crust can be effectively reduced following improvement with the geotextile.

Table - 5 : CBR VALUES OF **SUBGRADE SOIL**

Natural soil CBR (%)		Improved soil CBR (%)	
Unsoaked specimen	Soaked specimen	Unsoaked specimen	Soaked specimen
2.10	1.61	6.03	4.78

It may be mentioned here 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 the port were badly damaged. Plate 1 shows the unreinforced section of the road as it exists today even after several relayings. Plate 2 shows the section of the road reinforced with jute geotextile. The difference in the appearance of the road surface in plates 1 and 2 indicates significant improvement after intorduction of geotextiles.

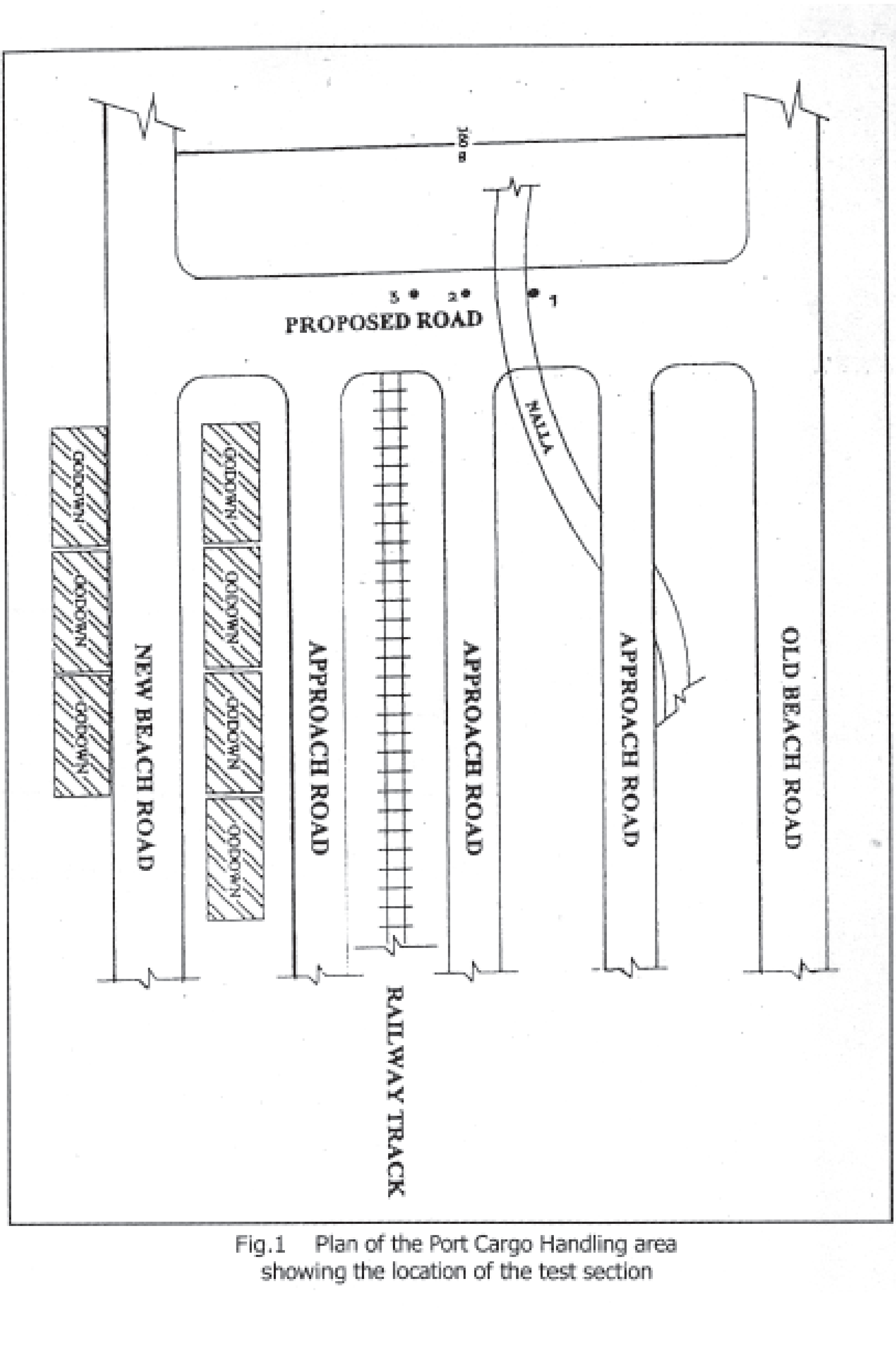

Fig.1 Plan of the Port Cargo Handling area
showing the location of the test section

CONCLUSION AND RECOMMENDATION

A case study of a road section reinforced with jute geotextile has been presented. Water content, void ratio, compression index, dry density and CBR have been compared before and after laying of the jute geotextile. While water content, void ratio and compression index decreased, dry density and CBR increased on introduction of jute geotextiles indicating significant improvement in the engineering behavior. Hence, jute geotextile is very effective in weak subgrade soils in reducing their compressibility and increasing their strength. In the present case, an unpaved road laid on the reinforced soil is still giving good service even after a lapse of 7 years.

ACKNOWLEDGEMENT

The author is thankful to CRRI and IJIRA for choosing him to carry out the project in Kakinada.

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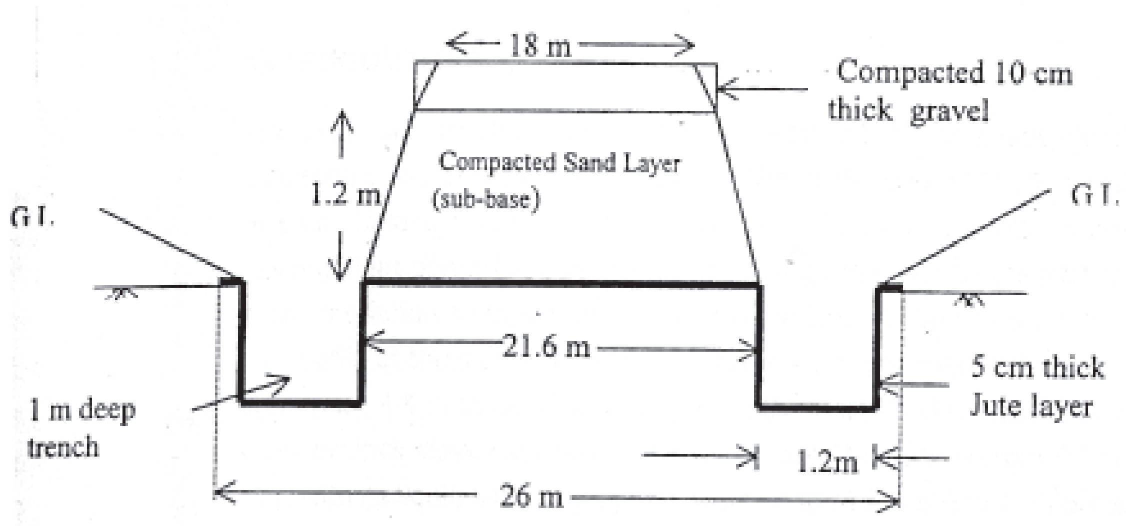

Fig 2 Cross - Section of the pavement improved with jute geotextile.

APPLICATION OF JUTE GEOTEXTILE IN RURAL ROAD CONSTRUCTION UNDER PMGSY – A CASE STUDY IN WEST BENGAL

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ABSTRACT :

Potential of Jute Geotextile (JGT) as an improver of road sub-grade has not been explored to the extent it should have been. The main reservation of the engineers against its use in roads is the biodegradability of the jute fabric. The studies and field trials carried cut so far confirm that soil in general get naturally consolidated on imposition of dynamic load as a result of separation of the sub-grade from the overlying base layers posed by insertion of Jute Geotextile. Low extensibility of JGT is also instrumental in enhancing the bearing capacity of the sub-grade due to membrane effect. The process of natural consolidation takes about a year to maximize beyond which longer effective life of any geotextile is redundant technically. The case study presented in this article is about the design and application of woven Jute Gectextile in a rural road in the district of South 24 Parganas in West Bengal under PMGSY programme to confirm the earlier findings. The work has just been completed and its performance is being monitored.

1. INTRODUCTION

1.1 Jute Geotextile (JGT), a natural technical textile, was tried long before man-made Geotextile was put to use in roads. Geotextile made of jute was reportedly used in Kingsway at Dundee, Scotland way back in 1920, in Strand Road, Kolkata in 1934 by Bengal PWD and sporadically in other roads long before the use of man-made geotextile as an improver of sub-grade in roads was conceived. The trials unfortunately were not monitored and followed up. As a result, the potential of Jute Geotextile in road construction has remained unexplored. Extensive laboratory studies conducted by eminent engineers and scientists in India and abroad have confirmed the excellent performance of JGT in strengthening weak sub-grade of roads in general. Based on the laboratory findings, Jute Geotextile was first tried for construction of a road on very soft marine ciay in Kakinada Port, Andhra Pradesh and was completed successfully in April 1996. The work was carried out by the Port Authority with direct technical and monitoring support of Central Road Research Institute and JNTU College of Engineering, Kakinada and with fabric support from Indian Jute Industries' Research Association. Several other roads in West Bengal have been constructed later with JGT on the sub-grade intending to function as separator, filter and drainage medium.

1.2 This article is a case study in a rural road construction in West Bengal under PMGSY where Jute Geotextile has been used on the sub-grade for improving its CBR.

2. MECHANISM OF FUNCTIONING OF JGT IN ROAD CONSTRUCTION

2.1 Functionally there is no difference between man-made Geotextile and JGT. As a separator it prevents intermixing of sub-grade and sub-base. As filter it ensures "soil-tightness" on the one hand and facilitates dissipation of pore water pressure on the other. Jute Geotextile is an excellent drainage medium and can transmit water efficiently through its own thickness both across and along its plane. On application of repeated dynamic loads on the road-top, entrapped pore water is squeezed out without allowing migration of top soil particles. The process ultimately ensures natural consolidation of sub-grade. The consolidated soil mass known as "Filter Cake" attains a higher CBR usually 1.5 to 3 times the control value after a lapse of about one season cycle normally.

2.2 The principal reason of enhancement of CBR and, for that matter, bearing capacity of the sub-grade is separation along with the membrane effect. Due to stretching of the fabric on imposition of load JGT exerts an upward reaction against it. Low elongation ac break and high initial tensile strength of JGT help in the process. For designing the right fabric, it is necessary to know the average particle size distribution of the sub-grade, its permeability and the dynamic load the road is expected to sustain.

3.0 GEOTECHNICAL DETAILS OF THE ROAD

3.1 Construction of Andulia-Boyratala road was undertaken by the North 24-Parganas Zilla Parishad under PMGSY scheme. The road starts from Lauhati-Haroa State Highway and ends at Boyalghata. Total length of the road is 3.50 km and the estimated cost is Rs. 147.71 lakhs.

3.2 The type of soil at Andulia-Boyratola Road is generally brown silty clay with admixture of small quantities of sand.

The critical soil characteristics are stated below :

Grain Size distribution:

Location (km)	Type of Soil	Sieve analysis percent Passing			
1.50	Organic Silty Clay	4.75 mm	2 mm	425 μ	75 μ
		92.5	77.5	49.5 0	26.3
		0	0	0	0

Atterberg Limits :

Liquid Limit (%) : 48.50

Plastic Limit (%) : 28.20

Plasticity Index : 20.30

Proctor Density of Sub-grade Soil:

OMC : 23.5%

Max. Dry Density at OMC : 1.72 gm/cc

Soaked CBR value at 5.0 mm penetration = 3.16% :

I.S. Soil Classification : OL

4.0 PAVEMENT DESIGN

4.1 The pavement design was based on the findings of S. D. Ramaswamy and M. A. Aziz, Department of Civil Engineering, National University of Singapore. CBR of the road at Kakinada Port was found to have enhanced by nearly 3 times after 7 years of its completion. As a conservative approach the findings of Ramaswamy & Aziz have been considered in the design, taking CBR enhancement with JGT as 150% of the control value. Salient findings in regard to CBR enhancement by Ramaswamy & Aziz are reproduced below :

Table 1 : Effect of Jute Geotextile on CBR Value

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

after Ramaswam & Aziz - 1989

4.2 Findings of Prof. A. Rama Rao after seven years of the application are also given below for information of the readers :

Table II - CBR of Sub-grade before & after Laying JGT

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

(after Sreerama Rao-2003)

4.3 Accordingly, the in situ CBR value of 3.22 has been enhanced by 1.5 times (3.16 x 1.5)% = 4.74% say 4% during designing the pavement on a conservative basis.

Considering the volume of traffic on the road as per traffic survey along with its annual growth rate @ 6% per year, CBR value of 4.0 (B curve-no. of commercial vehicles/day being 15 to 45) and average annual rainfall in the area to be 1500 mm, the pavement thickness is designed as per IRC: SP: 20- 2002 using CBR Curve for Flexible Pavement Design.

4.4 The thickness of pavement according to CBR curve (as per IRC:SP20-2002 page 98)

= 350 mm

1. Base course = 150 mm
2. Sub-base course = 200 mm

Total : 350 mm

Details of pavement layers :

A] Wearing Course : Thickness.

i) Seal coat - type-B = 6 mm

ii) Pre-mixed carpet = 20 mm

B] Base Course :

i) Grade III stone materials
(53 mm - 22.4 mm size) – 75 mm (2nd layer)

ii) Grade II stone materials
(63 mm - 45 mm size) – 75 mm (1st layer)
150 mm

C] Sub-base Course :

i) Grade Il jhama metal
(63 mm to 45 mm size) – 75 mm (2nd layer)

ii) Grade Il jhama metal
(63 mm to 45 mm size) – 75 mm (1st layer)

iii) Course to medium sand to prevent puncturing of JGT over laid on the sub-grade – 50 mm
200 mm

Total pavement thickness - 350 mm
(Base Course + Sub-base Course)

5.0 LAYING OF JGT ON THE SUB-GRADE

5.1 After completion of earth work in road embankment, the embankment was dressed to proper camber and grade at the sub-grade level. Rolling of the sub-grade was done by a vibratory road roller and a 8-10 T power roller for thorough compaction of the base soil at optimum moisture content. Laying of JGT was commenced on 12 April 2005. JGT was laid on the sub-grade of 3.75 m width along with 30 cm bearing on both sides of the pavement Specifications of JGT used are as follow :

5.2 Type of Woven JGT used :

Nomenclature	**30kN/M**
Width - (cm)	760 mm
Weight - (gsm)	810
Thickness - (mm)	2.00
Tensile Strength – (kN/M) (MD x CD)	30x30
Elongation at break (%) *MD* (warp) CD (weft)	 9 9
Burst Strength (KPa)	4500
Puncture Resistance (kN)	0.600
Permittivity at 50 mm constant head (per second)	350×10^{-5}
A.O.S. (micron) - 0_{95}	150

5.3 JGT was laid by unfolding the rolls in longitudinal direction. Normally JGT rolls are 76 cm wide and 75 m long. After laying one roll, the next roll was laid by its side and over it allowing a horizontal lapping of 150 mm. In this way the full pavement width was covered by JGT with a bearing of 30 cm on either side of the pavement. The overlain JGT was anchored suitably at about 90 cm apart in all directions with country nails of 15 cm long. Overlapped portion of JGT was pegged at closer internals in curves, depending on the extent of curvature. A thin layer of sand (50 mm thick) was spread over the JGT laid on the sub-grade. This will act as a cushion on JGT and will prevent puncture of the fabric from the sharp angular edges of aggregates in the pavement.

5.4 A layer of sand 100 mm thick was laid on both sides of the pavement in order to receive and transport water lined by JGT to road side drains. (Fig. 1 & 2).

5.5 The pavement was completed by compaction of 2 layers of 75 mm thick sub-base comprising of broken brick metal and 2 layers of 75 mm thick WBM-II & WBM-Ill consisting of stone metal. 20 mm thick premix carpet was laid on top of WBM as wearing course and finished with 6 mm thick seal coat Type-B.

5.6 The work is being monitored jointly by the Geotech Cell of IJIRA / JMDC and North 24 Parganas Zilla Parisad (PIU).

6.0 COST SAVINGS WITH THE USE OF JGT

6.1 The pavement thickness by using JGT is got reduced by 85 mm from the conventional method of design. There is thus a saving of 75 mm thickness of jhama brick aggregates. The cost of the same as per prevailing Schedule of rates of the area is Rs. 2,44,267.00. The cost of JGT including laying at site was Rs. 1,83,595.00 only. Thus there will be a net savings of Rs. 60,672.00 per km of road construction with the use of JGT.

7.0 CONCLUSION

7.1 One aspect that needs special mention is that brief effective life of JGT is not a discouraging factor in as much as soil gets consolidated to its maximum within a year or so. The consolidaticn is effected as a result of arrest of movement of soil particles on top with concurrent release of pore water due to imposition of extraneous loads. Separation of sub-base and sub-grade alsc contributes to gradual and natural consolidation of the sub-grade, It has been found from extensive experiments that the consolidation time required for the purpose varies between one and two years depending on the type of soil, ꞉ts moisture content and the extent and frequency of extraneous loads. In any case, geotextilebe it man-made or naturaldoes not technically need an effective life beyond two years. JGT can be made to last to two to three years without impairment of strength. Considering the economy, easy availability and environmental advantages, JGT should deserve larger patronage from the highway and geotechnical engineers.

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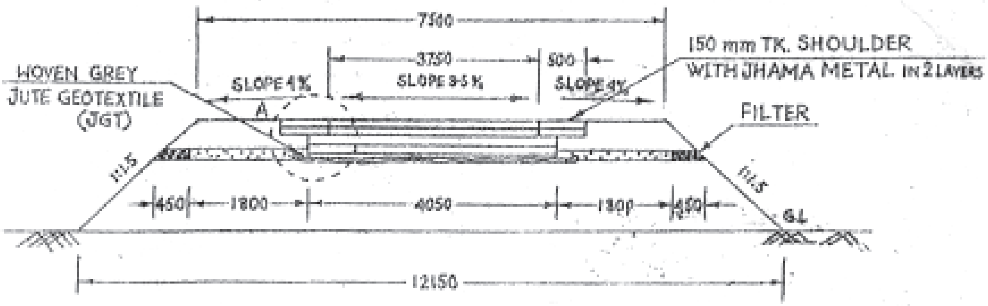

Fig. 1: **Typical cross section of road embankment using Jute Geotextile**

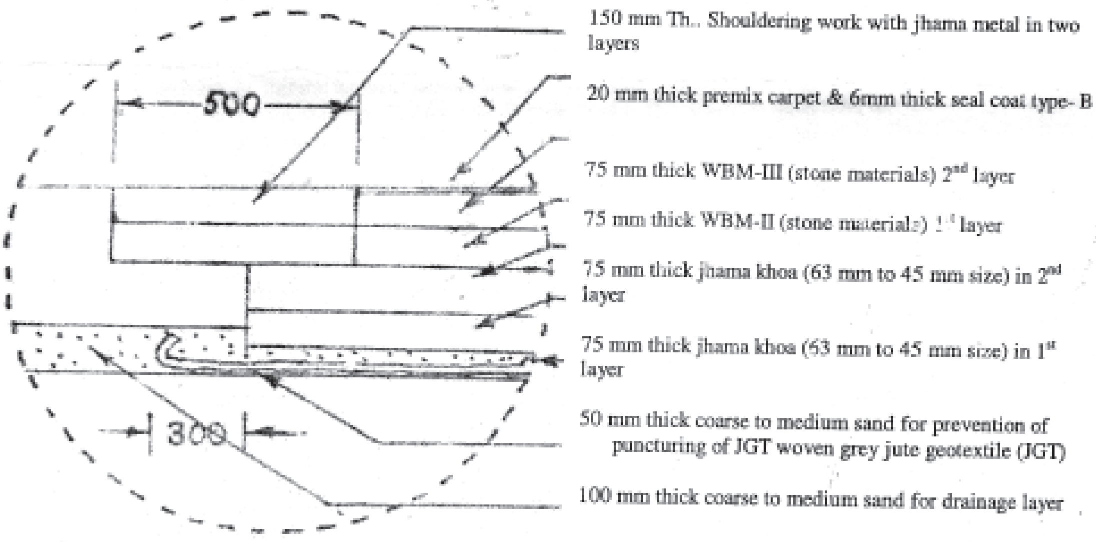

Fig. 2 : **Details of section – A (Pavement and drainage layer)**

JUTE GEOTEXTILE FOR ROAD APPLICATIONS - FIELD TRIALS BY CRRI

Jai Bhagwan, O.P. Yadav, N. K. Sharma

INTRODUCTION

After a significant period of investigations and research, the geotechnical engineering profession is well aware of the inherent weaknesses in soils and has devised methods for improvements. Geosynthetics have been used for several years to improve the soil behaviour and performance in different branches of Geotechnical Engineering. Today, these materials play a major role in civil engineering for a wide range of applications to facilitate construction, ensure better performance of the structures and reduce maintenance cost and are increasingly being employed in thousands of civil engineering projects related to fills and retaining structures, traffic structures, drainage, environmental engineering, etc. A few successful field trials have been conducted in India over the past few years, and increasing attention is now being given to the subject by several central and state research laboratories and academic institutions. India is a very large producer of jute the availability of natural jute in India in abundant quantity thus gives the natural fiber based fabrics an advantage in terms of cost. Jute is a lignocelluloses natural fiber but is biodegradable. There are various applications where the degradation of fabric does not hinder its application. The present paper brings out the high lights of the study conducted to promote the use of jute-based geotextiles in civil engineering applications.

OBJECTIVES

America and Europe occupy a dominant position in the development, manufacture and use of Geotextiles with a small-scale production in Japan. One report indicates that there are more than 500 different types of geotextiles available to the engineers. They are in a variety of form like woven, non-woven and also in non-textiles forms such as mesh, grid, grovel etc. The application of geotextiles depends on the specific requirement and also the fabric properties, including the form as well as manufacturing process involved.

For the jute geotextile to play an effective role, it is essential to design and develop specific fabric geometry to suit geotechnical applications in areas so that the geotextile can perform specific function like separation, filtration, drainage, soil reinforcement and erosion control. Further, the promotion of jute geotextiles in the real sense, will require a closer interaction with the user organizations like Railways, PWDs, Department of Forest, Department of Irrigation, Port Trust, etc. Marketing of this product will require demonstration projects and presentations in professional societies related to civil engineering. The activities were needed to be directed in the following main areas.

(i) Selection of areas of application.

(ii) Development of suitable geotextiles and application technology.

(iii) Demonstration, dissemination and test marketing.

(iv) Marketing in India and abroad.

Jute is a low cost, renewable, biodegradable and ecofriendly natural product. With the growing awareness about ecology around the world, it is worthwhile to develop jute geotextiles for specified end users as the products have a large growth potential.

FUNCTION OF GEOTEXTILES

In a given application, a geotextile can perform one or several functions to improve the hydraulic and/or the mechanical behaviour of a structure in which it is incorporated. The basic functions performed by a geotextiles are defined as follows:

Hydraulic Functions

Fluid transmission: A geotextile can collect and convey considerable flow of fluid within its own plane towards an outlet. This function of geotextile is known as the drainage function.

Filtration: A geotextile act as a filter when it permits liquid to pass normal to its own plane while preventing soil particles from being carried away by the liquid current.

Mechanical Functions

Separation: A geotextile acts as a separator when placed between two different types of materials, such as a fine soil and gravel, which have a tendency to mix when they are squeezed together under the action of repeated applied loads. The function of the geotextile is to prevent the intermixing of the two materials thereby to enable each material to retain its properties.

Reinforcement: When geotextiles are used as soil reinforcement, their prime role is to provide tensile strength to soil, which otherwise is comparatively strong in compression but weak in tension. It is important for the reinforcement function that the geotextile is capable of providing this tensile strength at a strain level, which is compatible with the performance of the soil structure. The reinforcement function of the geotextile may be divided into two subcategories viz. the geotextile (a) as tensioned membrane and (b) as tensile member.

A geotextile functions as a tensioned membrane when placed between two materials having different pressures and its tension balances the pressure difference between the two materials, thereby strengthening the structure.

The geotextile also functions in the following manner where it performs a combination of functions.

- Separation and filtration
- Slope protection
- Separation and reinforcement
- Separation and sealing
- Filtration and drainage etc.

APPLICATIONS OF GEOTEXTILES

The use of geotextiles in various civil engineering works has been increasing worldwide at a rapid rate. As mentioned earlier, the primary function of geotextiles is separation, reinforcement, filtration and drainage. Within these functions, a wide range of applications of geotextiles in geotechnical, highway and environmental activities have arisen and have been experimented in the field, as well as documented in literature. Following is a list of typical applications of geotextiles in which a particular function can be of significance.

Separation

(i) Between subgrade and stone base in unpaved and paved roads and airfield pavements,

(ii) Between subgrade and ballast in railroads,

(iii) Between landfills and stone base courses
(iv) Between foundation soils and flexible or rigid retaining walls and storage piles,
(v) Between foundation soils and flexible or rigid retaining walls and storage piles,
(vi) Between slopes and downstream stability berms.
(vii) Between drainage layer in poorly graded filter blankets
(viii) Between old and new asphalt pavement layers,
(ix) Between various zones in earth and rock dams.

Reinforcement

(i) Over soft soil for unpaved roads, airfields, rail roads and land fills.
(ii) Over unstable land fills as closure systems.
(iii) Lateral containment of railroad ballast.
(iv) To construct fabric reinforced walls.
(v) To reinforce embankments, earth and rock dams.
(vi) To stabilise slopes.
(vii) To reinforce jointed flexible pavements.
(viii) For use in insitu compaction and consolidation of soft soils.
(ix) To improve bearing capacity of shallow foundations.
(x) To reinforce asphalt pavement layers.

Filtration

(i) In place of granular soil filters.
(ii) Beneath stone base in unpaved and paved roads and airfields.
(iii) Beneath ballast under railroads.
(iv) Around crushed stone surrounding underdrains.
(v) Around perforated under drainpipe.
(vi) Around stone and perforated pipe for land drainage.
(vii) Around sand columns in sand drains.
(viii) Between backfill soil and gabion retaining wall.
(ix) As a filter beneath precast concrete blocks.

Drainage

(i) As a chimney drain in an earth dam.
(ii) As a drainage gallery in an earth dam.
(iii) As a drainage blanket beneath a surcharge fill.
(iv) As a drain behind a retaining wall.
(v) As a drain beneath railroad ballast.
(vi) As a drain beneath athletic fields.
(vii) As pore water dissipater in earth fills.
(viii) As a replacement for vertical sand drain.

(ix) As a capillary break.

(x) To dissipate seepage water from exposed soil or rock surface.

(xi) Drainage of pavement layers using geotextiles.

Erosion Control

(i) Stabilisation of slopes by promotion of growth of vegetation using geotextiles

(ii) Arrest of debris flows

FIELD DEMONSTRATIONS

To promote use of jute geotextiles in civil engineering applications, a series of field experiments were carried out using jute geotextiles for different functions. Application of jute geotextiles for different functions at different locations is described in the following sections.

JUTE GEOTEXTILES AS SEPARATOR

To improve pavements performance at Kandla Port

In Kandla port area, authorities were facing the problem of road construction on soft soil. The performance of pavements constructed on soft soils can be improved using jute geotextiles. The fabric as separator prevents the penetration of subgrade material into voids of granular base course. The permeability characteristics of the fabric also aids in faster dissipation of pore pressures and ensures better drainage which result in long term performance of the pavement. Provision of fabric reduces rutting and subgrade can develop its full bearing capacity. In the broad spectrum of geotextiles, natural geotextiles made of jute are very helpful. They are ecofriendly, economical and at the same time serve the desired function. The road network in the Kandla port trust area is being improved to facilitate better movement of vehicular traffic. The soil in the port-area is very soft. It was proposed to use geotextile as a separator between pavement layers. The jute properties of geotextile given in Table 1 used as a separator at Kandla port area.

Table 1: Properties ofjute geotextife ***used as separator at Kandla Port***

S.No.	Description of Property	Value
1	Type	Non - Woven
2	Tensile strength	2.81 kN/m
3	Thickness	6.91 mm
4	CBR push through load	0.5 kN
5	Index puncture resistance	0.077 kN
6	Inplane permeability	9.2×10^{-4} m/s
7	Falling cone test	No clear hole formed
8	Failure strain	30%

The table shows that the fabric has low tensile strength but fails at a large strain of the order of 30 %. In particular, in falling cone test, no clear depression or punching was observed under the fall of the cone indicating the resistance of fabric for puncturing with aggregate or the material used in base layers.

Design

The geotextile can provide restraint and acts as reinforcement and prevent localized bearing capacity failures, which result from individual stones being forced into the subgrade. The pressure at the stone/geotextile interface is related to the burst pressure for a given aggregate size. A design guide for separator function indicating the requirement of burst resistance was developed for the field application.

Construction Details

Site was cleaned properly from its rough surface. Spreading and compaction of murrum cushion was carried out subsequently. The area was instrumented by installation of settlement gauges. During the cyclone of Oct. 1996, the untreated stretch got badly damaged, however, the treated stretch was not affected.

The subgrade was compacted to the optimum water content and dry density of the subgrade material. 300 mm thick base course consisting of two layers of 60-125 mm size aggregates was laid. It was followed by a 200 mm thick WBM constructed using 40 to 60 mm size aggregates. A thin layer of murrum of average size of about 5 mm was provided at the interface. This corresponds to the requirement of the low bursting strength of geotextile and also helps in reducing the direct affect of large sized aggregates. The tensile strength of jute geotextile is low, however, it sustains larger strains of the order of 30 % and hence the fabric was considered as a separator and was used in the project. The jute geotextile was spread over the compacted subgrade followed by the base course and WBM layers.

Monitoring of the completed section :

The engineers of Kandla part trust monitored the completed section for its performance in terms of rut depth and other visible signs of distress. Settlements of the test section in relation to conventional pavement section are being monitored. Settlement of the test section in relation to conventional pavement section was recorded with the increase of pavement loads from 0.5 MT/sq. m to 2.0 MT/sq. m. Loads were increased in increments of 0.5 MT/sq. m each month from February 1997 to May 1997. Results of the settlements recorded from February 97 to May 97 sent by Kandla port trust, shows almost negligible settlements after six months and no signs of distress in the treated test section. This encouraging result has prompted the Kandla port trust to purchase another consignment of 15,000 sq. m of Jute geotextiles from DMA, which has been used for road and embankment construction in creel area in Kandla port.

Jute Geotextiles as Reinforcement

To improve embankments at Kakinada :

A deep-water port is under construction at Kakinada in Andhra Pradesh and within the port area a number of highway embankments are under construction for transporting cargo from the ships to the storage godowns. At the proposed location, the subsoil is soft silty clay and the water table is at 0.5m below the ground level. The whole area gets submerged during high tide. The highway constructed earlier faced many problems during and after construction such as subsidence of the fill during construction, excessive post construction settlements and lateral spreading of fill material etc. On the basis of settlement calculations, it was estimated that as much as 30% of the fill sinks into the soft subsoil during spreading of the fill itself, necessitating larger quantities of costly granular fill material, thereby, pushing up the cost of construction.

In order to mitigate the above problems, various alternatives were examined, among which geotextile has shown itself to be promising one. The use of geotextiles to improve embankments over soft subsoil is an effective and well-tried method for reinforced soil construction. Geotextiles may be used to improve i) the embankment stability against bearing capacity failure, ii) stability against slope failure through the foundation, iii) allow a more controlled construction over very soft or difficult foundation soils and ensure more uniform settlement of the embankment iv) and also act as separator between the embankment material and soft sub soil. To some extent they also performed drainage blanket for draining pore water during consolidation. Embankment stability usually needs to be improved only during the short period in which the foundation consolidates, and in such cases the long-term durability of the geotextiles reinforcement is of secondary concern.

Reinforcement in an embankment on soft soil is very effective when placed at or close to the foundation surface. If the reinforcement were absent, the factor of safety at the end of construction would fall to a value below unity. In other words, the desired cross section cannot be built without the reinforcement. Again the factor of safety starts increasing, as the strength of the foundation soil improves due to consolidation and the foundation soil attains the required strength. Thus the reinforcement is needed only to improve the stability during construction and in that period of consolidation during which the soil attains the required strength.

The main loading from an embankment is due to the vertical self-weight of the embankment fill, which causes horizontal stress in the fill, which in turn produces lateral forces (outward shear stress) The resulting outward shear stress, which acts on the foundation surface, reduces the foundation bearing capacity. So the primary role of reinforcement is to support the outward shear stress and relieve the foundation from the lateral forces, thereby, increasing the allowable height of the embankment that can be supported by the foundation soil. A layer of reinforcement placed in the embankment may resist lateral displacement by exerting an inward shear stress on the foundation surface thus reducing the lateral spreading of the foundation. Since the geotextile is placed between the embankment fill and the subsoil, it also performs the function of separator, thereby, eliminating the mixing of costly granular fill material with the subsoil. The geotextile along with the sand cushion will also act as a drainage layer for the escape of the pore water during consolidation.

A woven jute geotextile was used for reinforcement and also as a separator between the embankment and the soft subsoil. From the experiment it was found that the required strength of the subsoil developed within the short life of the jute geotextile, which is biodegradable and degrades in about 2 years and is economical as well as safe to use geotextile in this project.

Design aspects

In considering an embankment placed upon very soft soil foundation and supported by geotextiles the following design elements have to be checked for arriving at the required properties of the geotextiles.

(a) ***Bearing capacity:*** The check for bearing capacity failures and the geometry of embankment can be arrived at from the following considerations.

q_{all} = C Nc /FS

q_{all} = y.H_{all}

where

q_{all} = allowable bearing capacity

Y = unit weight of the embankment soil

H_{all} = allowable height of the embankment

Nc = bearing capacity factor

C = undrained shear strength of the foundation soil

FS = factor of safety

From the above equations we can calculate the allowable height of the fill.

(b) ***Global stability :*** It is necessary to check the stability against slope failure passing through the foundation cutting across the geotextile, thereby, arriving at the required strength design of geotextile in major and minor principal stress direction.

(c) ***Elastic deformation :*** The amount of elastic deformation allowed by the geotextile will govern the deformation of the embankment. The maximum strain at the required stress is assumed approximately 10%. This unable us to find the required modulus and failure strain in major principal stress direction and in minor principal stress direction for the geotextile.

$E = T_{reqd} / \varepsilon_f$

E = modulus of elasticity

T_{reqd} = tension in the geotextile

e_f = strain in the geotextile

(d) ***Pull out and anchorage:*** With the mobilization of all, or part of the fabric reinforcement's strength, the essential requirement is that the Soil behind the slip zone resists pullout. Sufficient anchorage distance behind slip plane should be available to mobilize the required strength.

$T_{act} = 2\ G\ L = 2(C_a + \sigma_\omega \tan\delta)$

$L_{reqd} = T_{act}/2(C_{a\ +}\ \sigma_\omega \tan\delta)$

where

T_{act} = actual stress in geosynthetic

C_a = the adhesion of soil geosynthetic

Tanδ = friction coefficient of the soil to geosynthetic

L = required anchorage length behind the slip plane

(e) ***Lateral spreading:*** It is necessary to arrive at the frictional properties of geosynthetic by considering the tension cracks developed in the embankment and active earth pres-sure exerted on the side. Assuming the fill material above the geosynthetic to be granular, the following criteria must be satisfied.

tan .= HK_a /L

where

L = length of the zone involved in spreading

Properties of materials

The topsoil up to a depth of 2m from the ground level is the mainly silty sand and clay mixture. The soil below this depth is black plastic clay. The soil in general found to have a natural moisture content ranging from 70% to 85% with bulk density varying from 1.3 g/ cc to 1.45 g/cc.

Undrained shear strength of the soil as determined from vane shear tests was found to be 4.6 kN/sq. m -6.0 kN/sq. m. Compression index (Cc) varied from .15 to .29 and coefficient of-consolidation (Cv) ranges between **1.1 X 10^{-3} to 3.0 X 10^{-3}** sq. cm.

Construction procedure

The geotextile is available in width of 75 cm., so, 10 pieces of geotextile are stitched at the site to make the width to 7m and 26m long geotextile (base width of embankment is 23m and anchorage length at both ends is 3m) and are carried to the site. Before spreading the geotextile the site was cleared off all debris and any tree roots. If any rough surfaces are left which cannot be cleared, are covered with sand to minimise the damage to geotextile. The geotextile is laid with its warp direction (strong direction) parallel to the width of the embankment. A trench of size 0.5m X 0.5m X 0.5m was dug in the soil on either side along the embankment length, for anchoring the geotextile the geotextile was placed in the trench and sand filling was done for proper anchorage. Ten pieces of geotextiles were stitched to make the width to 7.0 m and length 26.0 m and were carried to the site. Base width of embankment was 23.0 m and anchorage length at both ends was 3.0m. An overlap of 30 cm was given between two rolls of geotextiles. The geotextile was stretched manually, so that no wrinkles would be there while spreading, this also builds a small initial tension in the geotextile. An overlap of 30 cm was given between two rolls of geotextile. After spreading the geotextile and anchoring it at the two ends a sand cushion of minimum 30 cm thick was laid, to take care of the damage due to moving trucks or any other vehicles. Sand filling in the embankment was continued in the usual manner. Settlement gauges were installed to monitor the settlement in the embankment. The jute geotextile was used for 110m length of the road stretch. Approximately a total of 3000 sq. m of jute was used in this project.

Woven jute geotextiles with properties given in Table-2 was used at the experimental stretch at Kakinada Port area for reinforcement and also as a separator between the embankment and the soft subsoil. Monitoring of completed embankment i.e. both treated and control stretch, was carried out by JNTU College of Engineering, Kakinada.

Table-2 Properties of Woven Jute geotextiles used at Kakinada Port

S. No.	Property	Test value
1.	Thickness	5mm
2.	Weight	750gsm
3.	Tensile strength	15 kN/m
4.	Elongation	10%
5.	Puncture resistance	350 N
6.	Overlap length	300 mm
7.	Type of fabric	Woven

Drainage and Filtration

Design and construction or drainage filter using jute geotextile at Hanuman Setu, New Delhi.

The drainage filter should adequately satisfy its performance during and after construction of the structures. In case of high embankments constructed using flyash as fill material, the drainage aspects of the fill material is of critical importance during construction period because or high permeability or fly-ash. In the case of Road Over Bridge, such as Hanuman Setu, the filter criteria was critical during the construction as the water percolation into the back fill is more during construction particularly in monsoon season. After construction of ROB, the percolaiion of water was negligible as the road pavement material was impermeable and camber of 1 in 30 also facilitates a faster run-off. Thus, the filter thickness requirement was more during construction than after construction. In such cases, jute geotextile as filter can be effectively and economically used along with reduced thickness of conventional filter, which will be sufficient after the construction is over. As non-woven jute geotextile satisfy the filter criteria and had shorter life, it could be economically used in structures such as approach embankments to Road Over Bridges.

Design criteria

Fly ash was used as a backfill material in the said project. Because of lower specific gravity and finer gradation of the material, design requirement was more critical than the conventional backfill material. 750 gsm non-woven jute geotextile was substituted for 30 cm thick conventional filter. Conventional filter was designed based on normal practice of IRC.

The filter was designed according to the following criteria:

D_{15} of filter material < 4 to 5

D_{85} of base.material

D_{15} of filter material = 5 to 20

D_{15} of base material

D_{15} of filter material = 2 to 4

Maximum opening size of pipe

Grain size curve of filter material may be parallel to the base material.

Gradation of different materials :

i. Pond Ash

D_{15} = 0.075 mm

D_{85} = 0.09 mm

ii. Gradation type 1 (medium to course sand)

D_{15} = 0.45 mm

D_{85} = 3.0 mm

iii. Gradation type 2 (fine gravel, uniformly graded)

D_{15} - 15 mm

D_{85} = 20 mm

CONSTRUCTION

Fly ash was compacted in layers of 20-cm. thicknesses up to the edge of the facing panel. Once the height reached up to the next geogrid level, trench of width 0.6m was excavated in the compacted fly ash. Jute geotextile was cut to the required size and placed vertically in the trench. Sand and coarse aggregates were filled in the trench and compacted. Properties of the used for the application jute geotextile are given in Table 1. At the time when the construction of the embankment was just completed and only paving was left, about 100mm of rainfall occurred. From the visual inspection after the rainfall, it was found that jute geotextile retained the fine fly ash effectively and water drained through the jute geotextile.

Jute Geotextile as Drainage and Filtration application on Joshimath- Mallari Road :–

The stretch of Joshimath Mallari Road at km 3.5 on SH-45 in U.P., has been experiencing subsidence and sinking for the last many years. The stretch is located on debris slide area and debris consists of micacious sandy silt. A number of seepage points were observed on the uphill as well as downhill slopes. The road was experiencing subsidence during the monsoon every year, including damages to the restraining structures. Breast walls constructed earlier have got damaged due to slip. During rainy season, the whole slope mass gets saturated and surficial and subsurfficial water flows down the slope. The subsurface water flowing downhill side saturates the subgrade completely and exists in plastic state under the repeated load of moving vehicles. The pavement thus experiences continuous gradual subsidence under repeated loading at many locations in the stretch.

As a measure to arrest the sinking of road pavement, a systematic network of roadside trench drains and cross trench drains was proposed using non-woven jute geotextiles. Conventional roadside trench drains consists of a shallow trench filled with graded aggregate filter material with or without a perforated pipe. Such a drain is difficult to construct as the procuring and placing of graded filter pose problems. Such drains even if constructed would loose its efficiency due to clogging as the fine materials enter the filter material and filling the voids. The trench drains were made of rubbles encapsulated in non-woven jute geotextiles to prevent the finer particle entering into the voids of rubbles, thereby clogging the trench drains.

About 1000 sq.m. of non-woven jute fabric having 750 gsm has been used for drainage application on about 100 m. length of road stretch on Joshimath-Mallari road during June, 1996. The monitoring of field experiments on this particular stretch of treated road was carried out in June, 1997 and has shown very encouraging and satisfactory results. There has-been no further sinking and subsidences of the road at this location.

Jute Geogrid for Erosion Control of Denuded Slopes :–

On the basis of field studies, CRRI has come to the conclusion that shallow surficial slides constitute a significant proportion of landslides in areas with moderate rainfall intensity and where soil cover is medium cohesive in nature. Most surficial landslides occur as a result of denudation of vegetation on soil slopes consequent upon a cut being made for road construction purposes. Denudation of vegetation does occur due to landslides, both surficial as well as deep-seated. Surficial slides extend to only a couple of meters below the slope surface and originate as a result of erosion from flowing water. If erosion is allowed to proceed unchecked, there is the possibility that the damage may spread laterally or the depth of erosion may increase, eventually resulting in a much larger damaged slope area. Vegetative turfing represents one of the most important corrective measures in either case. In the case of freshly exposed cutting made for road construction, vegetative turfing is important, even as a preventive measure. In the case of deep-seated slides, however, vegetative turfing is only one of the ingredients of the total mix of corrective measures and as such it can prove to be effective only when conjointly implemented with other corrective measures. Vegetative turfing has proved to be, by and large, the most economical and simple means of protecting slopes of hills and embankments against erosion.

Based on several field trials carried out by the Institute, (Table-3) technique has been developed for treatment of erodible slopes as a part of landslide correction works either singly or in combination with other techniques.

Table-3. Field Experiments on erosion control using Jute geotextiles

Project site	Application	Specification of jute geotextile	Quantity used
Satun, Ponta Sahib-SH-1 in H.P.	Erosion control by growth of vegetation	Jute netting 2cmx2cm grids	2000 Sq.m
Kaliasaur slide	Arrest debris flow and growth of vegetation	Jute netting 2cm x 2cm grids	1000 Sq.m.

Brief details of the technique is given below :–

The slopes are initially demarcated, graded and fertilised. The leveling of the area must be ensured so that when netting is laid it may cover the entire area flush to the ground permitting water to flow over the netting/geogrids. First a dose of seed broad casting of locally available perennial grasses is done. Thereafter, jute netting/geogrid of 1.25 cm to 2.50 cm openings size and having roll width of 1.0 m to 1.25 m, is laid on the prepared slope surface firmly in the direction of water-flow. The widths of netting are secured against displacement by an overlapping of 5 cm to 8 cm and stitched or pegged down with 15 cm long steel nails about 1.0 m apart. The top and bottom ends of the fully stretched jute netting are fixed/anchored in trenches of 30 cm depth. Afterwards, another dose of seed broadcasting and dibbling of locally available grasses 15 to 20 cm apart, row to row is carried out.

The jute net provides innumerable miniature check dams thus absorbing the impact and kinetic energy of the falling rain drops and surface runoff, thereby, reducing its erosion potential. The soil, seed, grass root slips are kept in situ without being dislodged, thereby, getting full benefit of moisture. After the first rainy season, the seeded and sprigged vegetation soon envelops the entire surface thus protecting the slopes permanently. Jute geogrid have been observed to have a life of about 2 to 3 years in the field, which is sufficient in fully promoting the growth of vegetative cover over the denuded slope. Once vegetative growth is established within two monsoon seasons, the mission is accomplished for the jute geogrid. At the end of jute geogrid's life, the geogrid decomposes and in the process adds nutrients to the soil. The method proved particularly successful if it is so timed that advantage is taken of the increased moisture content of the soil resulting from the first couple of monsoon showers. Elsewhere in 1994, Oosthuizen and Kruger carried out a comparative study regarding moisture absorption capacity of jute, coir and sisal for erosion control purposes. Jute has maximum absorption capacity of about 400% of its dry weight as compared to about 175% for sisal and 150% for coir.

Laboratory and-analytical studies have been carried out at CRRI concerning the role of vegetation in improving the stability of slopes. It has been established by laboratory testing that the binding effect of roots imparts to the soil a cohesive strength equivalent to a minimum of 2.0 to 2.5 t/sq.m. Assuming an effective depth of penetration of 0.5m and increase in cohesive strength of 2.0 t/sq.m, analyses has shown that under certain conditions of slope geometry, a significant increase in the factor of safety is estimated up to a depth of about 6m. Thus, by providing a vegetative cover, not only the erosion of the slope is checked, but also the possibility of shallow failure averted, due to the strengthening of the top 0.5m of the hillslope.

Field experiments for erosion control in Himachai Pradesh :–

Before laying jute geogrid/netting singly on any denuded slope, selection of such a slides was made where only jute geogrid installation was required without the combination of other remedial measures such as retaining structures and drainage measures. If there is need of any other remedial techniques in combination with this technique, then user agency should implement these other techniques also subsequently. Otherwise, it would not be effective in controlling the erosion of denuded slides due to failure of slopes for the lack of implementation of other techniques. Keeping in view the above facts, a denuded slide area was selected in Himachal Pradesh in April 97, where only jute geogrid was needed to be used for erosion control. The slide area is located at km 31.20 at Sataun near Poanta Sahib on SH -1 in H.P. The width of the slide area is about 30 m and the height of the crown of the slide above the road level is about 120m.

In order to prevent the movement of debris and promote the growth of vegetation on slopes, which are in the denuded condition, about two thousand square metres of jute, geogrid was installed in June, 1997, The specifications of jute geogrid are given in Table-4. Locally available plants and grasses were dibbled subsequent to the installation of jute geogrid over the slope. The treated experimental stretch was monitored for its performances for a couple of years.

Table-4 : Specifications of jute Geogrids installed over the denuded slope

S. No.	Desciption	Properties
1.	Material	100% *Jute*
2.	Type	Woven with square grids
3.	Grid size	2.5 cm x 2.5 cm
4.	Mass	750 gsm
5.	Form	Continuous rolls of 1.2m width

Stabilisation of landslide at Kaliasaur

Description of Slide

Kaliasaur landslide is very old which is operative since 1920. Since then it has repeated itself a number of times. Records show that this landslide reactivates almost every year. The landslide is situated at the bank of meandering Alaknanda at km. 147 on Hardwar-Badrinath road. Disastrous occurrence of the landslide event can be marked in September 1989 when it blocked about one fourth of the river Alaknanda which flows about 100 m below the road level.

Geology of Slide Area

The main rock types in the slided area are represented by pink quartzite, maroon slates, dolomitic limestone and metabasic. The rock in the area is faulted and jointed. These rocks are pulverised and shows effects of cataclasis and mylonitisation. The rock is also marked by a number of mesoscopic shears. Quartzite has developed bedding joints, opening out on the free face towards the road, where as the slate bands are highly fractured. There are a number of scree zones. Scree deposits and middle one by fractured quartzite occupy the lower part of the slide. The length of the road affected by the slide area was approximately 300m. The slope angle ranged from 40 degree to 50 degree. The height of the crown above the road level about 165 m. The slide was multi-tier slide having combination of surficial and deep-seated movements. The area around the slide was thickly forested.

Mechanism of Slide

The crown portion of the slide appeared nearly vertical with a height of about 15m concaving towards the road and was in unstable condition. Village Chatikhal is situated less than a kilometer away from the crown of the slide. A series of tension cracks existed in the area between the crown and the village. The slided portion was found in denuded state both uphill side as well as down hillside of the road. The rock in the upper portion of the slide was found to be in weak state, weathered and fractured. The concave portion of the crown had become a shelter house for wild animals like deers and wild goats. The rock pieces break under the impact of the foot of the running animals and start falling down the steep slope. The upper portion of the slope was quite steep, of the order of 60^0 to 70°. and the falling pieces attain high speed. A falling stone hits another stone resting on the slope, which also starts falling down. In this way, a chain reaction was created setting into motion a number of stones and movement of the loose debris material. This sustained movement of the debris prevented any plant to take root and thus the slided portion remained in denuded condition for the last about 50 years.

Installation of Jute Geogrid

It was proposed to install jute geogrid on the denuded debris mass. The main object of the installation of jute geogrid at this site was to stop the sustained movement of the slope debris and need for plantation to be carried out. The uphill site slope material consists of gravel with fine soil, existing in a heterogeneous state. One thousand square meter of jute geogrid was used to protect an area on the denuded slope. The jute geogrid was in the form of rolls of width 1.2m and of continuous length. The total area or the slide debris is approximately 5000 sq.m. So, with 1000 sq.m. Only a part or the slope area could be covered. Top length of about 60m of the slide consists of partially weathered rock. The area covering a length of about 50m below this was selected for installation of jute geogrid. Geogrid pieces of 60m length were cut and a layer was laid. The top and lower ends of the geogrid were buried into trenches of about 50cm. depth. Next length was similarly placed along side of first length and the two lengths were stitched together. In this way, the entire fabric was laid to Cover 1000sq.m. of the area. Steel nails of about 8mm MS and of 40 to 50 cm. in length were also used to anchor the total free lengths on both sides. Nails were also used to anchor the fabric at various selected locations in the entire covered area. The fabric was laid in the month of June 1996. The executing authority was requested to identify locally available bushes and shrubs and carry out the plantation work during the coming monsoon. It was also advised to periodically spread the seeds of these plants.

Cost aspects and comparison with other techniques

Over the past few decades, geosynthetics have been recommended for erosion control in 'many projects in India. These geosynthetics based on petroleum products are very costly in India and. the user agencies are reluctant to use these geosynthetics on a wide scale basis. Availability of natural jute in India is in abundant quantity and this is the reason that natural jute geogrid gives an advantage in terms of cost. Jute geogrid is biodegradable and eco-friendly. With the prevailing price structure in India, the use of jute geogrid works out to be highly economical. A comparative cost study of different techniques for .erosion of denuded landslides has been made and shown in Table-5. From this study, it clearly shown that Jute-geogrid is one of the most cost effective and at the same time eco-friendly technique as compared to others.

Table 5 Cost Comparison for different erosion control techniques

Technique	Material cost (Rs)	Labour cost (Rs)	Overhead (Rs)	Total cost (Rs)
	For 100 Sq. m of stretch			
Jute-Geogrid	700	600	500	1800
Coir-Geogrid	2400	600	500	3500
Tenax MS-IOO	3000	800	800	4600
Amoco	5000	800	800	6600
Asphalt mulch	900	900	800	2600

Note: *Costs are approximate and based on the rates prevailing in 1997prices*

CONCLUSIONS

The completely biodegradable nature of jute netting has a distinct advantage over other synthetic used in the control of soil erosion in many developed countries where the demand for environmentally safer products is increasingly growing. The eco-friendly as-pects of jute netting can have a greater role in erosion control applications in several areas of highway constructions such as embankment slopes, pavement shoulder, flood control projects, ram and forestry applications and sand dune stabilisation.

Field experiments carried out at various places in India, has shown that the jute geotextiles play on effective role as various applications in highway engineering. The jute geotextiles can be more effective, eco-friendly and economical if used judiciously and conjointly with other measures. The jute geotextiles in their present form are suitable for separation, filtration, drainage and reinforcement functions. However, there is need to design and develop specifications of fabrics to suit geotechnical applications in different areas.

The field experiments have clearly demonstrated the applications of jute-based geotextiles for road construction projects. Sustained efforts are required for dissemination of technology and also to continue efforts to explore new areas.

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CONTROLLING LANDSLIPS WITH JUTE GEOTEXTILES

Tapobrata Sanyal

ABSTRACT

The phenomenon of land-slips has been under intensive study by geologists and geotechnical engineers. Vulnerability of ground conditions, geotechnical deficiencies, geological adversities, natural calamities like intense precipitation and anthropogenic interventions singly or in combination may cause land-slips. Geotechnical equilibrium is disquieted when the driving forces causing land-slips exceed the resisting forces. As a consequence, the top soil on slopes in hills may get disintegrated due to intensive precipitation or shaking due to tremors. In such circumstances the unconsolidated soil in the upper layer flows down rapidly down the slope and ultimately destabilizes it.

Usual remedial methods include geometric correction, hydrological modification, chemical or mechanical interventions. Presently the stress is on bio-engineering solutions. Bio-engineering method essentially consists in utilizing suitable vegetation to hold the top soil. Jute Geotextiles (JGT) could be a supportive aid in adopting bio-engineering measures because of some of its unique features.

This paper discusses about as to how and to what extent JGT could support bio-engineering measures in lessening the effects of land-slips.

INTRODUCTION

The phenomenon of landslides assumes different forms considering the nature of mass movement (of earth/rocks/ debris)and the type of materials moved. The International Association of Engineering Geologists (IAEG) has differentiated the nature of landslides/ slips as fall, topple, slide, spread and flow.

The reasons of landslips are principally geological and geotechnical accentuated by severe anthropogenic interventions. A detailed investigation into the causes of landslides by the International Geotechnical Society's UNESCO Working party on Landslides reveal that there could be ground causes (dominantly geological), morphological (caused by natural agents), physical and man-made.(April 1982). Landslips are triggered usually by these causes concomitantly.

Experience shows that severe and uncontrolled surficiial erosion is a major triggering factor behind landslips. External manifestation of such erosion is visually discernible, though the triggering factors may be several. Soil erosion on surface may be controlled by application of Jute Geotextiles (JGT) though admittedly control of surficial erosion cannot prevent landslips without geometric corrections, hydrological modification or appropriate chemical/mechanical methods.

The present global trend is to go in for bio-engineering measures which are essentially nature's intervention in controlling landslips. Admittedly natural interventions alone may not check landslips and often there has to be engineering measures that can mediate natural and man-made measures. JGT is one such product that matches with the said strategy.

This paper highlights application of JGT in checking erosion on surface which is a major triggering factor behind landslips.

Analysis of the Phenomenon of Soil Erosion

The phenomenon of surficial soil erosion may be analyzed considering four principal aspects. These are —

i) severity of overland flow

ii) intensity of precipitation

iii) steepness of slope

iv) bareness of ground

The role of each of the aforesaid four factors is clarified hereunder..

i) To assess the magnitude of overland flow i.e. its severity, we may refer to Universal Hydrologic Equation (UHE) which, in its simplest form, considers three outlets for dissipation of precipitation. These are—in-soil penetration, surface run-off and overland storage.

   In-soil penetration depends on hydraulic conductivity and the extent of saturation of the soil. The larger is the hydraulic conductivity of soil, the greater is the in-soil penetration and correspondingly the lower is the overland flow/surface run-off. On the other hand, the more the soil is saturated, the less will be the in-soil penetration resulting in higher surface run-off.

   Overland storage is interception of run-off. If a portion of the overland flow can be intercepted as storage, the erosive force will get somewhat reduced. The factor of reduction of overland flow velocity is however not covered under UHE.

ii) Detachment of soil particles as a result of kinetic energy (impact) of rain drops and their transport by the overland flow take place in sequence. In fact UHE and this phenomenon are to be considered in conjunction to ascertain the type and extent of control measures needed by providing a JGT-cover. The more intense is the precipitation, the higher will be the K.E. and more pronounced will be soil detachment.

iii) The velocity of overland flow accelerates transportation of detached soil particle. The magnitude of flow velocity is dependent on slope steepness. In plains it is the ground gradient that largely controls the flow vector.

iv) Bareness of the ground influences soil detachment. If the ground has a vegetative cover, detachment of soil as a result of precipitation will be far less. In fact vegetative cover also acts as a receptacle delaying release of overland flow and slowing down its velocity.

The main thrust to check surficial soil erosion would thus be —

a) To prevent, at least partly, direct impact of rain-drops on soil

b) To reduce the velocity of overland flow

c) To entrap detached soil particles, to the extent possible, while being transported by overland flow to control top soil loss

d) To arrange for intermediate storage of water overland, if possible.

The situation warrants that we have to look for a bio-cover that fulfills the aforesaid criteria.

How JGT Can Help ?

JGT if properly designed can fulfill the said criteria besides facilitating growth of vegetation in view of certain unique features of jute. These are

-High water-absorbing capacity—about 5 times its dry weight. JGT as a result helps in overland storage of water to some extent.

-3D construction of JGT helps in successive reduction of run-off velocity by acting as mini-barriers across the flow direction and can entrap a portion of the detached soil particles under transportation with the run-off

-Jute, being bio-degradable, facilitates growth of vegetation by acting as mulch, evening out extremes of temperature, retaining a congenial humidity level and thus creating a favourable micro-climate suitable for vegetation growth

-Adds nutrients to the soil at micro-level and increases its hydraulic conductivity

-Bio-degradable and renewable resource—absolutely eco-compatible.

Ingold (1991) earlier outlined these advantages of JGT in erosion control in his internal report to International Trade Centre (ITC).

- protection against rain-splash detachment
- high absorbing capacity of water
- reduction of the velocity of surface run-off
- high ground storage capacity
- creation of congenial humidity
- mitigation of extremes of temperature
- protection against direct sun-rays and desiccation
- providing a sufficiently open structure that does not inhibit plant-growth
- bio-degradation adding useful fibres to the soil
- providing an environmentally acceptable appearance posing no problem for future maintenance.

Design Approach

Considering the factors of economy and rate of vegetation growth it is advisable to opt for an open weave (O W) JGT with at least 4mm of thickness and of suitable mass in gm/sqm (*gsm*) that can reduce the run-off velocity progressively, effect good overland storage and allow vegetation to sprout before degradation of the fabric. Complete soil-cover with JGT is not an ideal solution as closely woven JGT will be uneconomical and may hinder the growth of vegetation at the desired rate.

The question that obviously surfaces is about the limit up to which jute yarn bundles in open weave JGT that are normally prescribed and used can withstand a certain velocity of surface run-off considering its extensibility and tensile strength for a specified opening. This should be the basis of design methodology for open weave JGT for soil erosion control.

It is therefore important to determine the maximum rain-drop diameter and the drop velocity to assess the kinetic energy of rain drops that can disintegrate the soil particles. The next step will be to have a realistic idea of the soil, especially its erodibility considering its average grain size, Plasticity Index, hydraulic conductivity etc. The third step will be to assess the terminal velocity of the overland flow which is a factor of the soil gradient, the slope length and the intensity of precipitation.

On the basis of the above inputs the open weave JGT should be designed. The design should specify the thickness of the fabric i.e. the diameter of jute yarn bundles, their tensile strength and the size of the opening (porometry) for a particular area based on data such as maximum intensity of rain fall, the gradient of the ground with length to be covered and the soil characteristics, especially its cohesiveness and hydraulic conductivity.

Specification of JGT

Three parameters that are critical for designing open weave JGT in view of the analysis as afore-said are—

a) Thickness of the fabric. This depends on the diameter of the jute yarn bundles that are used as warp/weft of the Open Weave JGT.
b) Tensile strength of the jute yarn bundles
c) Opening size of the O W JGT

Overland flow moves usually as a thin sheet of water. If the precipitation is intense the rainwater does not find time to infiltrate into the soil (Hortonian Run-off). Saturated soil also results in higher run-off (Saturation Excess Run-off). We need to determine the maximum velocity of the run-off over a slope first and also the thickness of the sheet of water under the severest conditions in a locality.

Thickness of the water-sheet may be a parameter in determining the thickness of the OW JGT i.e. the diameter of the weft-side jute yarn bundles lying *across* the direction of the surface run-off. The weft yarns act as micro-barriers reducing the velocity of flow progressively as it flows down a slope.

Kinetic Energy of rain-drops may be calculated from the following relation—

$KE = \frac{1}{2} m \times V_d^{\,2}$ where KE is the kinetic energy generated by rain drops, m is the mass of a rain-drop and V_d is the drop velocity. Mass of a rain-drop usually varies directly as the cube of the drop diameter (W H Wischmeier & D D Smith-1958)

The question of disintegration of soil particles depends not only on the KE of rain drops, but also on the soil composition. It is necessary to establish a correlation between KE and soil composition in terms of detachment potential of the soil. This can be done by simulation tests.

The next important consideration is the rate of transportation of the disintegrated soil particles with the overland flow. Transportation of detached soil particles obviously depends on the velocity of the overland flow and size of the disintegrated soil particles. The velocity of the overland flow is a factor of the intensity of precipitation as well as the slope of the ground. Lenard found that the terminal velocity caused by a rain-drop of 3 mm diameter could be of the order of 6.89 meters/second. In this case also a correlation between velocity of overland flow, and particle size (and of course its specific gravity) requires to be established.

The next step will be to consider putting on trial open weave JGT of different weight and thickness and to calculate if the yarn bundles can withstand the bending stress generated due to the overland flow.

The amount of storage of water by the chosen OW JGT may be calculated from the following relation (Sanyal 2006) —

$$S = \frac{N \times d^2 \times (4 \cot \beta - \pi) \times 10^3}{8} \ mm^3/m^2$$

where S denotes storage as a result of posing of micro-barriers by OW JGT against the overland flow, β is the angle of inclination of the ground slope, d is the diameter of the weft yarn-bundle and N is wefts per meter.

Absorption of water by the jute yarns will be added to this value. The hygroscopicity of jute varies between 450% and 500% of its dry weight. If an OW JGT of 500 gsm is installed and if hygroscopicity of jute is assumed to be 450% of its dry weight, the fabric is supposed to absorb water to the extent of 2250 gm/sqm of water i.e, 2.25 litres / sqm.

Following the relation above, it can be shown that with a slope of 1:2, d==4 mm & N=45, the storage will work out to 0.437 litres per sqm. In other words the total storage will be under the stated assumptions (2.25 + 0.437) or 2.687 litres per sqm.

But the calculations above do not consider the important aspect of the structural adequacy of a particular OW JGT against the velocity of overland flow generated due to a certain intensity of rainfall and consequent disintegration, transportation and entrapment of the detached soil particles by JGT. Resultant reduction of velocity of overland flow due to posing of successive micro-barriers by OW JGT against it requires to be determined also.

Admittedly not much study has been done on the issues pointed out in the preceding. Usually O W JGT is designated by its mass (gsm). In areas with high intensity of rainfall (@ $\geq$ 15 mm /hour), O W JGT of mass 730 gsm is recommended. In low and moderate rainfall areas OW JGT of 500 gsm has worked. It may be noted that O W JGT of any weight can be manufactured by jute mills. Typical specification of OW JGT may be seen in Table I.

Vegetation on Eroding Ground

JGT alone can generate vegetation unless the top soil contains seeds. It is important that vegetation is carefully selected. Vegetation should have deep and strong roots (up to about 2-3 meters) that increase the shear strength of soil and adds to its cohesive properties. In fact soil improvement depends on root morphology especially on root density and root length (Mickovsky & van Beek 2006).

Effectiveness of vetiver grass is now widely discussed. It has been reported that vetiver roots with tensile strength of 75 MPa improves soil strength by about 40%. Vetiver grass grows both in acidic and alkaline soils under a wide range of temperature variation (0°C to 50°C) and soil features including BC soil. Vetiver does not require maintenance, is durable and has a long effective life. (TVNI Web-site on Vetiver).

It is felt that the possibility of inter-weaving green vetiver grass with JGT should be explored (with suitable fabric engineering) as the combination can constitute an ideal turf-reinforcing mat (TRM) to withstand soil erosion far more effectively than any other bio-engineering measure.

Case Studies

1. HILL SLOPES ON KALIASAUR LANDSLIDE

Specification of Non Woven JGT

Table – 1

1.	Weight	500 gm/sqm.
2.	Thickness	5 mm
3.	Width	1220 mm
4.	Tensile Strength	10 x 7.5 kN/m (in warp & weft direction)
5.	Open area %	50%
6.	Water retaining capacity	500%

A study was taken up by CRRI to assess the causes of landslide on Kaliasur. A number of causative factors were determined to analyze the slopes to suggest the remedial measures. Kaliasaur landslide is very old which is operative since 1920. Since then it has repeated itself a number of times. Records show that this landslide reactivates almost every few years. The landslide is situated at the bank of meandering Alaknanda at km.147 on Haridwar-Badrinath road. Disastrous occurrence of the landslide event happened in September 1989 when it blocked about one fourth of the river Alaknanda, which flows about 100 m below the road level.

<u>Geology of Slide Area</u>

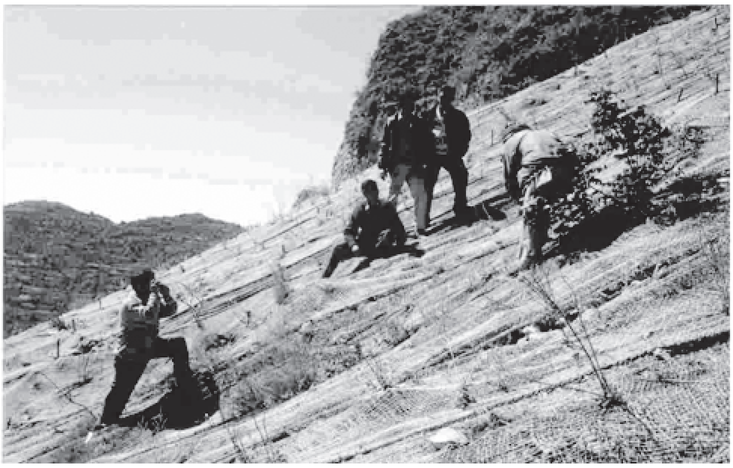
The main rock types in the slided area are represented by pink quartzite, maroon slates, dolomitic limestone and metabasic. The rock in the area is faulted and jointed. These rocks are show effect of cataclasis and mylonitisation. The rocks are marked by a number of mesoscopic shears. The rock in the upper portion of the slide was found to be in weak state, weathered and fractured. Quartzite has developed bedding joints, opening out on the free face towards the road, where as the slate bands are highly fractured. There are a number of scree zones. Scree deposits and fractured quartzite occupy the lower part of the slide. The length of the road affected by the slide area is approximately 300 m. The slope angle ranged from 40 degree to 50 degree. The height of the crown above the road level about 165 m. The slide was multitier slide having combination of surfacial and deep seated movements. The area around the slide is thickly forested.

<u>Mechanism of Slide</u>

The crown portion of the slide appeared nearly vertical with a height of about 15 m concaving towards the road and was in unstable condition. Village Chatikhal is situated less than a kilometer away from the crown of the slide. A series of tension cracks existed in the area between the crown and the village. The slided portion was found in denuded state both uphill side as well as down hillside of the road. The concave portion of the crown had become a shelter house for wild animals like deers and wild goats. The rock pieces break under the impact of the foot of the running animals and start falling down the steep slope. The upper portion of the slope was quite steep, of the order of 60^0 to 70^0. And the falling pieces attain high speed. A falling stone hits another stone resting on the slope, which also starts falling down. In this way, a chain reaction was created setting into motion a number of stones and movement of the loose debris material. This sustained movement of the debris prevented vegetation growth and thus the slided portion remained in denuded condition for the last about 50 years.

Installation of Jute Geogextile

It was proposed to install jute geogrid on the denuded debris mass. The main object of the installation of jute geogrid at this site was to stop the sustained movement of the slope debris and need for plantation to be carried out. The uphill site slope material consists of gravel with fine soil, exists in a heterogeneous state. One thousand square meter of jute geogrid was used to protect an area on the denuded slope. The jute geogrid was in the form of rolls of width 1.2 m and of continuous length. The total area or the slide debris is approximately 5000 sq.m. So, with 1000 sq.m. only a part or the slope area could be covered. Top length of about 60 m of the slide consists of partially weathered rock. The area covering a length of about 50 m below this was selected for installation of jute geogrid. Geogrid pieces of 60m length were cut and a layer was laid. The top and lower ends of the geogrid were buried into trenches of about 50 cm. depth. Next length was similarly placed alongside of first length and the two lengths were stitched together. In this way, the entire fabric was laid to cover 1000sq.m. of the area. Steel nails of about 6 mm diameter and of 40 to 50 cm in length were also used to anchor JGT at various selected locations in the entire covered area. The fabric was laid in the month of June 1996. The executing authority was requested to identify locally available bushes and shrubs and carry out the plantation work during the coming monsoon. It was also advised to periodically spread the seeds of these plants. Some photographs showing the laying of geotextile is shown in Fig. In this manner by promoting the vegetation growth, the landslide activity at Kaliasaur has been contained to a large extent.



Laying of JGT at Kaliasaur land slide, HP Sirmaur

2. FIELD EXPERIMENTS FOR EROSION CONTROL IN HIMACHAL PRADESH

A denuded slide area was selected in Himachal Pradesh in April 1997, where only jute geogrid was needed to be used for erosion control. The slide area is located at km 31.20 at Sataun near Poanta Sahib on SH -1 in H.P . The width of the slide area is about 30 m and the height of the crown of the slide above the road level is about 120 m. In order to prevent the movement of debris and promote the growth of vegetation on slopes, which are in the denuded condition, about two thousand square metres of jute, geogrid was installed in June,1997. The specifications of jute geogrid are given in Table 2. Locally available plants and grasses were dibbled subsequent to the installation of jute geogrid over the slope. The treated experimental stretch was monitored for its performances for a couple of years. Monitoring showed very good performance of JGT in promoting vegetation growth and containing surfacial slides.

Specifications of Jute Geotextile installed at Sataun (H.P)

Table 2 :

Description	Properties
Material	100 per cent Jute
Type	Open Weave with square grids
Grid size	2.5 cm x 2.5 cm
Mass	750 gsm
Form	Continuous rolls of 1.2m width

Slope at Sataun Covered with vegetation after JGT Application

3. REHABILITATION OF MINE SPOILS AT SAHASRADHARA

The CSWCRTI, Dehradun selected a highly degraded abandoned limestone mined watershed near Sahasradhara in Doon valley in the outer Himalayas for rehabilitation by integrated soil and water conservation measures on watershed basis. Geo-jute was used to rehabilitate the highly erodible mine spoil slopes as described below.

Description & Physiography of the watershed

Dhandeula Kharawan Limestone quarry, Sahasradhara watershed area measuring 64 hectares, is situated in the lesser Himalayan zone of Doon valley at an altitude from 820 m – 1310 m above msI. Surface mining operations results in a huge quantity of over burden. The over burden to mineral ratio being as high as 5:1. Mineral rejects and overburden piled up at several places in the watershed were highly erodable and difficult to vegetate due to absence of top soil and poor fertility. The area receives an annual rainfall of about 3000 mm, 80 per cent of which is received during monsoon months (June to September). The area is characterised by Krol belt comprising limestone, gypsum, marble, slates and dolomite, etc. The mine spoil is sandy loam in texture with high gravel content. (60 per cent of the material is greater than 16 mm size), alkaline (pH – 8.0), calcareous ($CaCO_3$ – 61 per cent) and poor in fertility status (Organic carbon – 0.13 per cent, Nitrogen – 0.02 per cent and available P_2O_5 – 0.4 kg per hectare) and poor water holding capacity (Dadhwal et al. 1992). The poor fertility of the mine spoil inhibits the growth of vegetation. The watershed is having an average slope of 50 per cent, at some points the slopes are exceeding even over 100 per cent.

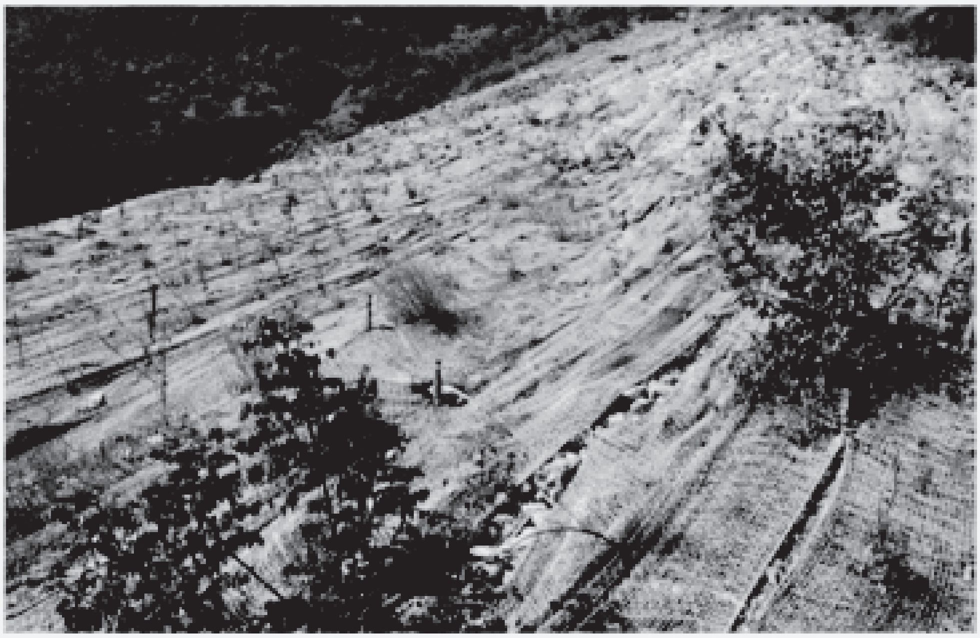
The unscientific mining operations destroyed almost all the vegetation cover of the area comprising of mixed deciduous forest species of subtropical type. This along with high rainfall and steep slopes caused heavy debris movement from the watershed, leading to frequent vehicular disruption, entailing a huge recurring maintenance cost annually. The siltation of the river downstream led to frequent floods in monsoon destroying agricultural and other forest lands.

Geo-jute for mine spoil rehabilitation

Geo-jute was tried to give temporary protection to these slopes and help protect the vegetation till it establishes. The specifications of the geo-jute used were: Weight – 500 g/m2, strand thickness – 5 mm and open area – 65 per cent. Different slopes (30 – 70 per cent) covering an area of 0.86 hectare were treated. Besides geo-jute, synthetic geo-textiles were also experimented for their performance.

Application technique

Seeds of suitable tree species (Acacia catechu, Leucaenaleucocephala etc.), were spread on the area and scarified. Grass mulch locally available was spread at the rate of 2 – 3 ton per hectare. Geo-jute was spread on the area loosely. The two adjoining widths were overlapped by about 10 cm and fastened with jute threads. Wooden sticks were driven to hold the mesh at place. Rooted slips of grasses like Saccharum spontaneum (Kans) and Thysanolaena mixima (broom grass) and cuttings/root slips/rhizomes of *ipomoea carnea, cites negundo, Arundo donax* and hybrid napier were planted in openings between strands at close spacings. The technique for application of geo-jute is shown in ……..



Sprouting of plants after laying of JGT.

Vegetation Growth

In the geo-jute area there was good growth of grasses compared to control section. *Thysanolaena maxima* grass recorded an yield of 3052 kg per hectare (oven dry) compared to 640 kg per hectare 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 per hectare compared to 1960 kg per hectare in control, *Saccharum spontaneum* also showed good performance. The grass roots provided good anchorage to the soil in the second year of plantation itself. Survival of tree species was observed to be poor. The geo-jute biodegraded in about two years, by then the vegetation cover had established itself. The vegetation cover in the geo-jute applied area was better than the vegetation cover in the synthetic geo-textiles applied area.

Moisture improvement

The geo-jute helped in moisture conservation by upto 50 per cent. It was observed that in the geo-jute area the moisture content 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). In seven days period, the seeds can germinate and moisture in deeper layers can sustain the tender plants. There was still good amount of moisture below 30 cm depth after one month from the day of occurrence of 20 mm rainfall event.

Properties of JGT used

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

RESULTS :

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 yarn manure (FYM) recorded an excellent yield of 9850 kg/ha compared to 1960 kg/ha in control.

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.

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).

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.

JUTE GEOTEXT1LE IN HILL SLOPE MANAGEMENT - CASE STUDIES IN SIKKIM AND MEGHALAYA

Tapobrata Sanyal **Sunil Verma** **P.K. Choudhury**

ABSTRACT

The hilly North Eastern states are usually slide-prone, mainly due to existence of localised geologically vulnerable zones topped with weak overburdens. Border roads in these states are mostly aligned abutting uphill slopes on one side and downhill slopes on the other. Overburdens on getting soaked after precipitation slide down and fall over the roads causing subsidence and total blockade, specially during the monsoon. Rain water initially accumulated on the top of the hills gush down when the saturation and friction limits are exceeded due to high intensity of precipitation, taking with it huge bulk of debris of the overburden.

In Sikkim which has assumed high strategic importance recently, is saddled with the landslide problems in a number of areas along the border roads-notably at Lanta Khola (72.4 km from Gangtok on North Sikkim Highway) and 9th mile (75 km from Sevoke on NH 31A). Conventional remedial measures have not been effective in the areas. In this paper, non-conventional and innovative reme-dial measures have been suggested in which Jute Geotextile figures prominently.

Similar situations, though at a lesser degree, exist near Shillong, Meghalaya at Sonapur slide (between .km 141 and km 142 on NH 44 connecting Shillong with Agartala, Tripura). The slide zone has received treatment with Jute Geotextile with satisfactory results with the active support from the authorities of project Setuk, Border Roads Organisation.

This paper also delineates the remedial approach and the experience in the aforesaid slide zone in Meghalaya.

1. INTRODUCTION

Out of several natural agents causing extensive damages to roads, landslide can claim to be a majorwrecker. The International Association of Engineering Geologists (lAEG)-has defined landslides as "mass movement of rock, debris or earth down a slope". Landslides may be looked upon from two aspects - the nature of movement and the material of movement. While the materials that are forced out due to sliding actions are basically rock, debris and earth, the nature of slides may be fall, topple, slide, spread and flow. Permanent International Association of Road Congress (PIARC) has defined each of the above five landslide varieties.

In the comprehensive Report on Natural Disaster for Roads prepared by PIARC (1995), several massive landslides in the hilly terrains of India-notably the one in Sikkim in 1968 - have been mentioned. The number of landslides in that year in Sikkim and West Bengal totalled around 20,000 killing about 33,000 people. In fact, landslides in the North-Eastern states of India including the Northern West Bengal are common during the monsoon. A number of studies have been made in regard to assessment of landslide damages. The direct cost of landslides on the road transportation system can be objectively estimated by measuring the affected stretch of the road, duration of road closure, extent of damage to adjoining stretches and the number of casualties. Duration of road closure has a direct bearing on the natural economy and has an indirect monetory impact. The endeavour should therefore be to identify potential landslide areas and to undertake preventive measures before landslides are allowed to take place. Jute Geotextile (JGT), an engineering fabric made of Jute, may help provide biotechnical solution to landslide problems selectively.

The paper discusses two potential landslide zones in Sikkim and one in Meghalaya and suggests remedial measures by selective use of JGT. Border Roads Organisation (BRO) handles all the three affected zones. While remedial actions have already been taken in Meghalaya, the suggestive measures at two places in Sikkim are under consideration of BRO.

2. Reasons of Landslides

There are several causes for landslides. Vulnerable ground conditions, geomorphological adversities, occasionally occurring natural physical forces and anthropogenic intervention - one or some of these reasons may be instrumental in precipitating landslides. The table below has been adapted from the recommendations of the International Geotechnical Society's UNESCO Working Party on Landslide Inventory (April, 1992).

Table

Causes of Landslides

i)	Ground Causes	(a) weak, sensitive or weathered materials (b) vulnerable ground structure (Joints, fissures etc) (c) change in engineering properties (permeability, plasticity etc)
ii)	Morphological Causes	(a) ground uplift (tectonic, volcanic etc) (b) erosion (wind, water) (c) scour (d) deposition and overloading on the slope crest (e) denudation (forest fire, drought)
. iii)	Physical causes	(a) prolonged and intense precipitation (b) rapid drawn down (c) thawing (d) swelling and shrinking (e) artesian pressures
iv)	Anthropogenic Causes	(a) excavation (at the toe of slope) (b) loading on slope crest (c) dewatering of reservoirs (d) deforestation (tree-felling) (e) mining (f) artificial vibration (g) water impoundment and leakage from utilities

The reasons enumerated above tend to destabilise the equilibrium by either increasing the driving forces causing the landslides or by decreasing the resisting forces acting to stall them. In slopes-specially in hilly regions-continual erosion of the surficial soil may cause their steepening beyond its limiting angle of stability (determined basically by the angle of internal friction of the slope-soil). Agents causing soil erosion are several. In hilly terrains in India, it is high surface run-off caused by precipitation that causes slope soil erosion more than other reasons. Internal piping is also a reason for such erosion in hills with overburdens.

Over-saturation of overburdens on slopes due to precipitation is a major cause of slides/slips in the North-Eastern part of the Country. Denudation of slopes is another factor that enhances vulnerability of slopes to slides/ slips.

The effects of dynamic physical events as precursors to landslides often go unnoticed. Seismic activities can adversely alter the ground stresses within a slope. Tectonic forces can cause ground uplifts. Accumulation of rain water on top of a slope, melting of ice sheets etc can also undercut slopes.

The resisting forces against slides get weakened due to reduction of the inter-particular bondage and, as a consequence, the shear strength of the ground mass. Obstruction to natural drainage paths within the slope-soil may lead to development of undue pore water over-pressure and is a major factor in causing reduction of slide-resisting forces. Slope materials also degrade. Deformations may take place along old slip-surfaces and pre-developed shear zones within a slope.

Quite frequently, the state of stress within a slope may undergo progressive changes. Superficial assessment of the nature of the existing overburdens may sometimes be deceptive because anisotropic stress conditions may develop within natural geological formations. Lateral stresses that develop do not have any predictable correlation with the vertical stresses computed from gravitational considerations.

Rate of slides may vary according to specific nature of the local geology, the overburden , characteristics, the intensity and duration of rainfall etc. Slide movements are understandably rapid in gradients steeper than 30°, exceeding a few metres per second in some occasions.

3. Remediation Concept

Remediation concept in countering landslide basically consists of two types - assessing pre-failure conditions for taking up mitigation measures and taking in hand retro-fit means to restore the failed areas.

The first type involves evaluation of the proneness to and potential for land slides and plan pre-slide measures. The best option is to relocate highways, if feasible technically, geologically and I economically. The unstable overburdens should either be removed or contained. Construction of bridges may also be considered at side-hill locations with shallow overburdens.

In the second type, the concept lies in increasing the forces to resist the landslides and/or decreasing forces propelling the slides. In an existing slide-prone area, the measures are to provide adequate passage for flow of discharge during the monsoon by cascading, to make adequate drainage outlets, benching of slopes and growth of deep-rooted vegetation on the slope for reduction of forces propelling slides.

In increasing the resisting forces, use of buttresses and counter-weight fills, installation of pillars/ palisades/ anchors/ nails etc, treatment with chemicals when the soil type is seen to react positively with certain chemicals, replacement of soft soils with a shear key and the like may be thought of. PIARC has advocated adoption of simple solutions'like counter weighting, drainage in countries with abundance of raw materials and availability of cheap labour. The Congress has strongly recommended use of biotechnical solutions for both fill and cut slope stabilisation.

4. Role of Jute Geotextiie (JGT)

Slide-generating forces are too severe for JGT and, for that matter, any geotextiie to resist them. JGT could be laid on the slopes after undertaking concurrently corrective measures in regard to guiding and facilitating the flow of water and providing lateral restraints to prevent spread of the weakened soil-mass. JGT, when laid on slopes, can reduce the velocity of surface run-off by acting as mini-check dams and can effect storage of the overland discharge to some extent by absorption of water. Jute, being highly hydrophilic, can absorb water to about 5 times its dry weight-a feature that no geotextiie can claim to posses. The mechanism is explained below -

According to Universal Hydrologic Equation, precipitation is distributed in three modes - surface run-off, through flow and storage on ground. The main erosive agent is the surface run-off which can be minimised by increasing storage and through flow. Through flow is dependant on soil permeability and also soil-saturation. Moreover, water infiltration into soil due to precipitation is a slow process usually and does not normally cause soil erosion.

We can only increase overland storage and curb the velocity of surface run-off to some extent by using Jute Geotextiie. It is understandable that if soil permeability exceeds the rate of rainfall, there is no question of any surface run-off occurring. In the reverse situation, surface run-off will take place, its velocity depending basically on the inclination of slope. The problem is complicated as a result of dis-uniformity in the rate of infiltration with time.

Yarns of JGT put up mini-barriers against the surface run-off when placed on slope. Weft yarns of JGT form a series of mini-cross barriers, reducing the velocity of surface run-off on the one hand and absorbing water on the other in the process. Due to the high degree of water-absorbing-capacity of JGT, the effective storage normally is not insignificant. Damming and water-absorbing effects of JGT contribute substantially in combating surface flow. The average moisture absorbing capacity of Jute (and hence, of JGT) is 485%, meaning 500 gsm JGT can absorb 2425 g/m^2 of water. This is much above what other geotextiles can effect. Open-weave 500 gsm JGT having 4mm dia wefts with 45 nos. wefts in a metre can store 0.44 litres of water per sq.metre for a 1:2 slope. The amount of water absorbed by JGT when added to this quantity of storage, produces an overall storage (absorption plus storage) of 2.87 litres per sq.metre. This is a unique feature of Jute Geotextiie.

Besides effecting overland storage and curbing the velocity of surface run-off JGT, in its improvised forms, can provide simple drainage solutions. Rubble-encapsulated JGT drains can be inserted into the slide-prone overburden on the slope to facilitate drainage. Such horizontal concealed drains may also help in lowering subsurface water-level. PIARC has mentioned about use of such drains to stabilise large landslides.

In a situation of erosion pumping, prefabricated vertical jute drains (PVJD) may be effective. Insertion of PVJDs - usually 100 mm wide and 5 mm thick with coir / jute wicks inside - is not easy and require special equipments. PVJDs help extract water from the interior of the soil body.

As already indicated, PIARC has recommended use of biotechnical solutions e.g. slope stabilisation with vegetation Jute Geotextile fits in admirably in such cases. Mulching properties of JGT on biodegradation help retain a congenial humidity on the soil and creates a micro-climate conducive to faster and sustained vegetative growth.

5. Situation in the Identified Areas in Meghalaya & Sikkim

The three sites that have been identified for case study in Meghalaya and Sikkim are -

(a) Sonapur Slide in Meghalaya

(b) Lantakhola slide and

(c) 9th Mile slide, in Sikkim

(a) Sonapur Slide in Meghalaya

Present Situation -

The slide zone is located on NH 44 (Shillong to Agartala) at the 142 km passing through Khasia & Jayantia hills in Meghalaya. The highway abuts hill slope on one side and the river Lubha at the toe of the down hill slope on the other. A massive landslide recurred in 2002 during the monsoon blocking the highway upto a length of 200 meters.

The slope is geologically unstable comprising clay mixed up with disintegrated stones/grits. The dip is between 40° and 60°. There are defined seepage points on the slope, which saturate the overburden gradually after onset of the rain, liquefying the clayey portions of it and reducing the slide-resisting force. The slide of the weakened soil mass starts under favourable conditions. The instability of the downhill slope could be due to erosive current of the river during the monsoon, eating away the toe of the downhill.

(b) Lantakhola Slide (Sikkim) -

Present Situation -

Lanta Khola slide is located at a distance of 72.4km from Gangtok on North Sikkim Highway. Geologically, the slide belongs to higher Himalayan crystalline sequence having gneiss as the basic ingredient. The slide width is around 50 to 70 metres, extending vertically with a not-very-steep surface slope. The road is on the influencing zone of the slide with a .visible debris-overburden of about 20 metres (unconsolidated, heterogeneous water-soaked consisting of micaceous silty sand), The debris contain both fragmented boulders and fine silt. It could not be ascertained on visual inspection if there is a stable bed well below the overburden. There are no well-defined slip curves in the slide zone which is controlled by undefined transitional planes.

A small stream of water which trickles through the slide zone in dry season, gains immensely in magnitude during the monsoon and washes down boulders and matrix ofsilt and clay. This sudden onrush of water dislodges the pavement, finds its way through, over and under the road and flows down the slope forming rills, gullies and ditches.

(c) 9th mile Slide (Sikkim) -

Present situation -

The slide is located on NH 31 A, 75 km from Sevoke. It affects almost half-a-kilometre of the road. The crown of the slide rests at a height of 250 to 300 metres above the road level. The phenom-enon of persistent subsidence and destabilisation reportedly started in 1957 and has been in high prominence since 1999. The slide is classified as a debris slide culminating in debris flow along with toe destabilisation caused by the river Rangichu.

The debris is basically weathered rock. There are evidences of seepage of ground water and also overland flow during the monsoon.

Measures taken by BRO could not withstand the vagaries of nature. There has been dislocation of stone-faced cascades, surface drains and retaining walls. BRO has been successively shifting the road gradually towards the uphill to keep the carriage-way through. Presently, there is a difference of level between inward and outward lanes. It is quite likely that-the outward lane may give in having been built overfills.

6. Remedial Measures for the Slide Zones in Meghalaya and Sikkim

Lantakhola Slide —

Temporary Remedy –

- ✔ Channelising/guiding the monsoon discharge through stone-faced cascades and side guide walls taking into account the maximum discharge during the monsoon.
- ✔ Facilitating passage of water under the road taking the maximum discharge into consideration. RCC slabs may be considered for the pavement with intermediate supports, keeping provisions for water-passage(maximum discharge).
- ✔ Management of slopes both on the upstream and the downstream sides by use of Jute Geotextile overlain by suitable vegetation.
- ✔ Providing lateral restraints at different levels (upstream and downstream sides) by driving secondhand rails
- ✔ Building of cess/shoulder
- ✔ Providing longitudinal and cross drainage, considering ‘worst event’ inputs

Necessary for providing a permanent solution -

- ✔ Geological and hydrological investigation. It is different to manage movement of thick unstable debris during the monsoon. We need to know the location of the stable rockbase under the debris for using it as support of the road superstructure as well as of the stone-faced cascades.
- ✔ Soil investigation < particle size distribution, soil permeability, Plasticity Index and other essential properties.

9th mile Slide -

Temporary Remedy -

- ✔ The best way would be to construct a new inward track, abutting the toe of the uphill slope and ljp^{r} treating the present inward track as the outward lane. In that event the present outward lane would serve as a retaining structure, providing lateral stability.
- ✔ Prevention of toe erosion of the downhill slope by constructing/remodelling the retaining wall and spurs for repulsion of flow of the river.
- ✔ Management of slopes (u/s and d/s sides) by use of appropriate Jute Geotextile overlain by suitable vegetation.
- ✔ Rebuilding of the stone faced cascades and road side drains after due consideration of the maximum discharge of flow.
- ✔ Providing lateral restraints at different levels on u/s & d/s sides by second hand rails
- ✔ Building up of eroded cess/shoulder
- ✔ Providing longitudinal and cross drainage - JGT encapsulated rubble drains may be tried.

Necessary for providing a permanent solution **-**

- ✔ the extent of subsurface flow / maximum surface run-off
- ✔ the extent of overburden and the location of the stable rock below
- ✔ geological and hydrological investigation
- ✔ soil, investigation (particle size distribution, soil permeability, Plasticity Index and other essential properties).

Sonapur Slide -

Short term remedy undertaken :

i) Channelisation of seepage water in a conventional way with drop walls and guide walls,

ii) Passage of water under the road,

iii) Longitudinal drains on the toe of up hill slopes,

iv) Cross drains at suitable intervals,

v) Covering of bare slope with open weave JGT and vegetation.

Action taken by BRO :

BRO has done an excellent job for protecting the uphill slip deposits. Sausage crate walls filled up with boulders were constructed at different levels. The spoil deposits were covered with open mesh JGT (292 gsm) in benches and slopes. Broom grass seeds were spread for vegetation on the slopes.

Planning Long Term Solutions

For planning long term solutions, geological and geotechnical investigations are necessary to diagnose the inherent weakness of the slide first after which long term solutions can be thought of.

7. CONCLUSION

Biotechnical measures taken at Sonapur slide with JGT basically for slope stabilisation have so far been effective. Vegetation has already taken roots into the slope soil. But as already indicated, such measures are of palliative nature having deep-seated ground/physical/ morphological causes which still remain to be adequately addressed. In fact, the inherent causes that disquiet the road-stability have to be identified before permanent measures can be planned.

The remarks apply to slides at Lantakhola and 9th mile slides in Sikkim also. But the problems in Sikkim slides are certainly more severe then those encountered in Meghalaya.

PIARC has incidentally recommended investigation techniques to assess the risk-potential of any vulnerable area. Terrain reconnaissance is the first step in this direction.Geologic maps, climatological records and other information are also available. Remote sensing of the areas of concern based on satellite imageries is the next step. Interpretation of imageries requires not only special expertise, but also specific knowledge of the soils and geologic history of the area under study. The third step advised by PIARC is regular field inspection by an expert. Detailed evaluation of the potential for landslides requires laboratory testing of soil and also rock materials at regular intervals. Selection of proper laboratory test-procedures for determination of soil-resistance is critical. In 1991, the United Nations established a world landslide inventory. The data base can be gainfully utilised by planners and engineers in India to know about the landslide risk potential of any area in India.

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9. REFERENCE

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