Effectiveness of Jute Geotextile for Hill Slope Stabilization in Adverse Climatic Conditions

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ABSTRACT
Efficacy of jute geotextiles (JGT) in hill slope management stands substantiated as a result of its unique attributes such as its bio-degradability, hydrophilic properties, and ability to moderate temperature extremes have few parallels among ecofriendly natural fibres. The mechanism of containment of top soil erosion is the resultant effect of velocity of surface run-off propelled by gravity, ground friction, hydraulic conductivity of the slope fill, absorption of a portion of run-off by jute yarns of open weave JGT, and barrier effect posed by them on the other. JGT also acts as mulch creating a microclimate that fosters quick growth of vegetation on biodegradation. JGT plays an important role in bioremediation of slope-erosion problems. The paper delineates climatic factors, types of JGT used, and the prevailing site conditions of various trial sites, with an attempt to analyze the mechanism of functioning of JGT in low temperature zones.

RÉSUMÉ
L'efficacité du géotextile de jute (GTJ) sur les terrains en pente réside essentiellement dans ses particularités propres, comme sa biodégradabilité, ses propriétés hydrophiles et sa capacité à régulariser les grands écarts de température. Très peu de fibres écoresponsables possèdent ces caractéristiques. Le principe anti-érosion est le résultat d'une action combinée de l'inertie du sol par gravité, la friction, la bonne évacuation de l'eau du sol tout en étant en partie absorbée par les mailles de jute. Le GTJ agit également comme paillis, en créant un microclimat favorisant la croissance de la végétation pendant la biodégradation. Le GTJ joue un rôle important pour solutionner, de façon biologique, le problème d'érosion de terrains inclinés. Cet article définit les facteurs climatiques, les types de GTJ utilisés, et les conditions prévalentes aux différents sites d'essais considérés, avec une tentative d'analyser le mécanisme de fonctionnement des GTJ dans les zones de basse température.

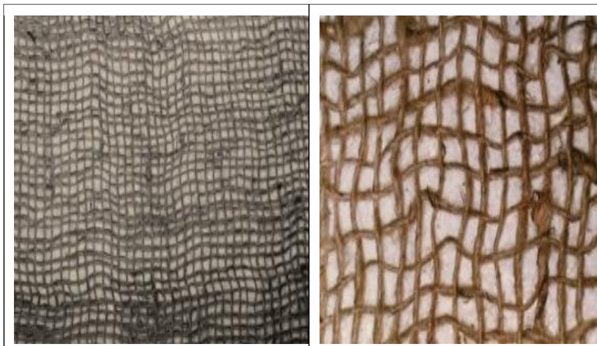
1. INTRODUCTION

Jute geotextile (JGT) is a natural technical textile sourced from 100% natural eco-friendly jute fibre, and is being increasingly used worldwide for stabilization of earthen and hill slopes. Its efficacy in addressing various soil-related problems stands established after about 215 field trials conducted so far. The unique attributes of jute, notably its hygroscopic character, high initial modulus, drapability, and spinnability, enhance its functional appropriateness for control of surficial soil erosion as an integral part of the bio-remediation technique. JGT has been used with success in plains and moderate altitudinal zones, but has not been tried so far in low temperature zones with wide fluctuations in temperature.

In April 2011, in association with the National Jute Board (NJB) of India, the Border Roads Organization (BRO, Board Road Task Force BRTF 16) undertook a pilot study within the project HIMANK for addressing hill slope distress in an area of highly diverse seasonal temperatures using open weave (OW) JGT with a weight per unit area of 292 g/m^2, at an altitude of 2,660 m above mean sea level (MSL), and adverse climatic features, near their project office at Spituk, Leh, Dist - Ladakh, Jammu & Kashmir.

The trial proved a success with the barren slope appearing green with vegetation within two to three months, and in turn preventing wind-propelled erosion in particular. These encouraging results prompted BRO to undertake another project on the Upshi-Sarhu-Manali Road, about 90.4 km away from Leh at both uphill and downhill slopes situated at an even higher altitude of 4,900 m above MSL with the use of OW JGT with a weight per unit area of 500 g/m^2. The geological features of the site was more adverse as compared to the first trial.

The result remained positively consistent in the second trial as well. The sandy soil of the hill slope was found to have stabilized within 3 months of installation of JGT and vegetation started sprouting. The interesting development was the formation of icicles only on the JGT-laid portion. Further it was also observed that JGT did not appear to lose its tensile strength, even after two years of application in this climatic zone, which could be due to the fact that microbial attack on JGT was less in sandy soil and in climatic extremes. It is felt that in-depth research and development work should be carried out on this aspect.



Weight per Unit Area 292 g/m^2	Weight per Unit Area 500 g/m^2

Figure 1. Open-weave jute geotextile (OW JGT) samples.

2. LOCATION & CLIMATIC FEATURES OF THE SITE

Ladakh and, for that matter, Leh, is encircled by the Karakoram Mountain Range in the north and the Himalayan Mountain Range in the south. The 1st site of vulnerable stretch treated with JGT, is situated at Spituk near the head-quarters of BRTF-16 on the NH-1 Highway, at an altitude of 2,660 m above MSL, with temperatures ranging between -30°C to +40°C, relative humidity of 5% to 40%, wind velocity of 110 KMPH, and snow fall of 40 cm. The second site is situated at Rumtse on the Upshi-Sarhu-Manali road at about 4,900 m above MSL and 90.4 km away from Leh, with temperatures ranging between -35°C degree to +35°C, RH of 2 to 25%, wind velocity of 90 km/h, and snow fall of 150 cm.

Due to its high altitude, Ladakh experiences temperature extremes: very cold winters and intensely hot summers. The area is windy and usually receives rainfall twice a year during June to September and October to May. Glacier-melted water is the major source of surface water. Ladakh lies on the rain-shadow side of the Himalayas, where dry monsoon winds reach Leh after being robbed of its moisture in the plains. The area experiences both arctic and desert climate. Therefore Ladakh is often called the ''Cold Desert'' having the following features:

1. Wide diurnal and seasonal fluctuation in temperature with –40°C in winters and +35°C in summers
2. Precipitation is very low with annual precipitation of 100 mm, mainly in the form of snow.
3. Air is very dry and relative humidity ranges from 6% - 24%
4. Irrigation is mainly through channels from the glacier-melted water.

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

3. HILL SLOPE FEATURES

Leh valley is a repository of para-glacial landforms namely moraines, dunes, sand-sheets, alluvial fans, and palaeo-lakes. Large temperature variations result in mechanical breaking of rocks that gives rise to unconsolidated material over the hill range and along hill slopes. Pebbly-gravely material, boulders, fragmented shells etc., creep down along the unstable slopes, or are carried down by the glacier or glacier-melted water. This valley was formed as a result of diverse erosive processes. The angle of hill slope site varies from 30° to 45°; slope height of the first site is 3 m, while that of the second site is 45 m. Both the sites were highly erodible and the second site exhibited signs of seepage of water moving laterally with settlement at places.

4. NATURE OF THE PROBLEM

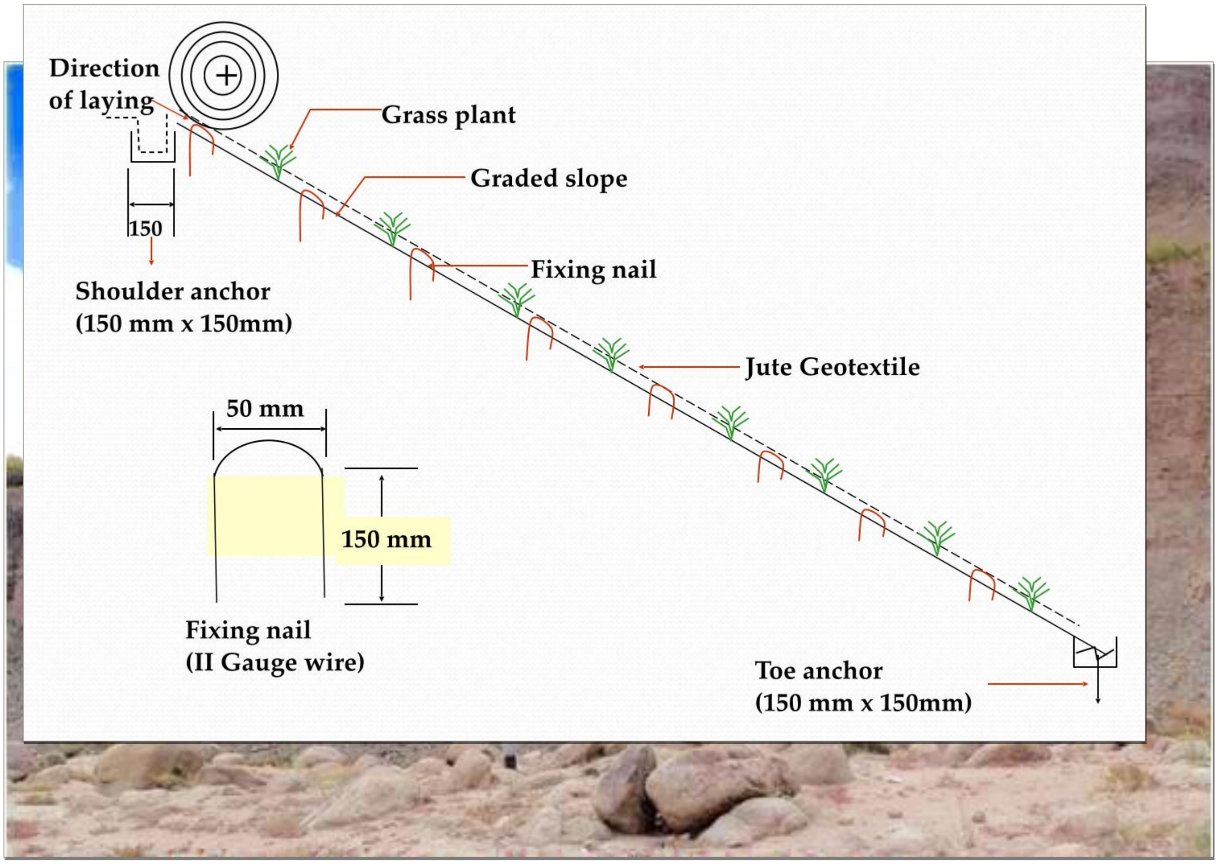
Non-cohesive erodible materials such as sand mixed with pebbles move down the slope by action of gravity and high winds, thus affecting road communication, fluvial regime of waterways, and vegetative growth. The area has a signification military presence, and the transportation of defense materials and the movement of army officers to the border areas like Kargil & others, are thus severely hindered.

5. REMEDIAL CONCEPT AND MEASURES TAKEN

Engineers of Project HIMANK of BRO, in consultation with NJB, decided to give a trial with Open Weave JGT in the area with the objective of a) providing cover over the area for arresting top soil detachment, b) controlling migration of dissociated particles, and c) containing the detached particles within the pores of OW JGT. The second stage of the remedial step is to bind the top soil by the root system of vegetation that will thrive due to the mulching and nutritional effects of Jute.

6. PROCEDURE OF APPLICATION

As usual, application is followed by levelling the slope containing sand formed by weathering of rocks, laying of JGT on the surface, and anchored suitably both at the top and bottom, and spreading seeds of local species vegetation that thrive in the adjoining area.



Figures 2 and 3. Nature of erosion along roads in the test

area (Leh, District - Ladakh, Jammu & Kashmir).

Figure 4. Method of installation of jute geotextile (JGT).

7. EXPERIMENTAL

At the first site, located near the project office of 16 BRTF of HIMANK, 1,000 m^2 of 292 g/m^2 OW JGT was laid in September 2011, following the standard method of installation of JGT to observe its efficacy in this climatic diversity. A wire crate toe wall was constructed as a lateral restraint. Surprisingly within a period of three months, it was observed that the top erodible sandy soil was seen to have attained primary stability with vegetation having started sprouting.

Figure 5. Application of jute geotextile (JGT) and its vegetative growth effect.

Table 1. Specifications of OW JGT

TYPE PROPERTIES	**1**	**2**
Weight per Unit Area (g/m^2) at 20% M.R.	292± 7 %	500± 10 %
Threads/dm (MD x CD)	12(+4, -2) x 12(+4, -2)	6.5(+4, -2) x 4.5(+4, -2)
Thickness (mm)	3± 10 %	5± 10 %
Width (cm)	122± 2 %	122± 5 %
Open area (%)	60± 10 %	50± 10 %
Tensile Strength (kN/m) [MD x CD]	10± 10% x 10± 10%	10± 10% x 7.5± 10%
Water holding capacity (%) on dry weight	400± 10%	500± 10%

Based on the encouraging performance of JGT at the first site, the second site, situated about 90.4 km away from Leh at an altitude of 4,900 m above MSL, and having a comparatively steeper angle, was treated with 4000 m^2 of 500 g/m^2 OW JGT in August 2013 following similar methods of application. Interestingly, here also, the sandy soil exhibited signs of stabilization, ice was formed on the fabric and vegetation sprouted through the pores of the fabric. There was no sign of erosion.

Sprouting of vegetation was also observed in the treated areas. The tensile strength of JGT did not wane even after two years of its application.

The first site was found stable within five to six months, and plants also took firm roots in the soil. The second site also showed growth of grass-like vegetation. Interestingly, formation of ice (as sleet) was found on the JGT-surface, probably due to combined effects of transpiration and condensation, along with the hygroscopic characteristics of JGT, appearing to have contributed to the phenomenon. Additionally, the durability of JGT was also seen to have increased. This entire mechanism deserves more in-depth observation and analysis.

Figure 6. Stabilized hill slope with jute geotextile (JGT).

8. OBSERVATIONS AND CONCLUSIONS

At the first site, the disintegrated soil particles were observed to have consolidated to a great extent and erosion caused due to wind and water checked. Different types of vegetables cultivated in the treated area showed lush growth. Snow formation on JGT was observed and almost no loss in strength of JGT was noticed even after two years of installation.

At the second site, the entire JGT treated area was observed to have stabilized within two months of installation of JGT, with no sign of erosion. Interestingly, formation of ice was observed only on the surface of JGT and nowhere else in the surroundings, which could be due to the hygroscopic and some other relevant properties of JGT causing localized cooling. This feature warrants a more in-depth study.

Overall, the initiative taken by BRO has proved successful in confirming the suitability of JGT even in areas with climatic diversity.

About 4,000 m^2 of 500 g/m^2 OW JGT was used on both uphill and downhill slopes. The stabilized slope treated with JGT indicated that the erosion of slope is being initially taken care of by JGT, and thereafter by vegetation. This dry and desert like area has very low rate of precipitation, $\geq$ 100 mm, and disintegrated rocks metamorphosed into sandy soil. Erosion in this area of the Himalayan and Kumayun Mountain Range, is caused mainly due to high winds. Erosion was also observed to be under control with the use of JGT.

Formation of icicles was observed only on the surface of JGT and not on any other adjacent barren areas. Presumably this phenomenon occurred due to the hydrophilic characteristics of jute which could have induced a cooler ambience. The ice formation on JGT may be taken as precursor to the growth of vegetation on the molten ice, in the form of water, is supposed to foster vegetation.

On the basis of such encouraging results BRO has decided to use 500 g/m^2 OW JGT for mitigating similar nature of soil related problems for a stretch of about 70,000 m^2 at Thoise Air Field, Ladakh.

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