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INTRODUCTION

JUTE & JUTE GEOTEXTILES*

JUTE PLANT & ITS FIBRES

Jute plants are grown mostly in the gangetic delta in the eastern part of the Indian sub-continent. People used to consume its leaves as a vegetable and also as a household herbal remedy. Its potential as an important natural fibre-source was a subsequent find. The spurt in use of jute fibres since the middle of the nineteenth century led to improvement of its method of cultivation and extraction of fibres followed by manufacture of fabrics with its yarns.

Jute plant has an erect stalk with leaves. It thrives in hot and humid climate, especially in areas where rainfall is in plenty. It grows up to about three meters in height and matures within four to six months. In China, taller Jute plants are being cultivated resulting in higher fibre production.

Jute has coarse natural bast fibres lying in the peripheral layer of its stem. It belongs to the genus Corchorus. There are over 30 species of this genus out of which C. Capsularis (known as White Jute) and C. Olitorius (known as Tossa Jute) are utilized for production of fibres. The fibres are extracted from the stem of the plant by a special process known as *retting*. Retting usually consists of tying the plants in bundles and immersing them in slowly flowing or stagnant water for about 2 to 3 weeks. The process of wetting makes fibre extraction easy from jute stem as it softens and dissolves the sticky substances, especially pectin. Extraction is done manually followed by washing and drying, to make the fibres suitable for commercial use. Jute research outfits are persistently endeavouring to improve retting methods.

COMPOSITION OF JUTE

The chemical composition of jute is as follows—

- α-cellulose -	59 - 61 %
- Hemicellulose -	22 - 24%
- Lignin -	12 - 14%
- Fats & waxes -	1.0 - 1.4%
- Nitrogenous matter -	1.6 - 1.9%
- Ash content -	0.5 - 0.8%
- Pectin -	0.2 - 0.5%

PHYSICAL PROPERTIES OF JUTE FIBRES

The average linear density of single jute filament lies between 1.3-2.6 tex for white jute and 1.8-4.0 tex for tossa jute with normal distribution. Coarseness of jute has some role in determining the strength of jute fibre. Coarse fibres are usually stronger.

Jute fibres are usually strong with low extensibility. It has a tenacity range of 4.2 to 6.3 g/denier, depending on the length of the fibre. Elongation-at-break of jute fibres is between 1.0% and 1.8%. Tossa jute is stronger than white jute. Jute fibre breaks within elastic limit and is resilient which is evident from its recovery to the extent of 75% even when strained quite a bit (1.5%). Its flexural and torsional rigidity are high compared to cotton and wool.

Presence of hemicellulose in jute fibres makes it hygroscopic, second only to wool. Tossa jute is slightly more hygroscopic than white jute. Jute fibres swell on absorption of water.

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*contributed by Tapobrata Sanyal

Lateral (cross sectional) swelling of jute fibres (about 45%) far exceeds its longitudinal swelling (0.4%).

During the process of addition of water, tenacity of jute fibres increases at the initial stages up to the relative humidity of 20%, does not vary for most of the period of water addition thereafter, but exhibits a downward trend when the relative humidity exceeds 80% or so. This phenomenon implies decrease in flexural and torsional rigidity of jute fibres when moisture absorption exceeds a limit.

Jute is not thermoplastic like other natural fibres. Charring and burning of jute fibres without melting is a feature of jute fibres. Due to high specific heat, jute possesses thermal insulation properties. Ignition temperature of jute is of the order of 193° C. Long exposure of jute fibres to hot ambience reduces the fibre strength.

Dry jute is a good resistant to electricity, but it loses its property of electrical resistance appreciably when moist. Dielectric constant of jute is 2.8 KHz when dry, 2.4 KHz at 65% RH and 3.6 KHz at 100% RH.

Co-efficient of friction of Jute fibres is usually 0.54 for white jute and 0.45 for Tossa variety. Moisture content in jute helps increase its frictional property.

GRADING OF RAW JUTE

The Bureau of Indian Standards (BIS) in its publication no IS :271-2003 has recommended grading of raw jute based on the fibre characteristics. The characteristics are—strength, freedom from defects, bulk density, colour, fineness and root content. There are sub-features to these characteristics. Based on these features eight (8) grades of each of Tossa and White Jute have been conceived, marked as TD_1 – TD_8 for Tossa Jute and W_1- W_8 in that sequence. Grading is done giving due weights to physical attributes of jute fibres. Maximum stress is given on fibre strength, root content and defects at the time of evaluation of the grading.

JUTE FIBRES - A LOOK BACK

The East India Company that took the administrative and commercial control of Bengal and its adjoining areas after its victory in the famous battle of Plassey, now in West Bengal, in 1757, discovered the potential of jute fibres. The British called it Indian Grass. Samples of the plant with fibres were sent to England in 1791. Around 1820, it was introduced to Dundee in Scotland, the then hub of textile industry in the West. Flax happened to be the most used natural fibre in those days. Experiments at Dundee revealed high initial strength of jute fibres and their spinnability by admixture of a softening oil. Ultimately jute replaced flax.

In 1838, the Netherlands placed large orders for jute sacks to transport coffee from the plantations in the eastern India. The increased demand of sacks for two major wars-Crimean War (1854-1856) & American Civil War (1860-65)—placed jute on a firm commercial footing. By around 1870 jute sacks turned to be the most sought after flexible packaging containers due to its low price and good quality. In the course of the last 150 years jute industry had to pass though vicissitudes; but despite intrusion of man-made yarns the industry has not lost its commercial relevance and happens to be one of the oldest surviving agro-industries in the world. There are reasons for its survival. Jute industry has behind it a strong R & D support that helps develop new uses and types of jute-based textiles. Growing concerns for environment and depleting petroleum reserves are the other prop factors. The inherent properties of jute fibres have no less contribution either.

Anyway, utilization of biomass and adoption of bio-engineering measures for addressing soil-related problems have become preferred options at present due to threats of pollution. Cellulosic materials are the main sources of bio-mass. Jute fibres are rich in cellulosic content and are proven for mechanical and thermal performance.

GEOSYNTHETICS

BACKGROUND

Man has been trying to overcome the problems related to soil since the dawn of civilization. The intricacies of soil behaviour were not known to man in the distant past. Structures were built and roads were constructed on soil based on experience without knowing much of different soil compositions and their behaviour under static and dynamic loads. In fact we realized the importance of soil much later in 1940s under pressure of necessity, as Terzaghi & Peck put it. Soil Mechanics, now known as Geotechnical Engineering, took shape subsequently as a distinct discipline.

Interestingly, natural materials were in common use in the past to obviate problems posed 'difficult' soils. We find evidences of use of woven mats made of reeds in ziggurants (temples) of Babylonia, of tree twigs with leaves in construction of the Great Wall of China and the like. Such improvised practices in some parts of India are still in vogue. In Kerala there is a convention to spread coconut leaves over sub-grades. Stolons of trees are laid on soft marshy soils to facilitate walking in some developing countries. Even the developed countries are increasingly favouring the old practice of using vegetation to control erosion of the surface soil. Construction of corduroy roads is also an example.

Natural products and contrivances were cornered after discovery of man-made polymeric materials in 1950s. It was the pressure of commercial necessity that prompted the related industry located in developed countries to diversify. They watched the decline in consumption of traditional textile materials arising mainly out of import of cheaper variety of textile products from the developing countries. Taking the cue from the improvised uses of natural ingredients in overcoming soil-related problems, the technologists thought of making fabrics with artificial polymeric materials such as polyamide, polyethylene that could address the precise technical requirements to improve soil strength and behaviour. This was how the concept of geosynthetics originated. Developed countries like USA, the Netherlands started using man-made geosynthetics for prevention of soil erosion in particular from the early 1950s. Later other countries in Europe followed suit and by the late 1960s man-made geosynthetics became globally popular. It must be admitted that the effectiveness of man-made geosynthetics was based on years of rigorous research, studies and field trials.

Geosynthetics are of two broad types-woven and non-woven. Woven geosynthetics also include fabrics with comparatively large openings (open weave construction) and are usually made by interlacing two or more sets of yarns/fibres/filaments/tapes. The sets are woven together with one set running in a lengthwise direction (warp) and the other running across (weft). Woven geosynthetics are categorized either on the basis of the type of threads or on the basis of the fabric function.

Non-woven types are manufactured by bonding or interlocking of staple fibres, monofilaments or multifilaments that are either randomly or specifically oriented. Mechanical, thermal or chemical means and suitable combinations of these methods achieve the desired bonding or interlocking of fibres. Geogrids i.e. polymer lattices are also non-wovens, made by perforating extruded polypropylene or HDP sheets. Warp knitting is also resorted to produce a kind of non-woven. Knitted fabrics are basically made of laterally interlaced parallel threads. The interlacing points are not specially bonded in such fabrics. Natural geogrids are uncommon.

It is however felt that natural composites may be tried for manufacture of geogrids. 3-D mats that are manufactured by extrusion of monofilaments or polymers or by application of hot pressure on polymer sheets may be brought under the non-woven category. These mats are used mainly for drainage.

Both woven and non-woven geosynthetics are permeable. Impermeable geosynthetics are known as geomembranes, available in the form of planar sheets. The fundamental difference between geosynthetics and geomembranes lies in cross-permeability. Not all impermeable materials or waterproof barriers are however geomembranes. Geomembranes are manufactured from thermoplastics or bituminous products.

Natural fibres are obtainable from four sources. These may be categorized broadly as i) wood fibres (soft & hard woods), ii) vegetable fibres (jute, coir, ramie, kenaf, cotton etc.), iii) animal fibres (wool, silk, feather etc.) and iv) mineral fibres (asbestos, inorganic whiskers etc.). Not all fibres are suitable for making of natural geosynthetics. Large-scale availability and physical properties of natural fibres are determinants in regard to suitability of manufacturing of natural geosynthetics. Vegetable fibres are considered the most suitable for making of natural geosynthetics. Jute happens to be the ideal among natural fibres because of its availability, conformance to the desired physical properties and very good spinnability. In fact, jute industry in the Indian sub-continent has behind it a wealth of experience in making of yarns from fibres, beside the tradition of extracting bast fibres from the plant of the same name and other accompanying processes such as retting.

The growth of man-made geosynthetics over the last three decades has been remarkable. From 10.2 million sq.meters in 1970 the consumption has soared to 2475 million sq.meters in 2006-07—the growth rate being 10% to 15% since 2000-01. It has been projected in a study conducted by Freedonia Group that the global demand of geosynthetics could reach 4760 million sq. meters by 2018 while the demand of natural geosynthetics might be around 10% of this demand by 2018. The market for geosynthetics is still confined to USA, Canada, developed countries in Western Europe, Japan and Australia. These countries account for nearly 33% of the global consumption at present. It has been predicted that the Asia-Pacific region would consume 53% of the geosynthetics demand by 2018.

The striking part of the growth of the global geotextile sector is that geosynthetics made of natural ingredients like jute, coir, sisal, kenaf, ramie constitute only 5% to 6% of the present global consumption. Continuing thrust on sack-marketing and lack of proper marketing strategy by the industries concerned are the major reasons for the paltry share of natural geosynthetics. The other factor of the insignificant contribution of natural geosynthetics is the lack of systematic and thorough study on their performance and behaviour in soil of different kinds under different nature and extent of external loads. The studies conducted so far have not been intensive as a result and the results of performance of natural geosynthetics in field applications sometimes lack technical details. Things, however, have started changing in so far as jute is concerned.

An international project on Jute Geotextiles has recently been taken in hand with the major funding from the Common Fund for Commodities (CFC), Amsterdam, an organ of UN, with the initiative of International Jute Study Group, Bangladesh and support from the Governments of India & Bangladesh. National Jute Board, India is the Project Executing Agency. Jute Diversification promotion centre, Dhaka is the collaborating agency in Bangladesh. Research Institutes such as BESUS, IJT, IJIRA in India and BUET, BJRI in Bangladesh are the facilitating agencies to the project. The main objective of the project is to develop potentially important JGT in areas of erosion control and rural road construction and to secure global accreditation for the developed products.

The global textile industry is now poised for transformation. Not only geosynthetics, but a host of other diversified uses of textiles have been conceived. Innovative uses of textiles have opened up new avenues in research and studies in textile technology. Quite a few new textile products have been developed having non-traditional uses. These were first branded as 'Industrial Textiles' and have been subsequently styled as 'Technical Textiles'. Geosynthetics come under Technical Textiles. ('Geotech' category)

TECHNICAL TEXTILES (TT)

Technical Textiles, as already indicated, are non-traditional engineered textile products. The Textile Institute, Manchester, UK proposes the following definition of Technical Textiles.

"Textile materials and products manufactured primarily for their technical and performance properties rather than their aesthetic or decorative characteristics."

Basically Technical Textiles are supposed to meet the requisite technical specifications for a specific end-use.

Technical Textiles have emerged as the fastest growing sector of the textile industry globally. David Rigby Associates, UK were engaged by Messers Frankfurt GmbH in connection with TechTextil 1997 (The Industrial for Technical Textiles) to conduct a study and market survey on Technical Textiles. David Rigby Associates broadly classified Technical Textiles into twelve groups on the basis of end-uses as under —

Agrotech	—	for agriculture, horticulture & forestry
Buildtech	—	for building & construction
Clothtech	—	for clothing & components of footwear
Geotech	—	for geotechnical & civil engineering
Hometech	—	for furniture components & household textiles
Indutech	—	for industrial applications
Medtech	—	for medical applications
Mobiltech	—	for automobiles & other transports
Oekotech	—	for environmental protection
Packtech	—	for packaging
Protech	—	for protective uses
Sporttech	—	for sports & recreation.

The list is indicative of thee widening market of TT. The growth of TT has been due to utilization of new fibres, use of effective coating materials and improved processes of manufacture of TTs.

GEOSYNTHETICS

The term Geosynthetics, embraces both man-made and natural geotextiles according to the International Geosynthetics Society (IGS). Earlier the term was used to denote only man-made geotextiles. According to knowledgeable sources, the change in the name has been prompted by the fact that the word textiles is losing its relevance in the context of the new diversified products that have been developed or are going to be developed in future for soil-related applications. Anyway, we prefer to call natural Geotech by geotextiles preceded by the type of natural fibres that are used in their making e.g. Jute Geotextiles (JGT), Coir Geotextiles.

Geosynthetics may be defined as a planar textile fabric or material that is used in or on soil to improve its (soil's) engineering performance. The clause 'engineering performance' has a wide connotation. It signifies basically the capacity of any soil to remain stable by withstanding different kinds of imposed loads. Control of soil erosion and earth slips, prevention of soil migration from under the base of a structure, dissipation of water from soil-body and separating soil layer from overlying courses are the critical functions geosynthetics are supposed to perform to improve the engineering performance of soil. In fact the conjunctive functions as indicated lead to improvement of soil performance as a whole.

The reason of inclusion of natural geotextiles under the fold of geosynthetics could be that both man-made and natural types are manufactured from synthesizing polymers. Synthetic and natural polymeric materials are characterized by their macromolecular construction signifying that large molecules are their basic ingredients. Macromolecules in turn are formed as a result of combination of monomers that are smaller units with similarity in shape. The process of combination of monomers to form polymers is known as polymerization. Man-made macromolecular materials are broadly of three types—thermoplastics, thermosets and elastomers. All the three types possess distinct characteristics of their own due to their individual molecular structure. Petrochemical derivatives are the biggest source of man-made polymers.

Threats arising out of dwindling petroleum reserves and increasing environmental degradation are prompting technologists to opt for natural alternatives wherever possible. Developed countries are now inclined towards adoption of bio-engineering measures to address soil-related problems. Plant-derived fibres as a result are now turning out to be the most sought after materials of the 21st century (Bledzki & Gassan, 1999; Mohanty et al 2002; Netravali & Chabba 2003).

Versatility of jute fibres has made it possible to manufacture natural Geotech to meet the specific technical requirements. Both woven and non-woven fabrics can be made out of jute yarns possessing the requisite tenacity, initial strength, extensibility and other physical properties for a variety of end-uses related to geotechnical applications. By far the most preferred application of JGT is in the sector of slope and surface soil erosion control. Open weave JGT with thickness of 4 mm and above helps in reduction of velocity of surface run-off, enables ground storage due to its hygroscopic nature and facilitates vegetative growth. Jute has the potential to progress commercially in the field of geosynthetics in the coming days for the sound support of several research organizations that are continually engaged in quality improvement and innovative product development and the industry which is well-equipped to make customized Jute Geotextiles.

THEORY & LABORATORY STUDIES

JUTE GEOTEXTILE IN CIVIL ENGINEERING APPLICATIONS

N. Som

SYNOPSIS

The field application of Jute Geotextiles in civil construction works are highlighted. The properties of geojute compare well with geosynthetics for many field applications. Some cases of geotextiles applications are presented. The need for more field studies with geojute is emphasized.

1.0 INTRODUCTION

Geotextiles constitute a group of fabrics made from synthetic polymers, such as polypropylene, polyester, polyethylene, polyamide and PVC or natural fibres, including cotton, jute, coir and bamboo which are finding wide application in all kinds of geotechnical constructions. The major functions of geotextiles in engineering applications have been identified as separation, reinforcement, drainage and filtration. Some of these functions, e.g., drainage and filtration are primarily dependent on the properties of the geotextile itself without having any predominant dependence on the geomorphological features of the area. The other functions, e.g., separation and reinforcement are dependent on the nature of the subsoil in so far as the strength and deformation characteristics of the subsoil become important in determining their suitability in a given situation.

In separation and reinforcement functions of geotextiles the major consideration that determines the effectiveness of geotextiles is the permissible deformation. For geotextiles to be effective in reinforcement of the soil, sufficient deformation has to be allowed so as to enable the tensile strength of the fabric to come into play. This makes them particularly suitable in soft clay deposits which are by nature susceptible to large deformation.

2.0 Geological features of soft clay

Soft clay is found abundantly in many parts of the world, e.g., Scandinavia, the US, Canada, Mexico City, South-East Asia, China, the Middle-East and the Indian subcontinent. Most river valleys of the world, such as the Nile in Egypt, the Mississippi in the US, the Tigiris and Euphrates in Iraq, the Yangtze in China, the Ganga and Brahmaputra in India and the Mekong in South-East Asia have abundant deposits of soft clay. Marine clays found along the coastal plains of the world also fall under this category.

Soft clays are, in general, recent sediments laid down by river (alluvium), sea (marine) or lakes (Lacustrine). Kukal (1971) suggests three possible river depositional environments, viz., river channels, natural levees and flood plains. Much of the river deposits are found in the alluvial plains near the delta where deposition has occurred during periods of high flooding. These deposits are characterised by bedding and laminations, sometimes intercalated with sand seams. They are, however, subjected to repeated desiccation near the surface. The zone of desiccation may extend to depths of up to 5m (Brenner et al 1981)

The engineering properties of soft clay are characterised by physical parameter- such as grain size, Atterberg limits, consistency etc., and mechanical properties like shear strength, compressibility, sensitivity and permeability. Table 1 gives the engineering properties of some soft clay deposits.

3.0 Fields of Geotextile Application

The main functions of geotextiles make them suitable for application to many practical problems (Ingold & Miller, 1988). Some of these applications are :

- Temporary roads and yards
- Permanent roads
- Repair of permanent roads
- Railway tracks
- Embankments in soft ground
- Drainage applications
- Retaining walls, and
- Erosion control

Most of these applications are particularly suitable to the geological features prevailing in many parts of India, Bangladesh, South-East Asia, China and Japan. Vast areas of alluvial and marine deposits in these regions contain soft clay of high compressibility and low shear strength. They give rise to problems of stability and settlement even under small superimposed loads.

Geosynthetics have been used extensively in recent years in various construction works in India. These materials are highly resistant to biological and chemical degradation and have sufficient tensile strength and permeability for direct ground treatment applications. Geotextiles made out of natural fibres, e.g., jute geotextiles, have got high permeability but they are bio-degradable and possess less tensile strength, in general. They have not been promoted as widely as geosynthetics. Consequently their application, so far, has been on a limited scale.

Table 1 : Properties of Geotextile Fabrics.

(a) Jute Geotextile

Type of jute geotextile	Mass/unit area (g/m^2)	AOS (mm)	Thickness (mm)	Tensile strength (kN/m)		Elongation at break (mm)		Puncture test	
				MD	CD	MD	CD	Loan (N)	Deformation (mm)
DW TWILL	750	0.10	1.90	32.80	16.75	13.9	10.1	690	10.20
Jute Canvas	660	<0.075	1.70	27.20	16.65	16.0	8.0	267	9.00
Russian	420	0.25	1.30	15.65	5.65	15.0	5.68	315	5.40
Hessian	350	>0.85	0.80	5.85	7.40	4.25	2.45	252	5.50
Hessian	229	>0.85	0.97	3.25	2.55	3.25	1.00	166	5.00

(b) Synthetic Fabric

Type of Synthetic geotextile	Mass/unit area (g/m^2)	AOS (mm)	Thickness (mm)	Tensile strength (kN/m)		Elongation at break (mm)		Puncture test	
				MD	CD	MD	CD	Loan (N)	Deformation (mm)
Typical non-woven	200	0.2	2.0	13.5	-	50	-	420	23.6
Typical Woven	315	0.25	0.76	44	26	31	39	684	13.8

Table 1 (contd.)

(c) Properties of Soft Clays

Clay	Geologic type	Liquid limit (%)	Plastic limit (%)	NMC (%)	Undrained shear strength (t/m^2)
Mexico City clay	Lacustrine	300	100	300	2.5
Avonmouth clay, UK	Estuarine	70	20	60	2.0
Bombay marine clay	Marine	90	40	60	2.5
Norwegian quick clay	Marine	40	17	38	1.2
Normal Calcutta clay	Alluvial	60	30	50	2..5
Cochin marine clay	Marine	80	40	76	2.0
Bangkok clay	Marine	120	50	80	1.5
Champlain sea clay, Quebec	Marine	60	25	80	1.0

4.0 Use and Composition of Jute

Historically, jute has been used in a conventional sense for sacking and wrapping, carpet backing, matting and handicrafts. Jute fabrics used to be the main packaging material for cement and foodgrains but synthetic fibres have taken its place in a big way in modern times. The present day use of jute has been shifted to blended yarns, furnising fabrics, blanket and knitted products, carpets, pulp and paper and geotextiles commonly known as geojute.

The main constituents of jute by weight are the following :

Alpha cellulose	:	60%	Hemi cellulose	:	20%
Lignin	:	17%	Minerals, fatty & waxy substances nitrogenous matter etc.	:	03%

Jute fibres constitute about 7-9% by weight of green plant. It has a multi-cellular structure which helps to get mixed with the soil and strengthen it.

Jute fibres can be converted into fabrics - for use as geotextiles - by woven and non-woven processes.

5.0 Properties of Jute Geotextile

Jute geotextiles may be manufactured to different specifications. A comparison of typical properties of jute geotextile and synthetic fibres is given in Table 1.

For engineering applications jute geotextiles may be made to the following typical specifications, as shown in Table 2.

Table 2 : Properties of Jute Geotextile

Property	Woven	Non-woven
Weight (gm/m2)	760	1000
Thickness (mm)	3	8
Width (cm)	76	150
Permittivity (m/sec)	0.5	3.4×10^{-4}
Strength (warp x weft) (kN/m)	25 x 20	7 x 3
Strain at break (warp x weft)	10% x 10%	25% x 30%

Suitable treatment with tar and bitumen usually improves the strength of jute geotextiles.

6.0 Bio-Degradabilty

Bio-degradability is often considered a disadvantage of jute geotextiles. It is believed that after degradation the strengthening effect of the fabric is lost and the performance of the soil in terms of strength and permeability deteriorates. But jute has been found to be fairly resistant to rapid deterioration when embedded permanently in wet soil below ground water table. In weak subgrade consolidated under the overburden with consequent and gain in strength with time, the performance of the structure becomes less and less dependent on the fabric. So long-term bio-degradability does not necessarily influence bearing capacity significantly.

Jute degrades through aerobic processes and produces lignomass with extra nitrogen, phosphorous and potassium. Bio-degradation helps to minimise environmental pollution.

7.0 Geotextile Applications

Jute geotextile is yet to have wide acceptance in civil engineering applications in India. However, geotextiles (mostly geosynthetics) have been used widely in recent years in road and railway construction, embankments and retaining walls, erosion control and drainage. Some of these application in India are highlighted below.

They should give some indication of the potential use of jute geotextile as they often have matching properties for use in place of synthetic fibres and are less expensive.

7.1 Temporary Roads

Most construction sites require access to the site through weak surface deposits. Temporary roads are built by spreading a carpet of coarse granular material (stone metal) over the soft subgrade to act as a load dispersing medium which keeps the stresses on subgrade low. As shown in Fig. 1. However, extensive rutting occurs on the surface due to the granular fill getting lost into the soft subgrade under continuous pressure from the moving vehicles. This gives rise to perennial maintenance problems. The problems can be minimised, if not overcome, by providing a suitable layer of geotextile at the interface of the granular fill and the subgrade.

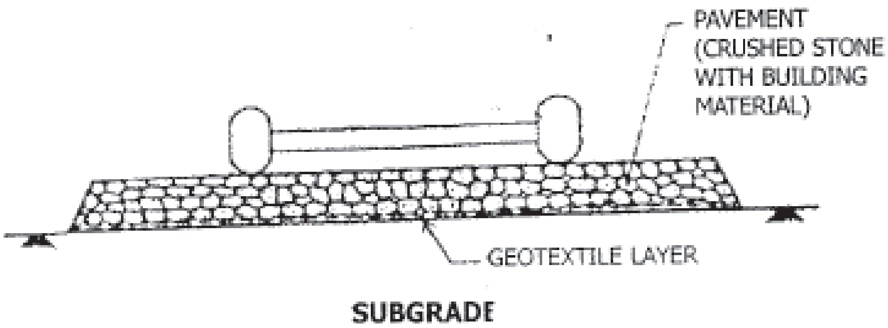

Figure 1 : Geotextile in temporary roads.

This not only keeps the thickness of the granular fill intact but the tensile strength of geotextile allows reduction in thickness of the stone filling as well. Effective use of geotextiles has been made in a fabrication yard on soft dredged fill to make the area suitable for movement of heavy cranes for jacket fabrication (Ghoshal & Som 1989). A depth of 700 mm of stone aggregate was placed on the soft subgrade with geotextile at the interface (Fig. 2). This not only allowed a saving of 200 mm of stone filling but enabled rapid construction of the fabrication yard.

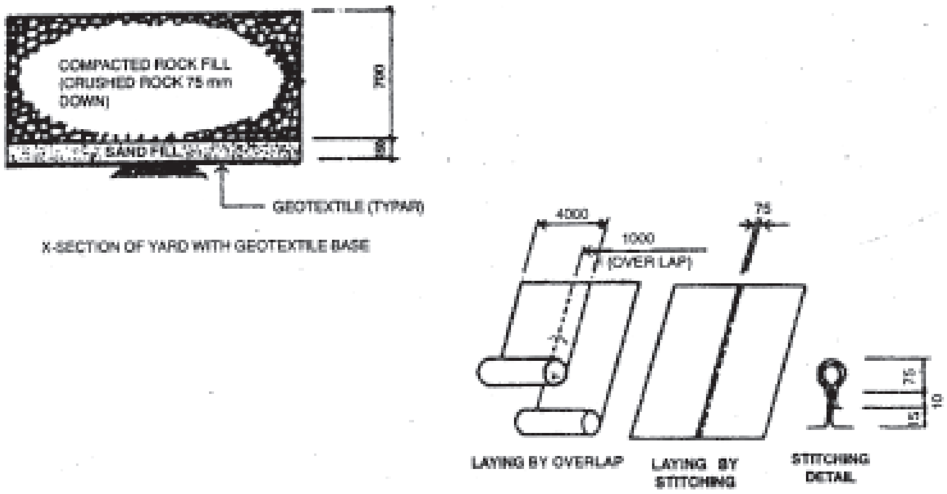

Figure 2 : Geotextile in fabrication yard near Haldia Port.

7.2 Permanent Roads

Geotextile in a permanent road not only allows reduction in the thickness of the pavement on a soft subgrade by the reinforcement action of geotextiles but gives less maintenance problems for long-term use. Besides, the geotextile prevents stagnation of water below the subgrade and allows free drainage of water into the side drains and prevent the subgrade from getting softened due to ingress of water, (Fig. 3). Also when placed in the bituminous surface layer, geotextiles prevent reflective cracking of the road surface. Tiwari and Ranjan (1989) reported the use of non-woven geotextiles as a pavement overlay to reduce reflective cracking in the runway of the Ahmedabad airport in Gujarat, (Fig. 4). Strips of fabric were placed at the crack location on a V-shaped groove filled with a bituminous tack coat. Firm contact of the fabric with a tack coat was made using a heavy roller. Observations showed that cracks appeared within six months in areas where there was no fabric while, in the treated area cracks began to appear only after two years - that too on a very minor scale.

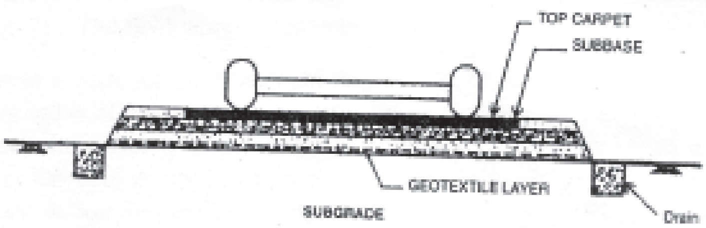

Figure 3. Geotextile in permanent road

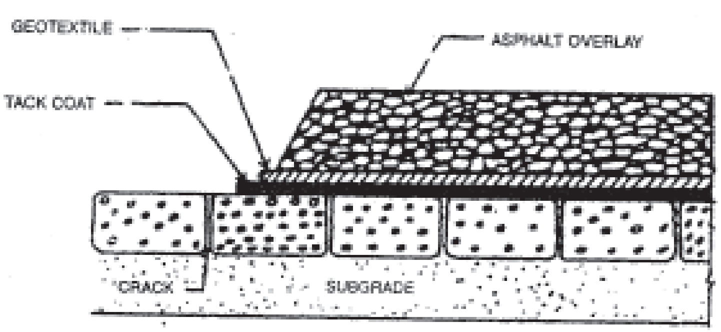

Figure 4. Geotextile as pavement overlay for treatment of cracks in airport runway.

Railway tracks are supported on a layer of ballast which disperses the load into the subgrade soil. The ballast continuously penetrates into the soft subgrade and requires regular replenishment in the same way as the pavement in the soft subgrade does. Geotextiles may be used to separate the ballast and the subgrade soil both in new construction and in strengthening jobs. (Fig. 5).

As estimated 2,400 km of track belonging to Indian Railways is founded on weak soil and approximately 300 km of rail track require strengthening every year (Sarkar, 1989). Non-woven geotextiles have been recommended for strengthening of tracks in Indian Railways.

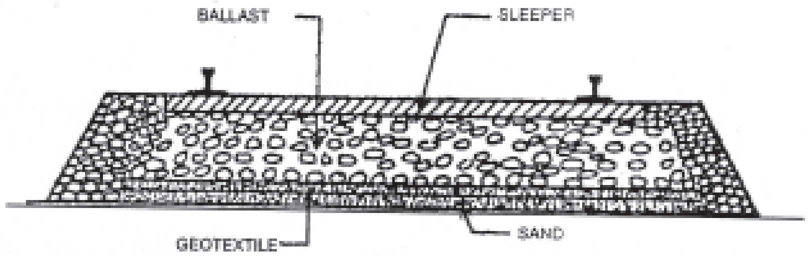

Figure 5 : Geotextile in strengthening railway track.

7.4 Embankments and Retaining Walls

The reinforcing effect of geotextile is used more effectively in construction of embankments and retaining walls in soft soil. With use of geotextile in horizontal layers within the fill and at the base it is possible to have a steeper side slope and savings can be effected by a reduction of filling in the embankment. More importantly, in urban areas, economy is achieved by reducing the land coverage on either side of the embankment. The usual procedure of slope stability analysis by the limit equilibrium methods are applicable to design, taking into account the tension capacity of the fabric.

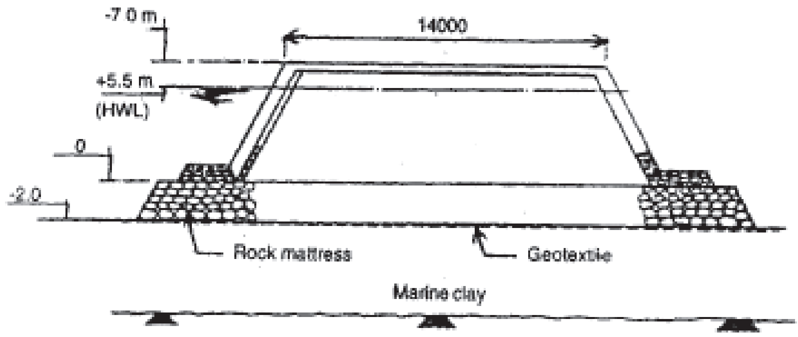

Figure 6 : Geotextile in guide bound in soft marine clay at Nava-Seva Port.

Non-woven geotextiles have been used in Nava-Seva Port near Bombay to stabilize 9 m high guide bunds on soft marine clay (Iyengar, 1990). The geotextile was laid on the marine clay at a water depth up to 6 m from a flat-decked barge. It was covered with a rock mattress and earth filling was done in stages to build up the embankment, (Fig. 6). The use of geotextiles reduced the quantity of natural rock by 30% and the cost by 50%.

7.5 Erosion Control

Geotextile may be used for river bank protection, as an alternative to the granular filter, below the rip-rap on the sloping sides of the bed to be protected from erosion. Construction is quick and often cheaper than granular filter. Grouted mattresses made with geotextiles are also used to replace stone walls where boulder is difficult to obtain. Geojute is being used below revetment to control river bank erosion for stabilizing bridge foundations in Lakwa, Assam, (Fig.7). The field work is currently going on.

Widespread erosion of the Bhagirathi downstream of Farakka Barrage has been treated by providing quilts of nylon net on the graded slopes of the river above low water level and placing stone chips over it, (Fig. 8). Below the low water level, however, a 900 mm thick boulder layer has been dumped directly on the geotextile fabric. This led to a saving of time, ease of construction and better quality control (Char et al 1989). Grouted geosynthetic mattresses have been used as canal lining under flowing water conditions to prevent erosion of the canal bed in the Kakrapar canals in Gujarat. Mattresses were laid in lengths of 15 cm in the canal bed as well as on the side slopes and then filled with a cement-sand slurry (Parikh and Shroff 1989).

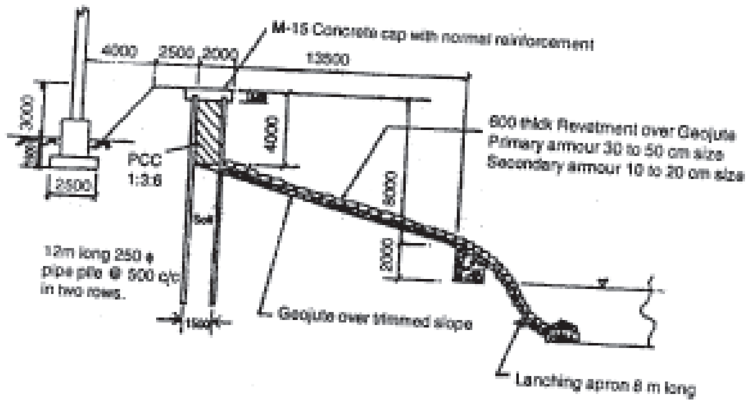

Figure 7 : Geotextile below revetment for river bank erosion in Lakwa, Assam

8.0 Application Areas of Jute Geotextiles in Road, Railway and Embankment Construction

(a) Controls subsidence of a pavement by separating and preventing intermixing of the soft sub-grade and the harder sub-base.

(b) Arrests migration of soil particles and allows water to permeate across it. Also acts as a drainage layer along its plain. Can be tailor-made to cater to the requirements of porometry, permittivity and transmittivity. Enhances CBR-value.

(c) Control reflective cracking of pavements and prolong their fatigue life when used in asphaltic overlays.

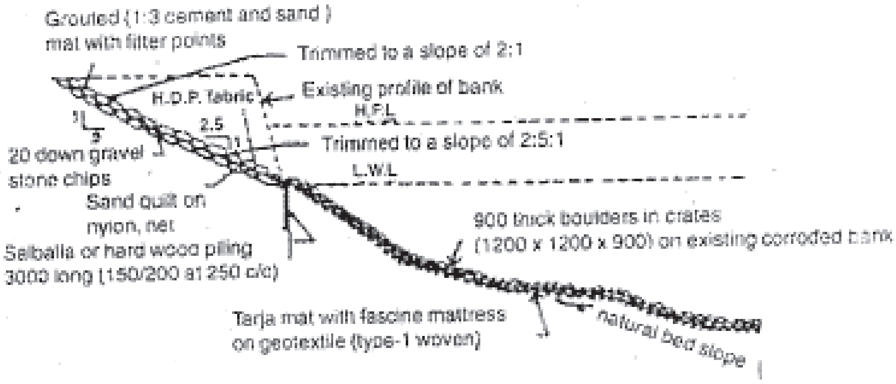

Figure 8. Geotextile in erosion control at Farakka.

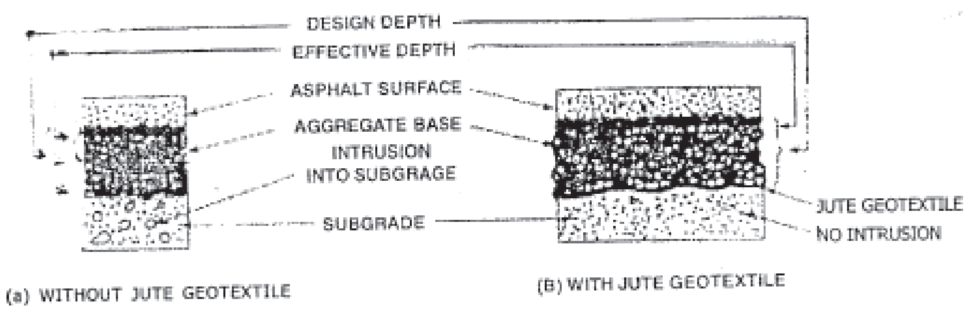

Figure 9 : Pavement with Jute Geotextile

(d) Enhances strength and stability of road embankment built with materials of uncertain behaviour like PFA, when interposed at appropriate levels. Also keeps lateral dispersion, subsidence and slides (slip circle failures) under check.

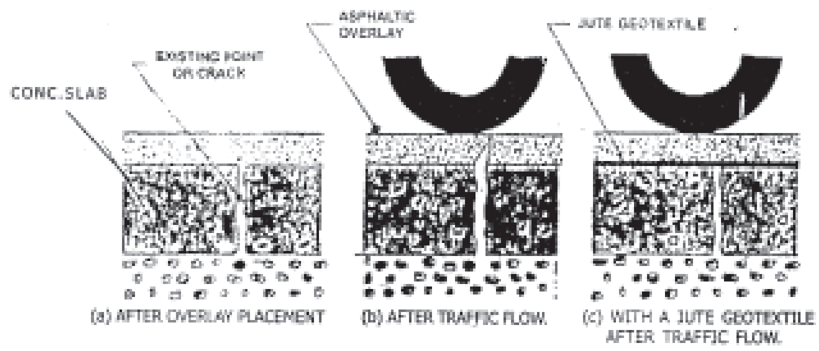

Figure 10 : Control of refractive cracking with Jute Geotextile

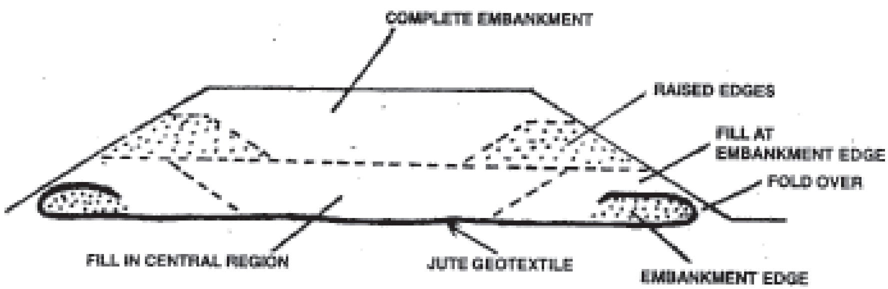

Figure 11 : Geojute in embankment construction

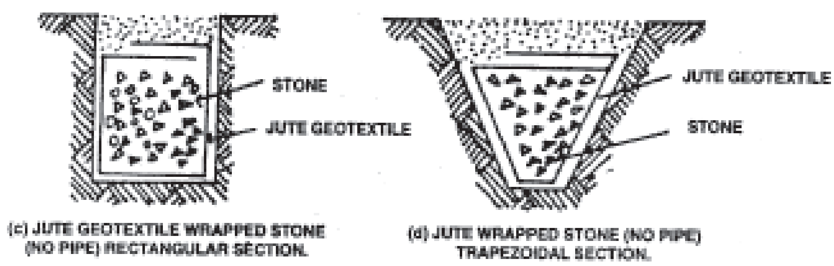

Figure 12 : Jute Geotextile in trench drains

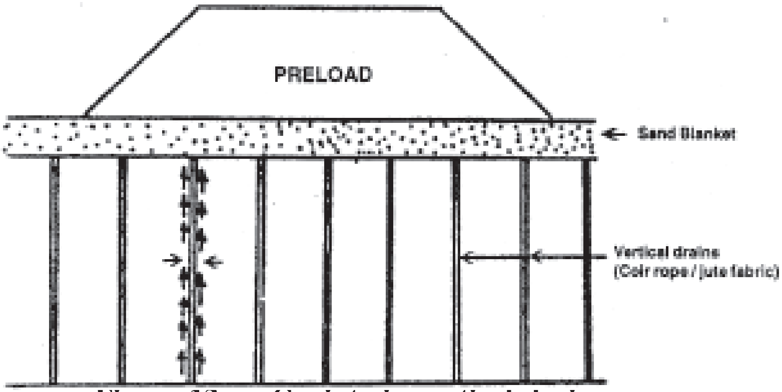

Figure 13 : Geojute in vertical drainage

(e) Provides effective drainage system when used as peripheral cover in trench drains, especially in hilly terrains.

(f) Vertical fibre drains, help drain out entrapped water from within an embankment. Has widespread application in ground improvement with vertical drains.

(g) Slopes of embankments with problematic soil may be stabilised by applying jute geotextile to help grow vegetation faster and anchor soil for a permanent solution.

9.0 The Indian Potential

Geotextile, including geojute, are having increasing application in the construction industry in India today. They are now looked upon as a cost-effective solution to many soil and foundation problems. Most of the geotextile usages described in the preceding sections have potential for application in the vast areas of alluvial and coastal plains of India. Given the wide extent of the country and the development work being undertaken in terms of road and railway construction, embankments and dams, erosion control, river bank protection etc., the potential market of geojute in India should be quite high.

It has been felt, however, that major application of geojute in India would be in road construction while drainage and erosion should also be important application areas. The advantages of using geojute in soil reinforcement and railway construction and maintenance have still to gain wide acceptance.

One of the major factors that go against large-scale application of geosynthetics- in India is the high cost of the fabric itself. The current market price of geosynthetics in India being quite high, there is a natural reluctance to go for them as alternatives to traditional methods of construction. Geojute should have major advantage in this respect because its cost is generally much lower that of geosynthetics. Applied research, including (prototype studies and performance evaluation should be undertaken extensively in the promising areas of geojute application in order to build up the confidence level of potential users of geojute in construction works.

CONCLUSION

Geojute or jute geotextile has many potential applications in civil construction works. The engineering properties of jute fabrics are suitable for separation, reinforcement, drainage and filtration functions and can be suitably used in overcoming geotechnical problems of weak soil. Applied research including performance evaluation of geojute applications are needed to highlight the beneficial uses of geojute in the field.

REFERENCES

Brenner, R. Natalaya, P., Chilngarian, G.V. and Robertson. J. 0.(1981). 'Engineering Geology-Soft Clay'. In Soft Clay Engineering, ed. E. W. Brand & R. Brenner. Elsevier, New York, USA. Chapter 2, pp. 159-238.

Char, S. A. Suryanarayanan, N. and Singh, K. (1989). 'Use of geotextiles in erosion control'.^Proceedings of the International Workshop on Geotextiles, ed. C. V. J. Varma, Tata-McGraw-Hill Publishing Co., New Delhi, India, pp.

83-89.

Ghoshal, A. and Som, N. (1989). 'Use of geotextiles in a heavy duty fabrication yard - A case study' In Use of Geosynthetics in India: Experiences and Potential. Report No. 207, Central Board of Irrigation and Power, New Delhi, India, pp. 321-324.

Ingold,T. S. and Miller, K. S. (1988), 'Geotextile Handbook'. Thomas Telford, London, UK.

Iyenger, S. S. (1990). 'Reinforcements in a submarine clay'. Proceedings of the 4th International Conference on Geotextiles, Geomembrances and Related products, vol. 1, ed. G.D. Hock. Balkenma Publication, The Hague, p. 164.

Kukal, Z. (1971). 'Geology of Recent Sediments'. Academic Press, London, UK.

Parikh, P. and Shroff, A. V. (1989), 'Use of grouted mattresses for canal bed/slope protection'. In use of Geosynthetics in India: Experiences and Potential, Report No. 207, Central Board of Irrigation and Power, New Delhi, India, pp. 310-20.

Sarkar, S. S. (1989). 'Formation, rehabilitation and track bed stabilisation in railways using extruded polymer geogrids. In use of geosynthetics in India - Experiences and Potential. Report No. 209, Central Board of Irrigation and Power, New Delhi, India.

Tiwari, A. B. and Rajan, V. S. (1989). 'Use of geotextiles overlay at Ahmedabad airport - A case study. In use of geosynthetics in India : Experiences and Potential. Report No. 207, Central Board of Irrigation and Power, New Delhi, India, pp. 393-399.

Koerner. Robert M. (1990), "Designing with geosynthetics" Prenticie Hall. New Jersey, Second edition, 1990, pp. 129 Rao. P. J ct al (1996). "Field experiments on Jute fabric soil stabillisers." Proc. National Seminar on Jute based Geotextiles. November 20. 1996. New Delhi.

Rao. P. J ct al (1961). 'Design and construction of drainage filter using Jute geotextiles at Hanuman Setu'. Proc. of National Seminar on Jute based Geotextiles, November 20, New Delhi.

Rao. P J ct al (1996). Jute geotextiles for improving the perfonnance of Highway Embankment on soft marine soil'. Proc. of National Seminar on Jute Based Geotextiles, November 20, 1996, New Delhi.

Rao. P.J. et al (1996),'Use of Jute geotextile as separator in pavements -A case study, Proc. of National Seminar on Jute Based Geotextiles, November 20, 1996, New Delhi.

JUTE GEOTEXTILE FOR ROADS

S. D. Ramaswami
M A Aziz

INTRODUCTION

Natural fibres such as jute were the forerunners of the man-made fibres used for centuries for making ropes and for manufacturing burlaps, sacks, hessian and carpet backing. But the use of jute products in civil engineering is relatively widespread for such purposes as sand-bags for concrete curing and protection. In geotechnical engineering, isolated uses are recorded such as the trials undertaken in Dundee (UK) in the 1920s where jute burlap was used under some sections of a new road on poor subgrade (UNCTAD/GATT, 1986). Jute mesh was probably first used in erosion control and highway side-slope protection in the United States in early 1930s. Jute nets have been used in the United States for ground applications for over twenty years and the annual consumption is stated to be 3,000 tons (UNCTAD/GATT 1985, 1986).

The United Nations International Trade Center is presently involved in the promotion of jute as a geotextile. Five companies have already established jute geotextile products for use in civil engineering. These are based in the USA (by far the largest market for jute geotextile products for erosion control and highway slope protection), West Germany, France, Switzerland and UK. Several erosion control and highway slope protection projects both in the UK, USA and also in Switzerland have recently been satisfactorily completed in applications where a biodegradable geotextile has been preferred for ecological reasons (UNCTAD/GATT, 1985).

Jute comes principally from Bangladesh, India, China and Thailand. In British India, the jute fibre was known as Indian Grass but in Bangladesh, it is known as Golden Fibre. Jute plant is woody type growing to about 3 m high and under its bark bundles of fibres run longitudinally down the stem (stem diameter varies between 20 to 30 mm) held together by sticky resin. When harvested, the cut stems are tied into bundles and kept submerged in water for 20 to 30 days, the process being known as 'retting'. The tissues of the stems are then broken down under bacterial action. The resulting soggy mass consists of strands of overlapping fibres. The fibres are then stripped off from the stem manually, washed in water and dried under the sun (BJRI, 1974). To-day, the production of various jute geotextiles is an enormous industry with world-wide production of around 3 million tonnes. Of this, about 50 percent comes from Bangladesh, about 30 percent from India and the remainder from China, Indonesia and Thailand. Synthetic geotextiles have been used in many geotechnical engineering applications (Nagarkar et al 1980, Robnettetal 1980,Ingold 1984,USFHA 1985). World consumption of synthetic geotextile has grown rapidly; estimates vary from 250 to 400 million m^2 per annum (Textile Horizon, 1985). One of the common uses of synthetic geotextiles is in road construction (McGown and Ozelton 1973, Jerrett et al 1977, Hore 1977, ASCE 1979, Lai and Robnett 1980, Sim 1984, Giroud and Noiray 1984, deBoer 1984). Synthetic geotextiles when used in areas where soft subgrades have created problems, have functioned very well resulting in increased durability and performance. Various laboratory and field investigations concerning the uses of synthetic geotextiles (both woven and non-woven) in various geotechnical applications are reported in literature (Ingold 1984, Giroud and Noiray 1984). But very little information is available on the application of natural jute geotextiles for geotechnical purposes. The authors conducted some studies on the feasibility of using jute fabric with or without coir/jute mat, jute net and jute mesh as a geotextile (Ramaswamy and Aziz 1982, 1983, Aziz and Ramaswamy 1984, Aziz and Mansur 1982). From its study, it is evident that jute geotextile can be used for stabilizing soft subgrades.

EXPERIMENTAL INVESTIGATION

An extensive investigation has been conducted at the Department of Civil Engineering, National University of Singapore in order to study the physical properties, strength parameters and performance characteristic of jute fibres, jute fabrics, jute mesh/net/mat. The properties of jute fibres are given in **Table I** (Lee et al 1980, Ramaswamy and Aziz 1982, 1983, Aziz and Mansur 1984, Aziz and Ramaswamy 1984, Mansur 1984). Basic requirements of jute fibres when used in producing good quality geotextiles are high tensile strength and elastic modulus. Typical properties of jute fabrics made of good quality jute fibres are given in **Table II** (Aziz andRamaswamy 1984). Comparison of properties of jute fabrics with other commonly used synthetic geotextiles is shown in **Table III** (Ramaswamy and Aziz 1983). Compared to other synthetic geotextiles, the jute fabric tested is found heavier and thicker and the percentage elongation at break is strikingly smaller whereas all other properties are more or less comparable. In addition, both dynamic and static load tests were conducted on jute fabrics. The equipment used for the dynamic load test consisted basically of a steel drum of 0.6 m diameter and 1.2 m high mounted on a loading frame. A hydraulic jack having a capacity of 2 tonnes (20 kN) provided the necessary loading force. The jacks were connected to a dynamic simulator. The dynamic load applied was 8 kN, the simulated contact pressure being 255 kN/m^2 and up to 1000 applications were made. The subgrade material used was clay having a natural water content of 40%. The clay was consolidated first for one month under 9.

Table I

Typical Properties of Jute Fibres

Property	Range of Value
Fibre length, mm	180 - 800
Fibre diameter, mm	0.10-0.20
Specific gravity	1.02- 1.04
Bulk density, kg/m^3	120 - 140
Ultimate tensile strength, N/mm^2	250 - 350
Modulus of elasticity, kN/mm^2	26-32
Elongation at break, (%)	2-3
Water absorption, (%)	25-40

Table II

Typical Properties of Jute Fibres

Property	Range of Value
Thread diameter, mm	1.75- 1.85
Mesh Size, cm^2	3x3
Weight, g/m^2	680 - 750
Grab tensile strength(wet),N	800 - 900
Elogation at break (wet), percent	15-20
Trapezoidal tear strength, N	300 - 350
Permeability, cm/sec	
i) under unstressed conditions -	10^{-2}
ii) under all round pressure of 500 kN/m^2	10^{-3} - 10^{-4}

Table III

Comparison of Properties of Jute Fabric with Other Commonly used Geotextiles

Trade names	Weight (gm/m^2) ASTM D-1910-64	Thickness (mm) ASTM D-1777	Grab tensile strength (N) ASTM D-1682	Elogation at break (%) ASTM D-1682	Trapezodial tear strength (N) ASTM D-2263	Permeability (cm/s) Failing Head	Type
Propex 4545	153	-	400 (Minimum)	50 (Minimum)	-	2xl0^{2}(Min) 3xl0$^{'2}$(Max)	Non-Woven
Mirafi 600X	-	-	1335	-	534	0.01	Woven
Typar	136	15mill	580	62	312	0.02	Non-woven
Supac 5-P	180	15mill	556-670	80	325	0.05	Non-woven (Polypropylene)
Petromal	146	-	512	65	-	-	Non-woven
Terram 140	280	1.1	1128	150	343	0.072	Non-woven 75%Polypr. 25% Nylon
Jute fabric	680-750	1.75-1.85	800-900	15-20	300-350	0.02-0.04	Woven

kN/m^2 overburden pressure. Two sets of test were conducted using two different thickness of aggregates. The results of the dynamic load tests are presented in **Fig. 1** which indicates that without the use of jute fabric, the rut depth can be as high as 22mm for a 100 mm thick layer of compacted aggregate. When the thickness of the aggregate was doubled (200 mm), the rut depth was found to be 18mm under the same loading intensity. But with the use of jute fabric, the rut depth for 100 mm and 200mm thick aggregate layers were decreased to 10 mm and 7 mm respectively. In both the cases, there were more than 50 per cent reduction in rut depth with the use of jute fabric. The results of the dynamic load tests on jute fabric correlate very well with those of Lai and Robnett (1980) who carried out similar tests on a synthetic geotextile known as Typar. Static load tests were conducted in tanks of 1 m diameter and 1.2m high

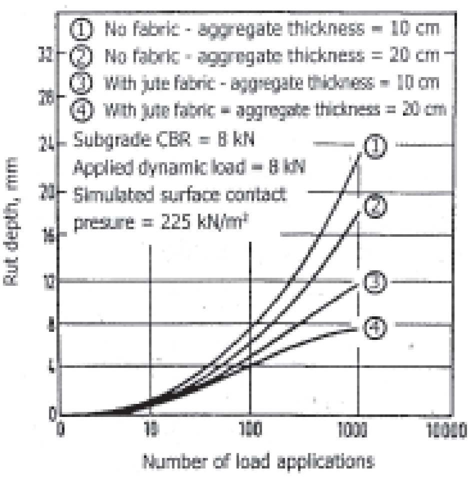

Figure 1 : *Typical Surface Rut Depth Vs Number of Load Applications Plots for Dynamic Load Test using Jute Fabric alone*

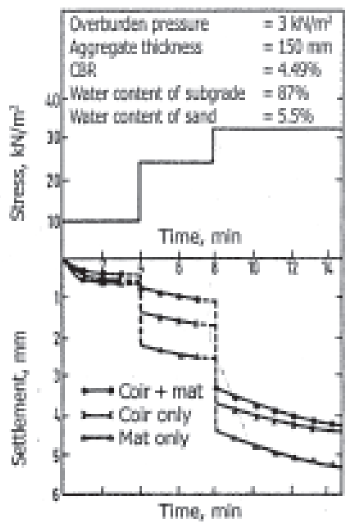

Figure 2 : *Short Time Rutting Test*

made of 8 mm thick galvanized iron sheet. The tanks were filled up with clay in layers of 100mm at a time and compacted. The total compacted depth of clay was about 600mm which was later surcharged by load of 0.8 tonnes (8 kN) over a plywood board of 20mm thick. This surcharge provided an overburden pressure equivalent to 10 kN/m^2. Altogether, six pressure cells were installed into each of the three tanks used. Surcharge operations in all the tanks took about a month to complete with settlement as much as 6 mm. Afterwards, the surcharge load was removed and the moisture content and vane shear values of the clayey subgrade were evaluated. This was followed by the placement of jute fabrics in the test tanks and backfilling of 100 mm thick moist sand (moisture content = 6%) which was overlaid by a plywood board wkhjijsurcharge loading of 170 kg simulating a pavement pressure of about 2.4 kN/m^2. In order to assess roughly the performance of the test models, preliminary short time (about 12 minutes) rutting tests were performed under a series of three loading pressures from simulated wheel loads of 350 N, 900 N and 1350 N. The first test tank was provided with only a thin compacted layer of sand aggregate (100 mm thick) and no jute fabric. The second test tank was provided with an ordinary layer of jute fabric at the subgrade/sub-base interface and the third tank was provided with jute reinforced with coconut coir-grid mat (Aziz and Ramaswamy 1994). The results of the preliminary short time static loading tests were found satisfactory (Fig.2) and hence the sustained long term (six weeks) loading tests were conducted under simulated wheel loads of about 1000 N on bearing plate of 200 mm diameter generating a surface contact pressure of 31,80 kN/m^2. Figure 3 shows the load settlement behaviour for the subgrade material with 200 mm thick aggregate layer. The satisfactory performance of jute fabric in stabilizing weak subgrade materials has been well reflected in Figs. 4 and 5. The subgrade/sub-base interface profile with and without jute fabric during the static loading test has been schematically shown in Fig. 4. Figure 5 shows the rut-time relationship for sustained seven weeks loading test under different experimental conditions.

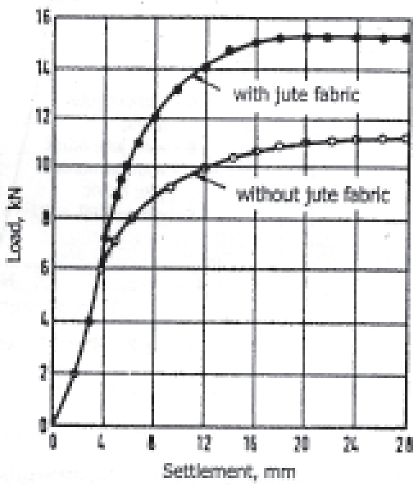

Figure 3 : *Load-Settlement Relationship*

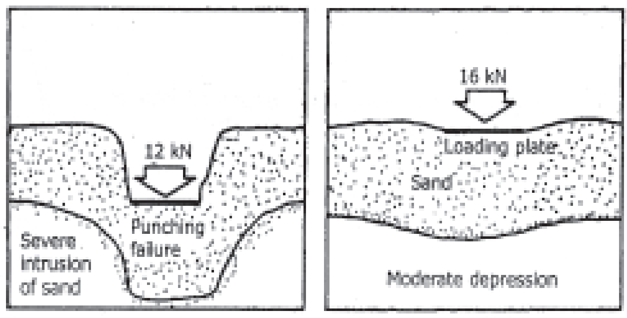

Figure 4 : *Subgrade/Subbase Interface Profile with and without Jute Fabric under Different Static Loading*

Both **Figs. 4 and 5** show the satisfactory performance of jute fabric as a geotextile under static loading conditions. Further studies were conducted using the coconut coir-grid matting underneath the jute fabric in order to evaluate further advantages derived by the use of such system (Aziz and Ramaswamy 1984). Jute fabric of 1.13 mm average thickness weighing 378 g/m^2 and coir (twisted coconut fibre threads) with average single strand diameter of 0.295 mm weighing 5.6 g/m were used in this investigation. The grid size adopted was 50 mm x 50 mm. Although the study could be carried out on a variety of jute fabric-coir grid combinations, the present study is expected to give a qualitative behaviour of the system in general. The stress-strain behaviour of a coir strand (0.295 mm diameter) is shown in Fig. 6. The rupture for the coir strand occurs at a strain of about 20%

much like the case of jute fabric. The following laboratory tests were carried out: (1) rutting test, (b) dynamic load test and (c) durability test.

Rutting Test

The test tanks containing soft clay and the geotextile prepared exactly the same way as for the sustained load test was used. The rut depth was measured by using loads of 300 N, 750 N and 1000 N in steps retaining each load for a total duration of 15 minutes and the rut depth was measured every minute (Fig. 7). The total rut depth was also measured by noting the long term (over one month) rut depth under a maximum sustained static load of 31.80 kPa **(Fig. 8).**

Dynamic Load Test

The test tanks prepared in the same manner as above were used to check the comparative performance of jute fabric-coir grid combinations under dynamic load repetition. The tests were carried out by applying 1000 loading cycles by using a dynamic load of 1.5 kN. The results of dynamic load tests are shown in **Fig. 9.**

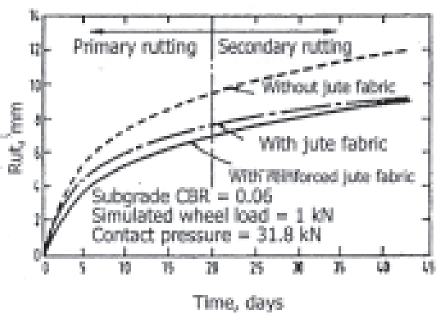

Figure 5 : *Rut-Time Relationship for Sustained Seven Weeks Loading Test*

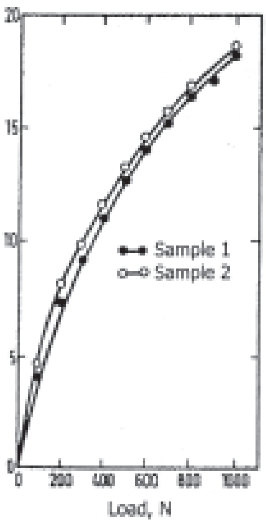

Figure 6 : *Stress-strain Behaviour of Coir Strand*

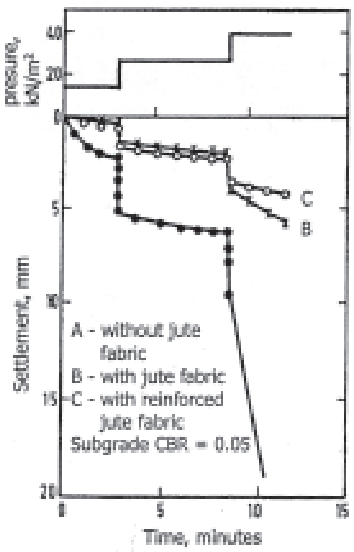

Figure 7 : *Short-Time Rutting Test*

Durability Test

Durability test was done by performing the grab tensile test on jute and coir specimens once in every month. The jute specimen consisted of blank samples treated with 40%, 50% and 60% bitumen and samples preserved with 3.5%, 6% and 12% tanal in. They were either soaked in acid solution (pH=3), alkaline solution (pH=12) or buried under the clay in a separate container. Two pieces of each sample were taken out for grab test (ASTM D 2262-71) monthly and the strength determined. Similar tests were conducted on coir samples.

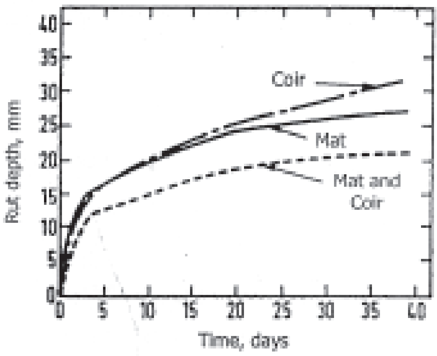

Figure 8 : *Rut Depth-Time Relationship for Sustained Loading Test*

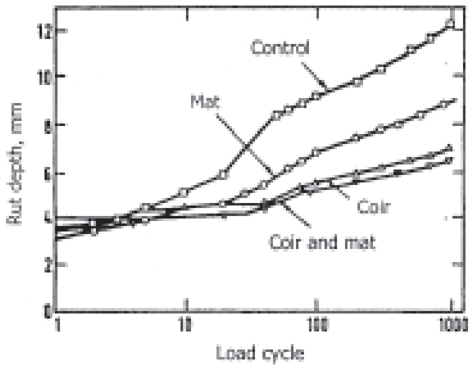

Figure 9 : *Rut Depth Vs Number of Load Application*

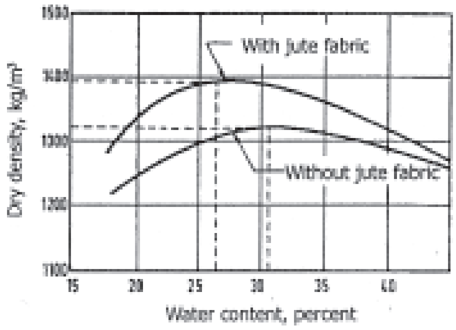

Figure 10 : *Effect of Jute Fabric on Compaction Characteristics of Subgrade Soil*

Unconfined Compressive Strength and CBR Tests

In order to study the influence of jute fabric on the strength of clayey subgrade, unconfined compressive strength and CBR tests were carried out in the laboratory on samples compacted with and without fabric layers in the saturated conditions (Ramaswamy & Aziz 1989, Aziz and Ramaswamy 1984). The standard proctor compaction tests were carried out on soils withoutfabric as well as on samples with 3 layers of fabric embedded at mid-depth. Figure 10 shows the effect of a fabric layer on the soil compaction characteristics. For the same compaction effort, the soil is seen to be better compactible when the fabric is used. The unconfined compression tests were carried out on samples compacted to 100 mm diameter and 200 mm long at the standard proctor compactive effort using optimum moisture content

Table IV

Effect of Jute Fabric on Unconfined Compressive Strength

Water content, %		25	30	35
Unconfined Compressive	without fabric	110	45	36
strength, kN/m^2	with fabric	300	115	65
% strain at failure	without fabric	8	10	22
	with fabric	26	30	42

of 25%. For these tests, with jute fabric, two layers were interposed within the samples at equal intervals while compacting. **Tables IV** and **V** respectively show the influence of fabric on the unconfined compressive strength and CBR values of samples compacted in the laboratory. The laboratory test results conclusively show that the stress-strain characteristics of the soil are better with the jute fabric than without it.

Table V

Effect of Jute Fabric 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

Field Trials

Since the laboratory tests gave only a qualitative indication of the beneficial effect of jute fabric, plate load tests were conducted to evaluate the insitu behaviour of the subgrade. The subgrade soil was soft to medium silty clay of natural water content of 35% and vane shear strength (insitu) of 20 kN/m^2. Plates of 300 mm diameter were loaded keeping them directly on the surface of the uncompacted subgrade in the first series and on the surface of jute fabric spread over the subgrade in the second series. The average results are shown in Fig. 11. The plate load tests confirmed that the jute fabric significantly improves the bearing capacity and settlement behaviour of the subgrade soil. The results of tests carried out using jute fabric were in tune with similar tests reported using synthetic fabrics (Jerrett et al 1977).

Use of Jute fabric for Haul and Low-Volume Roads

The economical design and construction of haul roads and other low-volume roads and stabilization of area sites can be a challenge to the road engineers faced with poor sub-grade soils. Jute fabric can be successfully used for stabilizing poor subgrade soils. Jute fabric can reduce the substantial amount-of aggregate required for stabilization just the same way as has been reported with the use of synthetic geotextiles (ASCE 1979) to roads not using jute fabric. Jute fabric is spread directly over the roughly levelled poor subgrade soil. In the case of clayey subgrades (percentage of fines exceeding 50%) it is recommended to spread the fabric after placing a layer of sand of 10 mm to 20 mm thickness. The fabric is then surcharged with granular material, preferably sand of 30 mm to 50 mm thickness, to act as a lower sub-base and it is rolled initially with light rollers and later if possible with medium to heavy rollers. A layer of sub-base consisting of coarse aggregate or crushed rock (locally known as crusher-run) varying in thickness from 200 mm to 300 mm may be placed over the sand layer and compacted. Under the surcharge action of sub-base layer and compaction rolling, the subgrade loses water content through the filter fabric and gains strength. Unrolling of the fabric can be done easily manually and great accuracy in alignment is not required. For multi-lane roads, an overlap of at least 300 mm is preferred where necessary. Wastage in overlapping can be reduced by just folding the edges together and stitching longitudinally by using a portable sewing machine. The fabric over the subgrade may be spiked if necessary by the use of U-shaped spikes driven at random as necessary to keep the fabric in place during construction and rolling. Proper placement of fabric to ensure lack of continuity with suitable overlapping or stitching wherever required is important. The extreme flexibility of jute fabric allows it to bend and fold making it quite versatile in easy spreading. In the event of a tear occurring, the damage remains localized and does not spread progressively like in the case of a woven cotton fabric. In this respect, the jute fabric can be considered to behave much like any other non-woven synthetic fabric. Any accidental damage does not therefore

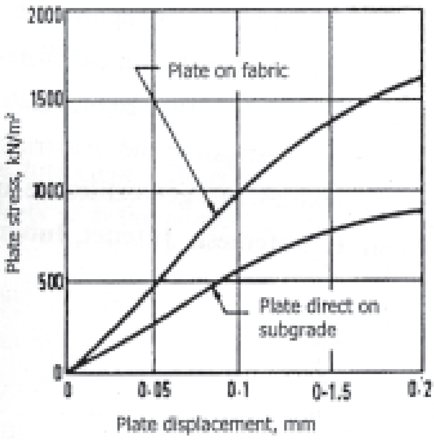

Figure 11 : *Effect of Jute Fabric on Bearing Capacity of Subgrade Soil*

affect the overall performance of the jute fabric. For unstable and wet subgrades, jute fabric appears to provide a satisfactory solution to stability and drainage problems. Figure 12 illustrates the jute fabric in position within the road structure. The jute fabric placed as above acts as a separator to eliminate the punching of aggregate into the soft subgrade as well as to resist'the infiltration of fines from the subgrade into the aggregate layer thus arresting any tendency for pumping. The drainage system also maintains optimum performance because the fabric does not get clogged under field conditions. The high tensile strength and tear resistance make the jute fabric to act as a support membrane to reduce localized distress to the road surface by redistributing-traffic loads' over a wider area of subgrade. This would of course result in the reduction of thickness of overall road structure resulting in some reduction in the quantity of earthwork as well. It has been reported (ASCE 1979, Nagarkar et al 1980, Giroud and Noiray 1984) that with the protection offered by geotextiles to be subgrade, less sub-base is needed and therefore less subgrade needs to be excavated.

Durability Aspects

Durability studies have confirmed that the jute fabric retains sufficient strength for about a year. Long term durability studies and the decaying of jute fabric with time under different environmental conditions are needed for proper long term assessment. **In the opinion of authors, the strength and condition of the jute fabric beyond a period of one year after placement should not be of any concern as by that time the fabric would have already played a very important role in providing a self sustaining subgrade for most types of soils.** After placement, the jute fabric will strengthen the subgrade by consolidating it by removing the water gradually in a step by step loading starting from the granular surcharge of sub-base, base and road surface layers, roller compaction of various layers and finally under the traffic wheel load compaction at least for a period of 6 months. **The gain in strength of the subgrade with time can well be compensated for the loss of strength of the jute fabric within the same time frame.** The granular drainage layer placed above the stabilized subgrade would continue to function permanently.

Other Road Related Applications of Jute Geotextiles

The United Nations International Trade Center is currently involved in testing and promoting jute as a geotcxtilc (UNCTAD/GATT 1985, 1986). International Jute Organization (IJO) also

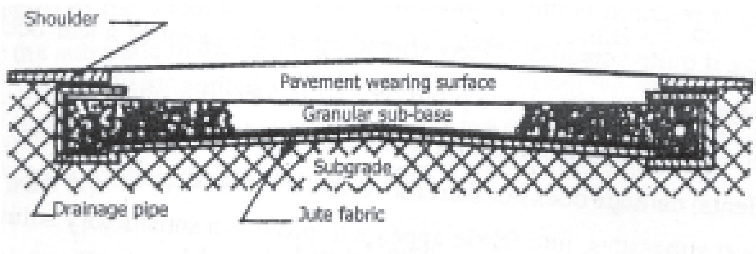

Figure 12 : *Position of Jute Fabric in Road Structure*

entrusted the execution of the market promotion project of the jute geotextiles covering Western Europe to the International Trade Centre (ITC). With a view to a better appreciation of utilization potential of jute geotextiles, these organizations have carried out extensive studies on the properties, functions and durability-of various types of jute geotextiles for erosion control and highway slope protection. In addition, studies are being conducted for its feasible application in soil stabilization, drainage, and soil reinforcement. The Bettelle Institute of London(Ingold 1984) and Bangladesh Jute Research Institute (BJRI1974) have initiated extensive laboratory investigation and field trials for a number of engineering applications and field trials on Jute Geotextiles. Jute geotextiles are marketed under a number of names which include **Jute fabric, Geojute, Jutemesh, Jutenet, Jutemat,** etc. These products are also sold under Trade Names like **Soilsaver, Antiwash.** Properties of jute fabric have already been discussed. Geojute, Jutemesh, Jutenet and Jutemat are synonymous. It consists of a heavy woven jute matting made from 100% jute yarn and has a open mesh structure **(Fig. 13).** Regular grades are quoted as being available at 500 g/m^2 and heavy weight grade at 800 g/m^2.

Normal thickness is 5 mm but considerable variation is apparent. Normal mesh opening size is 11 mm x 18 mm having an open area ratio of 60 to 65 percent. The tensile strength varies between 5.2 to 7.5 kN/m. Standard width is 1.22 m (48 inch) and roll lengths vary between 50 m to 70 m. The weight of such rolls ranges between 35 to 45 kg (UNCTAD/GATT 1985,1986). Geojute has been successfully used for highway slope protection, soil erosion control and strengthening of poor subgrade soils in countries like Bangladesh, China, India, USA, UK, France and Switzerland (UNCTAD/GATT 1985, 1986; Textile Horizon 1985).

Discussion and Conclusion

The Jute Geotextile has the potential of being used to serve as a filter fabric as well as a fabric reinforcement to stabilize and protect weak subgrades in road construction. When the jute fabric is placed directly on the subgrade and topped with a granular backfill to form a sub-base for the pavement, it is found to function in a three fold way : (i) it separates the subgrade from sub-base thus preventing the punching of the base material into the subgrade and at the same time the fines from the subgrade are also prevented from gaining entry into the road structures, (ii) it acts as drainage layer to remove excess water from softening the subgrade, and (iii) it helps to improve the bearing capacity and settlement behaviour of the subgrade by virtue of its action as a fabric reinforcement.

The Jute Geotextile is expected to contribute towards better road performance by reducing road defects with the consequent reduction in maintenance costs. The economy resulting in

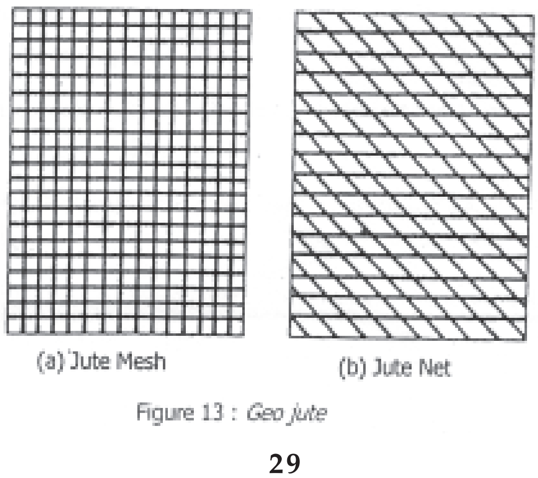

Figure 13 : *Geo jute*

reduced road thickness design and construction time is an added bonus. While the jute geotextile appears to function quite close to synthetic ones in performance, its durability aspect seems to pose a limitation on its use. However, jute geotextile is found to be fairly resistant to deterioration when embedded in wet soil under a narrow, margin of annual variation in subgrade water content (18% to 30%) and subgrade temperature (25°C to 30°C) conditions prevailing in the geographical region of Southeast Asia,. There is little doubt that the jute fabric and jute mats are initially very strong and ideal for use as a geotextile material.

After it is placed on the weak subgrade, the subgrade stiffens and becomes stronger on consolidation within about a year or so under the action of granular sub-base surcharge, self weight of pavement, construction rolling and traffic loads. The jute geotextile immensely helps in this rapid subgrade strengthening process in combination with the drainage layer above it. With time, the subgrade becomes less and less dependent on the fabric for its stability and therefore, the long term durability aspect of jute fabric should not deter its use as a geotextile for various applications in road construction. Jute geotextile materials are biodegradable and their uses in various geotechnical engineering applications are ecologically safe.

Jute fabric is useful for developing countries of the Asia-Pacific Region as a money saver as well as a construction expedient. The advantages resulting by its use will more than outweigh the cost of the material and laying. Being in the vicinity of the jute producing countries (Bangladesh, India, China, Indonesia and Thailand), the developing countries of this region can harness the benefits of jute fabric especially for the purposes of soil stabilization, slope protection and erosion control. For these countries, the jute fabric could serve as an economical alternative to the imported versions for certain applications resulting in substantial savings in terms of foreign exchange.

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REFERENCES

UNCTAD/GATT (1986). Use of Jute Fabrics in Erosion Control. Jute Market Promotion Project No. RAS / 77/04. International Trade Centre, Geneva.

UNCTAD/GATT (1985). Jute Geotextiles for Erosion Control-draft Specifications and Installation Guide. Jute Market Promotion Programme, Division of Product and Market Development. International Trade Centre. Geneva.

UNCTAD/GATT (1985). Jute Geotextiles Control Systems. Jute Market Promotion Project. International Trade Centre, Geneva.

BJRI (1974). Jute and Jute Products. Bangladesh Jute Research Institute. Brochure of the Agricultural and Industrial Exhibition. No. BGP 73/74, 4351B-2000, Dhaka, Bangladesh.

Ingold, I.S. ed (1984), Geotextiles and Geomembranes. An International Journal, Elsevier Applied Science Publishers, London, Vol. 1,1-40.

Geotextile Engineering Manual. US-Federal Highway Administration, National Highway Institute, Washington D.C., USA.

Nagarkar, P.K., Kulkarni, V.T. and Desai, G.V. (1980). Use of Fabrics in Civil Engineering Construction. Proc. Indian Road Congress, New Delhi, pp 5-17.

Robnett, Q.L. etal (1980). Use of Geotextiles in Road Construction : Laboratory Study. Proc. 1 st Canadian Symposium on Geotextiles. Calgary, Alberata, Canada.

Textile Horizon (1985). Jute Holds Ground. Industrial Fabrics. London.

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

deBoer, L.J. (1984). The Use of Geotextile in Highway Construction. Geotechnical News. Vol. 4, No. 3, pp. 24-33.

Sim. M. (1984). Geotextile's Use in Soft-Soil in Road Construction and Coastal Protection Works in Singapore and Malayasia. Proc. Conference on Geotextiles, Singapore.

Silence, P. (1987). Geotextiles in Roads and Highways : State-of-the-Art. Proc. Asia Pacific Conference on Roads, Highways and Bridges, Jakarta, Indonesia, pp. 22/1-2/11.

Hore, D.J. (1977). The Use of Fabrics in Geotechnics : a Review of the International Conf. Paris. ASCE Civil Engineering Journal, pp 57-61.

Giroud, J.P. and Noiray, L. (1984). Geotextile Reinforced Unpaved Road Design. Journal ASCE Geotech Eng. Div. Vol.1. 107, No. GT9, pp 1233-1254.

McGown, A. and Ozelton, M.W. (1973). Fabric Membranes in Flexible Pavement Construction over Soils of Low Bearing Capacity. Civil Eng. Pub. WKs., Review, London, pp 25-29.

ASCE (1979). Filler Fabric Stabilizes Soils in Road Construction. ASCE Civil Engineering Journal (1977), pp 55-57.

Jerrett, P.M., Lee, R.A. and Ridell, D.V.B. (1977). The Use of Fabrics in Road Constructed on Peat. Proc. C.R. Conf. Int. Soils Textiles, Paris, France, pp 19-22.

Ramaswamy, S.D., and Aziz, M.A. (1982). Jute Fabric in Road Construction. Proc. 2nd Int. Conf. on Geotcxtiles, Las Vegas, pp 359-363.

Ramaswamy, S.D. and Aziz, M.A. (1983). An Investigation on Jute Fabric as a Geotextile for Subgrade Stabilization. Proc. 4th Conf. Road Eng. Assoc. Asia and Australasia, Jakarta, Vol. 3, pp 145-158.

Aziz M.A. and Ramaswamy, S.D. (1984). Studies on Jute Fabric upon Coir-Grid Matting for Subgrade Strengthening (in French). Journal Revue ~~Generale~~-Des Routes et Des Aerodromes, Paris, Issue No. 59e, annee, pp 775-779.

Lee, S.L., Ramaswamy, S.D., Karunaratne, G.R, Aziz, M.A. and Das Gupta, N.C. (1980). Development and Performance of Fibredrain. Proc. Seminar on Engineering Design and Innovation in the 80's. Science Council of Singapore, Singapore, pp 10-18.

Aziz, M.A. and Mansur, M.A. (1982). A Study of Jute Fibre Reinforced Cement Composites. Int. Journal of Cement Composites and Lightweight Concrete, England, Vol. 4, No. 2, pp 75-81.

JUTE GEOTEXTILE SOLUTIONS FOR SURFACE AND SUBSURFACE DRAINAGE

S. D. Ramaswami

ABSTRACT

Jute geotextile and its components have been found to come to the rescue of fine grained soil and water related problems. Jute can be assembled and applied to act as a geotextile in its woven or non-woven forms. For certain specific applications jute geotextile may be used in a composite form for efficient operation in combination with other natural or synthetic materials.

In most of the drainage applications, the jute geotextile will have to perform also the functions of filtration and separation. Jute geotextile applications take full cognisance of the fact that jute is biodegradable and its initial high strength is not sustainable. After installation in place, the strength drops very rapidly with time. Such a behaviour is not considered to be a drawback. Jute geotextile types are environmental friendly, cost effective and the long term strength retention is not a criteria for satisfactory performance when applied to surface and subsurface drainage related problems. In this paper certain unique characteristics of jute geotextile which make them function efficiently are highlighted and a few proven drainage related applications are described.

INTRODUCTION

While geosynthetics dominate in all spheres of application, the jute geotextiles have now proven their mettle to match with geosynthetics in areas involving erosion, filtration, drainage and separation and such areas constitute about more than 50% of all geotextile applications. In such applications the initial desirable factors such as tensile strength, drainage'capacity and non-clogging filtration ability count very much.

Jute geotextiles in the woven or non-woven forms permit free flow of water both normal and interplanar directions. Recent trend in both the developed and developing countries very clearly suggests that the role of jute geotextiles exists in fluid control and solid control applications. Fluid control involves filtration and drainage and solid control involves separation and clogging.

A variety of needle punched non-woven geotextiles with jute and polypropylene blending (if necessary) can be produced for various applications. Durability treatment also can be made to retard ageing of jute geotextiles. Trends in world jute production and consumption in relation to its market potential along with jute geotextile properties and its potential have been reported (Ranganathan, 1994).

Suitability of various kinds of blends with jute have been tried for filtration, separation, drainage and erosion control applications. The role of jute geotextiles in the control of soil erosion which is promoting surface drainage without dislodging the soil particles through revegetation and potential that exists for them in various areas are well known (Ranganathan, 1994).

The function of drainage involves also effective filtration to prevent clogging and separation of overlying material and the underlying material from contaminating each other (Aziz and Ramaswami, 1984, Ramaswami and Aziz, 1982, 1989 and 1991).

The inherent qualities of jute geotextiles which make them so ideal for drainage applications are : initial high strength, high inplane drainage capability, high saturation and moisture retention, excellent drapability and biodegradability. Several drainage related application potential of jute geotextiles have been identified arid a few of them have been successfully tried on real life projects.

Jute Geotextiles Unique

Characteristics

There are certain characteristics which only the jute geotextiles possess those are lacking in geosynthetics. They are biodegradability, inplane drainage, absorption capacity and drapability. Initial high strength of jute geotextile equal to that of a geosynthetic counterpart is attainable and it II essential to cater, for handling and installation stresses and to transmit high initial stresses to the soil surface until it gains strength to sustain itself. Biodegradation brings about loss of strength and it is not deterrent to most drainage applications. In vertical drainage applications the prefabricated drains kink due to excessive soil settlements and more so if dynamic impacts are applied. Synthetic prefabricated drains often rupture and still permit efficient drainage to take place.

Inplane Drainage

One of the major considerations in the use of jute geotextiles is the inplane drainage capability which is indeed much superior to geosynthetics. Some of the application areas which make **use** of this special characteristic of flow within the fabric are the following :

- as interceptors for road drains (Ramaswamy and Aziz, 1982, Ramaswamy *et a/,* 1992 Ramaswamy and Aziz, 1984),
- as prefabricated drains to hasten consolidation (Lee *eta/,* 1994)
- to dissipate seepage forces in earth and rock slopes.
- to eliminate hydrostatic pressure behind retaining walls,
- as chimney drains for earth dams,
- to dissipate pore water pressures in synthetic fabric retaining walls,
- to dissipate pore water pressure in encapsulated soil systems.
- to transmit water from beneath rail track ballast.

Non-woven fabrics performs the function of inplane drainage more effectively than the wovens. Non-woven jute/jute blends sandwiched between two layers of woven or non-woven jute geotextile of fine pores can perform the above functions exceedingly well. Although embedded performance under undisturbed conditions may not be significantly affected by loss in strength due to biodegradation, durability treatment is recommended.

Absorption and Drapability

After the, devastating floods in 1988, a flood protection of 24 km long has been constructed around the city of Dhaka as a protection against major floods (Shahid, 1994). Jute grid was used to protect the slopes from rain water erosion. The ability of jute for this function was attributed to two reasons. Firstly, its water absorption and retention capacity. In its saturated condition it-has the ability to absorb rain water impact and thus prevent the soil particles from getting out of their position. Secondly, in its saturated condition, the flexibility and the weight of jute geotextiles is considerably more which imparts to it the unique quality of drapability that makes it cling to the ground irregularities to maintain intimate contact. This further helps in preventing dislodging of soil. Figure 1 depicts the action of jute geotextile in controlling surface erosion and drainage (Rankilor, 1994).

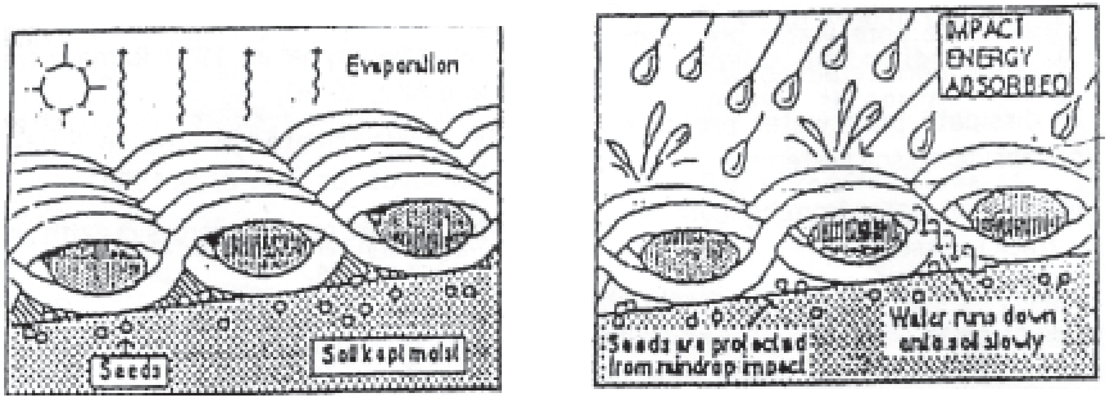

Fig. 1 : HARMLESS SURFACE DRAINAGE (After Rankilor, 1994)

Oosthuizen and Kruger (1994) carried out a comparative study of jute coir and sisal geotextiles for erosion control purposes. Figure 2 shows excellent moisture absorption capacity of natural geotextiles. Jute appears to excel followed by coir and sisal.

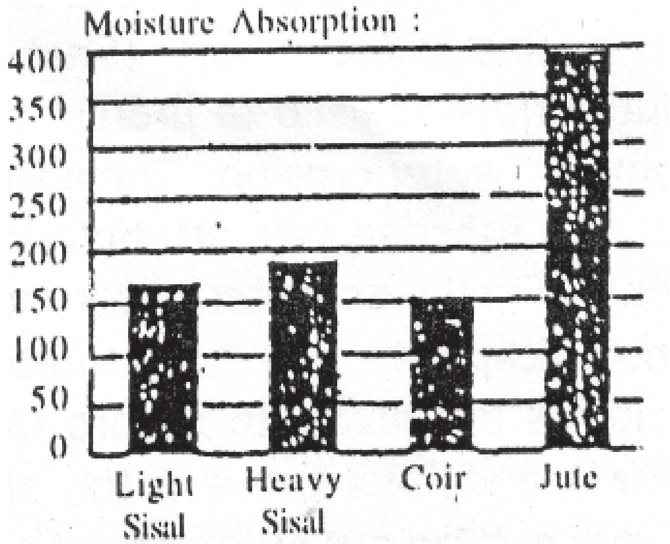

Fig. 2 : MOISTURE ABSORPTION AS A PERCENTAGE OF DRY WEIGHT (After Oosthuizen & Kruser, 1994)

Jute was also found to be more resistant to the ultra violet degradation by sun light as compared to coir. However, this is not significant as all natural geotextiles are to be stored in the shade before use and where they are buried in soil or used under water, the question of direct exposure is of no concern. In erosion control applications there is an imminent exposure. The gradual reduction in strength followed by biodegradation does not affect its function as it is quite normal and expected. Once vegetative growth is established, for the geotextiles, the mission is accomplished.

Drainage with Kinking

Much has been discussed about the natural fibre prefabricated drains (Lee et al, 1989a, 1989b, 1989c, Ramaswami, 1991).

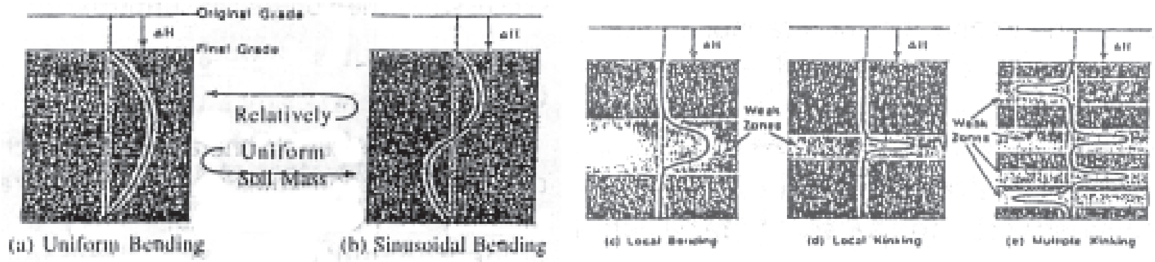

Fig.3 : Kinking Patterns of Prefabricated Drains (After Lawrence and Koerner, 1988)

Such drains are being used popularly in Indonesia for consolidating soft compressible clays. Unlike the geosynthetics prefabricated vertical drains which are susceptible to kinking damage (which clogs the path of water flow), the jute-coir drains are found to be strong and flexible enough to kink without rupture. Patterns of kinking of prefabricated drains (Lawrence and Koerner, 1988) are as shown in **Fig. 3.** No wonder therefore such drains have been used successfully even where dynamic impacts are involved (Lee et al, 1994). The sequence of procedure which has been adopted in some projects is shown in **Fig.4.**

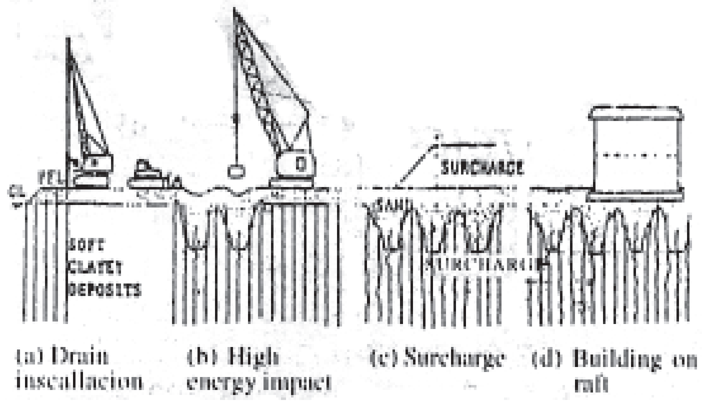

Fig. 4 : Sequence of Soil Treatment Using Jute Drain And Dynamic Impacts (After Lee et al, 1988)

Jute Drain

Jute prefabricated drain developed by the author jointly with his colleagues (Lee et al 1994, Ramaswamy et al 1992) has appeared in many publications and is quite well known by the name Fibredrain. This prefabricated drain is patented in the United Kingdom, Singapore and registered as an utility model in Japan. It is band shaped measuring 100 mm x 5 mm in cross section and made in rolls of about 200 m. It consists of four continuously funning coir strands running parallel to each other enveloped by two layers of woven jute fabric held together by longitudinal stitches.

The Fibredrain is being used in Indonesia for soft deep seated clay consolidation purposes. A pilot test is also presently in progress in Japan for adoption for large scale projects. Being 100% biodegradable, it is the only environmental friendly drain available today which makes its acceptable even by the developed countries. It is a very versatile drain that can also be used for horizontal drainage purposes as well in slope stabilisation and to fight seepage cases.

A recent example of application of Fibredrain is in the treatment of 18 m thick layer of soft clay for 90 ha residential cum recreational development in Indonesia (Lee et al, 1994). Using a spacing of 1.4 m in a square grid and applying a sand surcharge, the required degree of consolidation was achieved in just 3 month time period. Fig.5 shows the settlement curves monitored at the project cited above where jute fibre was used. Expected long term settlement of about 1m which 1m would have had drastic effects on the structures was achieved prior to construction in a period of about an year by the use of jute drains.

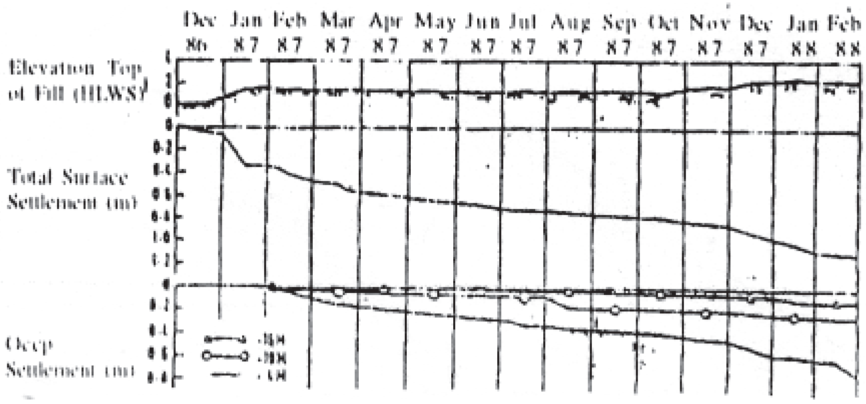

Fig. 5 : Loading History and Settlement Profile (After Lee et al, 1994)

For reclaiming land from the sea suitable dredged sand fill land cut fill or imported suitable non cohesive fills are commonly required. When suitable fill is not available and the sea bed material is clayey, dredged clay fill could be used sandwiching each clay layer between granular layers. In actual practice there are sand penetration and mix up problems since the clay fills are invariably soft. Jute geotextiles have been experimented to act as separation and filtration layers (Tan et al. 1994). Field trials using fabric (woven or non-woven with coir grid matting (Ramaswami and Aziz, 4982) may not only assist in handling and spreading but also aid install a more stable contamination free laying. The same technique is very appropriate for reclaiming the water logged areas to retain and consolidate the soil by expelling the water by filtration and drainage.

Siltfences

An excellent area of application for natural geotextiles (involving bamboo or small diameter tree trunks, timber poles), coir grids and woven or non-woven jute fabrics in combination is in soil fencing. Figures 6 and 7 illustrate the construction methodology (Rankilor, 1994). Such silt fences are temporary in nature. They can serve very useful purpose of trapping the fine grained soil especially during the monsoon season.

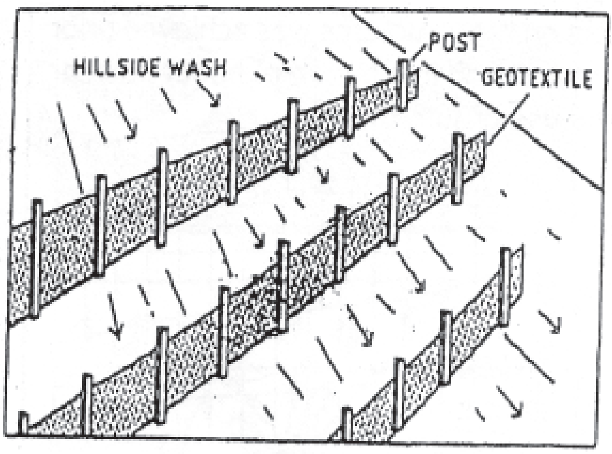

Fig. 6 : SILT FENCE ARRAY ON A STEEP HILLSIDE

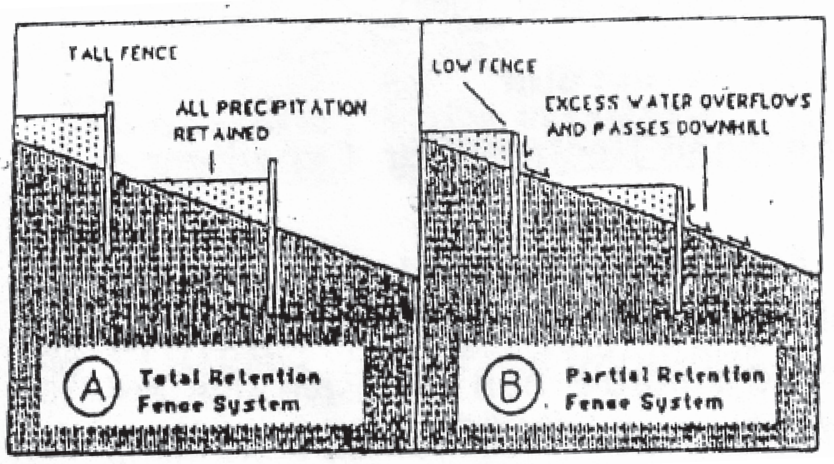

Fig. 7 : TOTAL (TALL FENCE) RETENTION PARTIAL RETENTION (LOW FENCE) (after Rankilor, 1994)

Pavement Drainage

Compacted subgrades impermeable shoulders for highway pavements often turn them into bathtubs (Cedergren, 1994). The concept of good drainage is that quickly draining pavements survived to 4 times longer than the slowly draining pavements. There are many ways in which jute geotextile in its varied forms can be used (Ramaswamy, 1991, Ramaswamy et al, 1992). Subgrade and subsurface drains supplemented by interceptor drains (Fig. 8) could help considerably. Again, filtration, separation and drainage virtues of jute geotextiles are called into play in such applications.

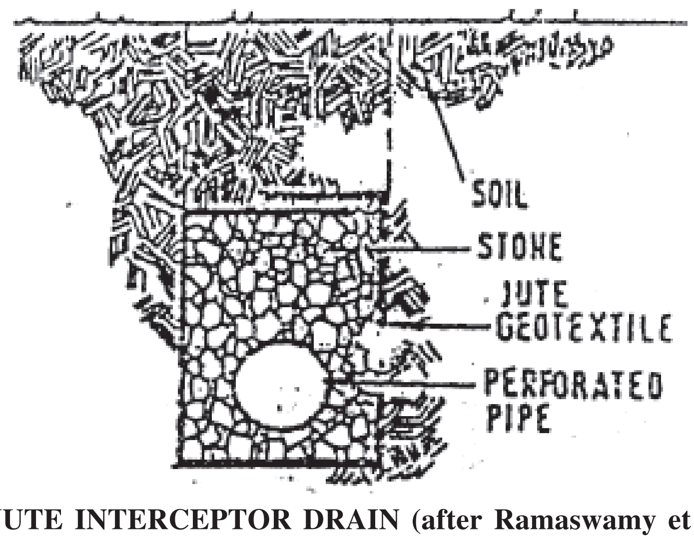

Fig. 8 : JUTE INTERCEPTOR DRAIN (after Ramaswamy et al. 1992)

Bank Protection

A recent successful application of jute geotextile impregnated with rot proofing agent for the erosion protection of banks of Nayachor island Haldia Port has been reported (Ramaswamy, 1992, Sivaramakrishnan, 1994, Sanyal, 1992). Siltation of 600 mm thickness over the geotextile was observed 8 months after being in operation. The properties of jute geotextile used, the specificati on requirements, the site conditions, construction details and performance observations are described by Sivaramkrishnan (1994). The properties of the fabric specially treated with 5% Hedraol-LT solution followed by bitumen in take of 100% are given in Table.

CONCLUSIONS

Jute geotextiles are ideally suited for drainage related applications in geotechnical engineering. They may be designed to cater to the needs of specific problems in any of the woven or non-woven jute formulations or in any of the many possible composite forms with other natural or synthetic combinations.

Applications in the form of prefabricated vertical and horizontal drainage as well as for slope and bank protection purpose using jute/jute composite geotextiles have proven to be dependable successes.

Technically feasible, environmentally compatible and economically viable usages.

Table 1 : PROPERTIES OF JUTE FABRIC FOR RIVER BANK PROTECTION AT NAYACHARA

Type	:	woven (D. W. Twill)
Mass	:	1538 g/m^2
Thickness at 10 kPa	:	2.83 mm
Pore size	:	150 microns
Breaking strength		
Machine direction	:	32.2 kN/m at 11.8% elongation
Cross direction	:	28.2 kN/m at 13.5% elongation
Puncture resistance	:	3790 kPa
Air permeability	:	16.2 $m^3/m^2/min$
Water permeability at 100 mm water head	:	20.4 $1/m^2s$

involving highways and railways, land reclamation and construction projects can be evolved replacing geosynthetics with jute geotextiles and their composites. The versatility of jute geotextiles and their formulations in adapting to filtration, separation and drainage applications deserve attention especially by the jute producing countries. By so doing, these countries can gain in many ways such as promoting large scale usage of their own indigenous natural product, to improve the infrastructural facilities, to protect the environment, to save foreign exchange to mention a few.

REFERENCES

1. Aziz, M. A. and S. D. Ramaswamy (1984): Studies on Jute Fabric Upon Coir Grid Matting for Subgrade Strengthening. Revue Generale Des Routes Et Des Aerodromes, N. 614, Paris, 56-58.
2. Cedergren, H. R. (1994) : America's Pavements : World's Longest Bathtubs. Civil Engineering, ASCE, New York, 56-58.
3. Lawrence, C. A. and R. M. Koerner (1988): Flow Behaviour of Kinked Strip Drains, Geosynthetics for Soil Improvement. American Society for Civil Engineers, New York, 22-39.
4. Lee, S. L., G. P. Karunaratne, N. C. Das Gupta, S. D. Ramaswamy and M. A. Aziz (1989a): Laboratory Testing and Field Behaviour of Fibredrain. ..Proceedings of Symposium on Application of Geosynthetic and Geo fibre in Southeast Asia, Kualalumpur, 117-126.

5. Lee, S. L., G. P. Karunaratne, K.. Y. Yong and S. D. Ramaswamy (1989b): Performance of Fibredrain in Consolidation of soft Soils. Proceedings of 12th International Conference on Soil Mechanics and Foundation Engineering, Rio De Janeiro, 1667-1670.
6. Lee, S. L., G. P. Karunaratne, N. C. Das Gupta, S. D. Ramaswamy and M. A. Aziz (1989c): A Vertical Drain Made of Natural Fibres for Soil Improvement Projects, Geotextiles, Vol.1, Tata McGraw-Hill Publishing Company Ltd. New Delhi, 271-. 276.
7. Lee, S. L., G. P. Karunaratne, S. *D.'* Ramaswamy and M. A. Aziz and N. C. Das Gupta,(1994): Natural Geosynthetic Drain for Soil Improvement Geotextiles and Geomembranes, Vol. 13, Nos. 6-7, Elsevier Applied Science, Oxford, 457-474.
8. Oosthuizen, P. and D. Kruger (1994): The use of Sisal Fibres as Natural Geotextiles to Control Erosion. Proc. 5th Int. Cong, on Geotextiles, Geomembranes and Related Products Vol.2, Singapore, 871-874.
9. Ramaswamy, S. D. and M. A. Aziz (1982): Jute Fabric in Road Construction. Second International Conference on Geotextiles, Las Vegas, 353-363.
10. Ramaswamy, S. D. and M. A. Aziz (1984): Jute Fabric Upon Coir Grid Matting forSubgrade Stabilization. Proc. Int. Conf. on Road Development, Paris, 75-779.
11. Ramaswamy, S. D. and M. A. Aziz (1989): Jute Geotextiles for Roads, Geotextiles Vol. 1, Tata McGraw-Hill Publishing Company Ltd., New Delhi, 259-266.
12. Ramaswamy, S. D. (1991): Appraisal Highlights and Recommendations on Jute Geotextiles, UNIDO Report, Viena.
13. Ramaswamy, S. D. G. P. Karunaratne and S. Palit (1992): Application of Biodegradable Jute Geotextiles Filters. Proc. Int. Conf. on Filters and Filtration Phenomena in Geotechnical and Hydraulic Engineering, Karlsruhe, Germany.
14. Ranganathan, S. R. (1994) : Development and Potential of Jute Geotextiles, Geotextiles and Geomembranes, Vol. 13, Nos. 6-7, Elsevier Applied Sciences, Oxford, 421-434.
15. Rankilor, P. R. (1994): The Past, Present and Future for Geosynthetics in Indonesia, Geotextiles and Geomembranes, Vol. 13, Nos. 6-7, Elsevier Applied Sciences, Oxford, 435-456.
16. Sanyal, T. (1992) : Control of Bank Erosion Naturally. Proc. National Workshop on Role of Geosynthetics in Water Resource Projects, New Delhi, 131-137.
17. Shahid A. S. M. (1994) : Geojute Provides Long Lasting Erosion Control, Proc. 5th Int. Conf. on Geotextiles, Geomembranes and Related Products, Vol. 2, Singapore, 895-898.
18. Tan, S. A. N. Muhammed, G. P. Karunaratne and S. L. Lee (1994): Use of Jute Geotextiles in Layered Clay-Sand Reclamation Scheme. Proc. 5th Int. Conf. on Geotextiles, Geomembranes and Related Products, Vol.2, Singapore, 867-870.