A Manual on Use of Jute Geotextiles in Civil Engineering

NATIONAL JUTE BOARD

Ministry of Textiles, Government of India

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FOREWORD

Geo-Textiles made of man-made and natural fibres such as jute have been found to be effective in improving geo-technical characteristics of soil and are being applied extensively for erosion control, slope management, strengthening of roads, stabilization of embankments, protection of river banks, consolidation of soft soil, etc. Jute geo-textiles (JGT), engineered from jute fibre have proven to be very useful in many of these applications. Apart from being cost competitive, jute geo-textiles has the added advantage of being eco-friendly.

There is a long felt need to collate technical inputs from published documents, experience from field trials and results of laboratory studies in a Working Manual to facilitate the use of jute geo-textiles in a variety of areas.

A Manual on the use of jute geo-textiles in civil engineering works was first published by the National Jute Board in May, 2001. In view of the encouraging response from civil engineers in India, the 2nd edition of the Manual was published in August, 2003. These were followed by the 3rd and 4th editions of the Manual in February, 2008 and October, 2009 respectively. Field applications of jute geo-textiles have been carried out in construction of roads, railways, waterways, slope stabilization and other related areas. An international project - "Development and Application of Potentially Important Jute Geo Textiles" (CFC/IJSG/21) was launched in 2010 simultaneously in India and Bangladesh. Under this project, five new varieties of jute geotextiles, two of them woven and three of open weave type have been developed. The woven JGTs developed under this project have been found to be techno-economically superior to those developed earlier.

A number of standards, guidelines, schedule of rates pertaining to different types of JGTs have been published by different government organizations. Studies and research are still continuing for development of new varieties of jute geo-textiles. Research on new areas of application of jute geo-textiles are in progress.

I would like to congratulate Sri Arvind Kumar M, Secretary, National Jute Board and his team for painstakingly reviewing and revising the earlier editions of the Manual and publishing this edition incorporating latest information.

We hope that this revised edition of the Manual will prove to be a useful and handy guide to the consultants and engineers interested to adopt these varieties of technical textiles in civil engineering works.

13/V/2016

(Dr. Subrata Gupta)
Jute Commissioner
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1.0 JUTE AND JUTE GEOTEXTILES (JGT)

1.1 Jute*

Jute is a coarse natural bast fibre. Two species of jute which are commonly cultivated are – corchorus capsularis (white jute) and corchorus olitorius (tossa jute). Jute plants are usually 2.5m to 3.5m in height. The matured plants are harvested from the field, tied in bundles and immersed them in running or stagnant water for about 3 weeks. The process is called 'retting'. The loose bark of the plant is then extracted as fibre, washed in clean water and dried in sun. Only a small portion (approx 4%-6%) of the plant thus obtained as fibre.

1.1.1 The separation is effected by micro-organisms which multiply in course of time, soften and dissolve the gummy and pectinous substances that bind the fibrous and non-fibrous tissues. Properties of jute e.g., colour, lustre and fineness depend on the conditions of retting.

1.1.2 The major components of the fibre are Lignin (12-14%), Holocellulose (83-87%), Wax (0.4-0.8%), Ash (0.5-1.0%) and Nitrogen (0.2-0.4%).

1.1.3 The strand of jute fibres consists of numerous individual filaments which form a meshy structure. These fibres have varying length, fineness, strength, extensibility, tenacity, stiffness and toughness.

1.1.4 Extensibility of jute varies within a short range which increases when it is wet or moist.

Tenacity of jute is usually high and remains stable over a range of 30%-80% of relative humidity. Under very wet or very dry conditions, tenacity of jute decreases.

Stiffness is a measure of resistance to bending (breaking stress/breaking strain).

Stiffness of jute is high at normal moisture content but decreases with increase in moisture content above the normal. Torsional rigidity of jute is also affected at high moisture content.

Toughness of jute is low on account of its low extensibility.

1.1.5 Jute is highly hygroscopic and can absorb water up to about 5 times its own dry weight. This property introduces in jute an element of variance in weight under different relative humidity.

1.1.6 Jute is a very good insulator of heat and electricity. This property also varies with the change in moisture content.

1.1.7 Some salient physical properties of jute are given below :

- Density-1.47gm/cc
- Average Fineness - 20 denier, i.e. weight in gm. of 900 metres of filament
- Tenacity - 4.2 gm/denier
- Average Extension at break - 1.2%
- Average Stiffness - 330 gm/denier
- Average Toughness Index - 0.02
- Hygroscopicity (average regain at 65% relative humidity) - 13%

Ref. : *Mukherjee R. R. (1955) – Structure and Physical Properties of Jute (Textile India)

1.2 Geotextiles

Geotextiles are textiles applied in soil to help its engineering performance. Geotextiles may be either man-made (loosely called synthetic) or natural. Man-made Geotextiles are made of artificial fibres like polypropylene, polyethylene and some other petrochemical derivatives. Natural Geotextiles, on the other hand, are made out of natural fibres like jute, coir, sisal and the like. Jute Geotextile (JGT) is a natural Technical Textile.

The prefix "geo" indicates soil and "textiles" are fabrics laid in or upon soil. According to the latest convention, the term 'geosynthetics' is globally accepted and includes not only man-made geotextiles, but also natural geotextiles such as **Jute Geotextiles (JGT)***.

Jute fibres can be mechanically spun into yarns and woven into permeable and drapable fabrics(woven fabric) or can be bonded together mechanically through needle punching (non-woven fabric).

1.3 Jute fibres as already mentioned are natural fibres comprising approximately 83% to 87% natural cellulose and 12 to 14% Lignin. The fabric made of jute yarns biodegrades, leaving a fibrous residue which improves the soil-structure. The other important feature of jute is that it does not draw upon the valuable nitrogenous reserves and ultimately decomposes as is usually the case with other natural fibres. Jute Geotextile acts like a straw or peat mulch aided by its degrading fibres which help retain the moisture and improve the soil-permeability. JGT possesses better drapability1 and also wettability2, compared to all other geotextiles.

JGT, like the man-made variety, helps improve, as a change agent, the geotechnical properties of the soil on which it is applied. JGT, being permeable, allows the water retained within soil to permeate *across* its plane and also to disperse water along its plane. The extent of cross-permeability (termed “permittivity”[3] when the thickness of the fabric is considered) and in-plane permeability (termed “transmissivity”[4] when the thickness of the fabric is considered) depends on several factors, especially pore size of JGT (termed “porometry”[5]). The porometry of JGT is also the determinant in retention of soil-particles on which it is laid. A properly designed JGT (in most cases, in relation to the mean diameter of the soil-grains i.e.,d_{50}[(6)]) arrests migration of the major portion of soil-particles and imparts strength to the soil-body by ensuring their retention within it.

It is therefore evident that JGT, as filter, is required to perform basically two contrasting functions - soil-retention on one hand and permeability on the other. Empirical relations recommended in Manuals of different countries for design of man-made Geotextiles for a specific application are not identical. The design-recommendations in respect of JGT for specific applications have been drawn with an eye to the range of available JGT vis-à-vis technical requirements.

Ref. : *Ingold T. S. (1994) - Geotextile and Geomembranes (Elsevier Adv. Technology)

(1) Drapability - Ability of a geotextile to make contact with the soil-surface without leaving any gap between the two. It is a measure of fabric - flexibility.

(2) Wettability - Ability of a geotextile to become saturated under an extremely low waterhead (usually a few millimeters).

(3) Permittivity - The amount of water moving across a Geotextile in unit time through unit area and at unit head. It is usually referred to as kn (Darcy's Coefficient)/t (geotextile thickness). Uniits-kn in metre/sec, thickness (t) in metre, Permittivity in Sec^{-1}

(4) Transmissivity - The product of water permeability along the geotextile plane i.e., K_1 (Darch's Coefficient) and t (geotextile thickness).Unit - k_1 - metre/sec, thickness (t) in metre, transmissivity in m2/sec.

(5) Porometry - measurement of Geotextile pore-size and its distribution.

(6) d_{50} - diameter of soil particle such that 50% are smaller than this diameter. Similarly, d_{85} implies that diameter of 85% of soil particles are finer than this diameter.

2.0 FUNCTIONS OF JGT :

2.1 A property designed JGT is supposed to perform the following functions usually in conjunction, in different application areas related to civil engineering :

- Separation
- Filtration and drainage
- Initial reinforcement
- Control of surface soil-detachment
- Vegetation or biotechnical support

2.2 Separation

Separation function implies segregation of two layers of materials by preventing their intermixing, i.e., intrusion of one layer into the other comprising either dissimilar materials or similar materials with different grades. The phenomenon causes reduction in design thickness of a particular layer making the overlying structure susceptible to failure.

In road-construction, separation is needed to separate the sub-base from the sub-grade for prevention of the yield of the pavement under axle loads of moving vehicles. Intermixing of two layers causes reduction in the effective thickness of pavement. Load carrying capacity and the pavement life are consequently reduced.

2.2.1 Separation of two layers for at least one season-cycle helps in natural consolidation of the base-soil. Experiments have proved that once natural consolidation takes place, chances of subsidence of a part of any road or structure due to intermixing become substantially less. Biodegradability of JGT therefore does not normally pose any technical impairment after a season-cycle of their application.

2.3 Filtration

As already indicated in para 1.3, JGT as filter is supposed to perform two contrasting functions -soil-retention on one hand and ensuring permeability of water through and along it on the other. JGT provides a technically superior solution to conventional granular graded filters used for control of erosion of river banks. JGT can be manufactured with pore-sizes commensurate with the median grain size of the base-soil to ensure their retention. At the same time, water is allowed to pass across and along JGT in the required measure without causing development of any differential overpressure. The functions of permittivity and transmissivity are therefore important. With a tailor-made JGT, differential water over-pressures across it can be effectively dissipated preventing migration of soil-particles concurrently.

2.3.1 JGT, like its man-made counterpart, first retains the coarser particles of the soil. These coarse particles block smaller ones in the soil which in turn prevents migration of even smaller grains. This phenomenon which is known as 'filter cake formation' is in fact an indication of formation of natural filter within the soil and its optimum consolidation. The situation can develop only if it is ensured that

JGT has made full contact with the base-soil (i.e. if drapability of the JGT is ensured). For ensuring full drapability, JGT requires to be suitably ballasted. This load on top of JGT not only prevents its uplift under certain conditions, but also protects the fabric from continuous exposure to weather.

2.3.2 Soil properly overlain by JGT is seen to develop 'filter cake' usually within a period of 3/4 months from the date of application according to laboratory tests carried out in Research Institutes. Development of 'filter cake' is a sure indication of the base-soil having attained natural stability. Once the soil attains natural stability, function of any separating fabric - be it man-made or natural, becomes redundant. Though laboratory experiments by some researchers have shown formation of 'filter cake' within about 3/4months from the date of application of JGT, it is advisable to ensure durability of JGT for at least one season-cycle. **(Fig. 1)** Biodegradation of a JGT therefore does not normally pose any deficiency in its expected performance as such.

2.3.3 Clogging is generally accumulation of particles usually inside the openings of JGT. Soil-particles at the base or particles in suspension of flowing water tend to block the pores of JGT by deposition within its own thickness. Chemicals in water are also responsible for chemical clogging of JGT-pores. Permittivity ofJGT is consequently adversely affected leading to progressive clogging. Such clogging may be allowed if the rate of deposition is slow or for a limited duration.

Differentiation is sometimes made between clogging and blocking. Clogging isaccumulation of particles within the geotextile pores while blocking is deposition of particles on the surface of a geotextile. Blinding is a severe form of blocking.

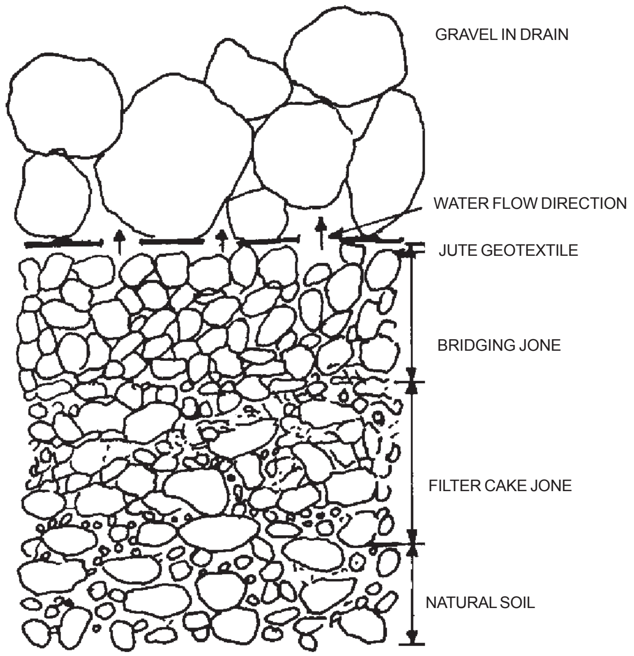


Fig. 1 FILTER CAKE FORMATION IN SOIL WITH JGT

2.4 Drainage

JGT performs drainage function within its own thickness. Proper drainage of soil accelerates its consolidation. Cohesion of the soil, as a result, is increased which, in turn, accentuates the separation effect of the JGT.

2.4.1 JGT possesses a high degree of transmissivity, i.e., can drain water effectively along its plane. JGT is also capable of holding water to about 5 times its own weight. In roads, lateral drainage of water from sub-base and sub-grade is critical. JGT used as a separator may facilitate the lateral evacuation of water from the road-structure and prevent water-accumulation at the sub-grade level.

2.5 Initial Reinforcement

JGT can reinforce soils which are usually weak in tension at the initial stages. Any large soil body e.g., an embankment, undergoes failure by vertical subsidence, lateral dispersion and rotational slides. When used in appropriate layers, especially across vulnerable planes of failure and distress, JGT can effectively control such failures. Soil-movement is curbed by its confining action. JGT also absorb a part of the stress that could cause a shear-failure. Stability of such soil-structures is thus substantially enhanced enabling faster construction without removal of weak soil layers.

2.5.1 As has already been pointed out, any soil-mass tends to stabilize naturally if proper separation, filtration and drainage can be ensured. JGT can be manufactured up to 40 kN/m tensile strength in both warp and weft directions

2.5.2 and can impart sufficient strength to soil body in the initial performing phase*. Once natural stability is achieved, it has been established that the technical function of a geotextile - natural or synthetic, becomes redundant.

2.6 Control of Surface Soil detachment

Soil particles on surface first get detached by rain drops. The resultant surface run-off transports the detached soil particles elsewhere. Such detachment and transport may also be caused due to strong wind.

2.6.1 JGT controls erosion of any surface-soil basically in two ways. First, it gives a protective cover (partial or full) to the exposed soil-surface. Secondly, it controls migration of the detached soil particles by reducing the flow of surface run-off. The finer particles are mainly transported leaving the coarser grains to remain in position. This phenomenon reduces the erodability coefficient of the soil. JGT absorbs a large part of the impact of the kinetic energy of rain-drops and controls rain-splash detachment. JGT-pores, in fact, act as successive miniature check-dams or a sort of micro-terraces on slopes which prevent, to a large extent, detachment and transport of soil particles and reduce the velocity of surface run-off.

2.6.2 JGT holds many advantages over man-made geotextiles in controlling surface soil-detachment and consequent erosion for its three dimensional construction. JGT, as

*Tensile Strength of a JGT can be increased substantially by appropriate plying or twining already stated, can retain almost 5 times their own weight of moisture, can attenuate extremes of temperature, can provide protection to seedlings from the direct sunrays and prevent dehydration of soil, allows air and light through its pores and provides micro-nutrients to the soil after biodegradation.

2.7 Bio-engineering Support

JGT facilitates, quickens and supports growth of vegetative cover on it. Once vegetation is grown, the function of JGT virtually ceases. Vegetation so grown, besides dissipating substantially, the kinetic energy of rain-drops, serves as a receptor of moisture with the help of leaves and stems. The wind-effects are also attenuated by vegetation. The velocity of surface run-off is also reduced by virtue of the surface rugosity (roughness) of the vegetation. The root system ensures soil-attachment and imparts strength to the soil-body. Soil-porosity and permeability are also improved, helping in control of erosion. And finally, vegetation provides a sustainable solution to the problems of erosion control. JGT, a natural product, fosters vegetation growth and paves the way for bio-engineering solution to the problem of soil-erosion.

2.7.1 The choice of species of vegetation depends on the nature and composition of the soil which vary from place to place. Live sods of perennial turf-forming grass may be laid on embankment slopes, verges (earthen shoulders) and at other locations.

Proper preparation of the soil bed, application of manure and laying of JGT are basic pre-requisites for growth of a good vegetative cover.

To ensure quick growth of vegetation, selection of the right type of vegetation species is extremely important. Studies have revealed that JGT enhances micro-climatic conditions (like temperature, soil-moisture) and organic matter-levels in soil which are conducive to quick and sustainable growth of vegetation.*

*Ref. Rickson R. J. and Loveday A. K. - Techno-economic Manual on Jute Geotextiles (Silsoe College, Bedfordshire

2.8 Bio-degradability of JGT

Geosynthetics' man-made and natural--act as change agents to the soil on or in which they are laid. Concurrent functioning of separation, filtration and drainage by the fabric ensures maximization of soil consolidation within a period not exceeding two season cycles. Longer life of geotextiles beyond this formative period is thus not a technical necessity.

Jute fibres/yarns usually degrade after one year or so when in contact with soil as a result of microbial attack. Interestingly, laboratory studies and field applications have confirmed that the rate of loss in strength of JGT is compensated by the corresponding gain in strength of soil. The soil ultimately becomes intrinsically self-reliant needing no extraneous support.

Biodegradation of JGT is thus not a technical disadvantage as is usually thought of. JGT can be made to last for more than 2 years and even more by treating it with suitable eco-friendly additives. Research is on to develop a suitable eco-friendly natural additive that can impart a longer life to JGT (up to about 4 to 5 years) without affecting the mechanical properties of the fabric.

3.0 SOIL PARAMETERS

It is essential that the designers and users know the essential geotechnical characteristics of soil that are important for applications of geotextiles.

3.1 Classification of soil

Soil is classified as sand, silt and clay on the basis of the grain-sizes as per table below:

Soil description	As per BS 1377 (in mm.)	As per ASTM (in mm.)
Coarse-grained soils		
A.		
i) Coarse Sand	2.0 to 0.6	2.0 to 0.25
ii) Medium Sand	0.6 to 0.2	
iii) Fine Sand	0.2 to 0.06	0.25 to 0.05
B.		
i) Coarse Silt	0.06 to 0.02	
ii) Medium Silt	0.02 to 0.006	0.05 to 0.005
iii) Fine Silt	0.006 to 0.002	
Fine-grained soils Clay	Under 0.002	Under 0.005

3.2 Assessment of geotechnical characteristics of the soil on which JGT is to be laid is a pre-requisite for selecting the right type of JGT for a specific site. The following properties of a soil need be determined before designing a structure or a protective work with JGT.

3.2.1 Grain size distribution of soil

It is represented by a semi-logarithmic curve which is a plot of particle size to logarithmic scale against the percentages, by weight, of the different particle sizes. (Fig. 2, 3 & 4)

The porometry of JGT (size of the opening in a JGT) should be decided considering the distribution-pattern of grains in a soil.

3.2.2 Plasticity of soil

Plasticity indicates cohesiveness of a soil. Plasticity is usually denoted by Plasticity Index (PI) which is the numerical difference between Liquid Limit (LL) and Plastic Limit (PL) {see cl. 3.3 for definitions}.

PI value less than 10 indicates a soil of low plasticity while PI value between 10 and 30 indicates normal plasticity of a soil.

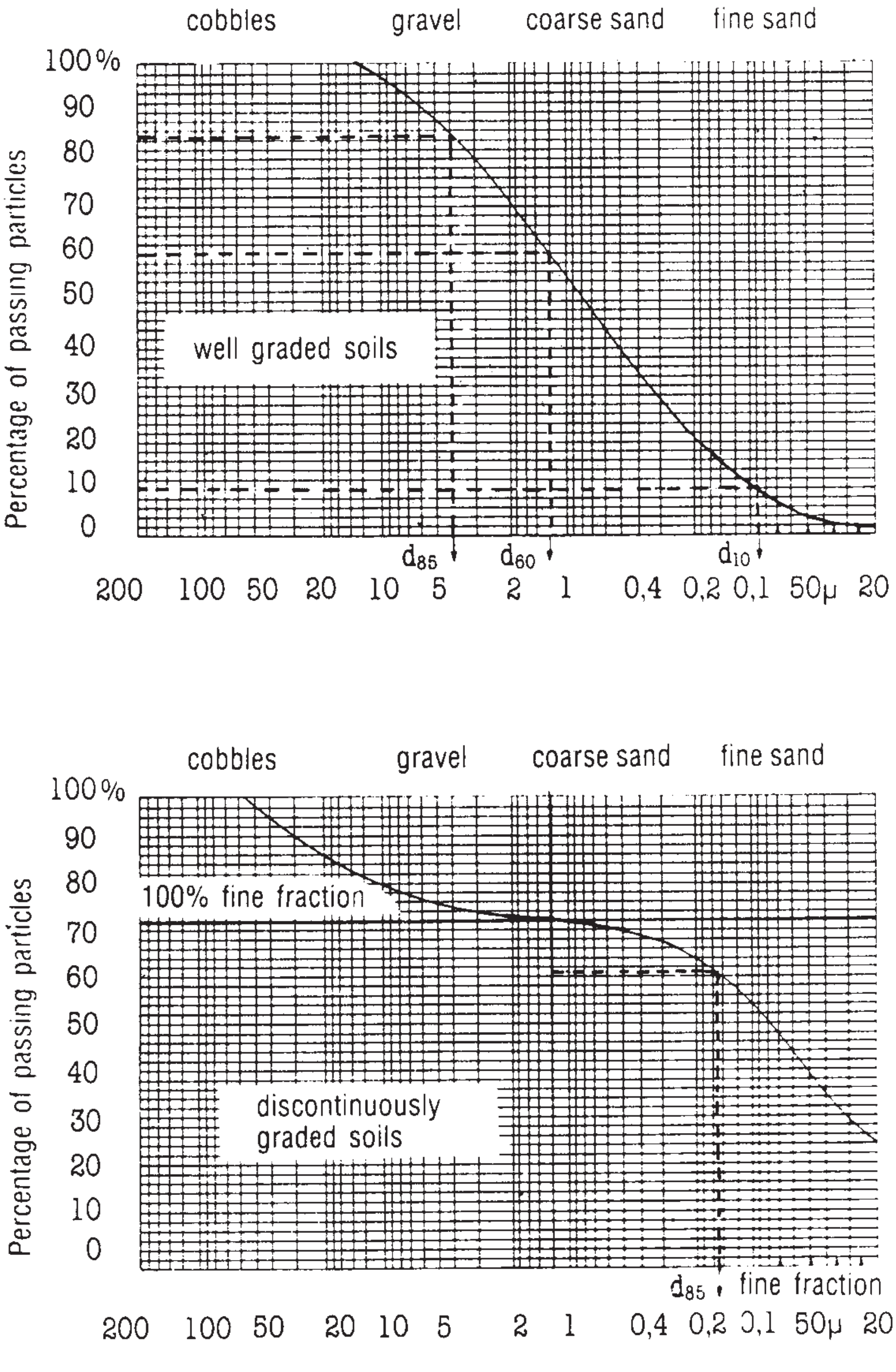

cobbles
gravel
coarse sand
fine sand
100%
90
80
70
60
50
40
30
20
10
0
Percentage of passing particles
well graded soils
d85
d60
d10
200
100
50
20
10
5
2
1
0,4
0,2
0,1
50µ
20
cobbles
gravel
coarse sand
fine sand
100%
90
80
70
60
50
40
30
20
10
0
Percentage of passing particles
100% fine fraction
discontinuously
graded soils
d85
fine fraction
200
100
50
20
10
5
2
1
0,4
0,2
0,1
50µ
20

Fig. 3

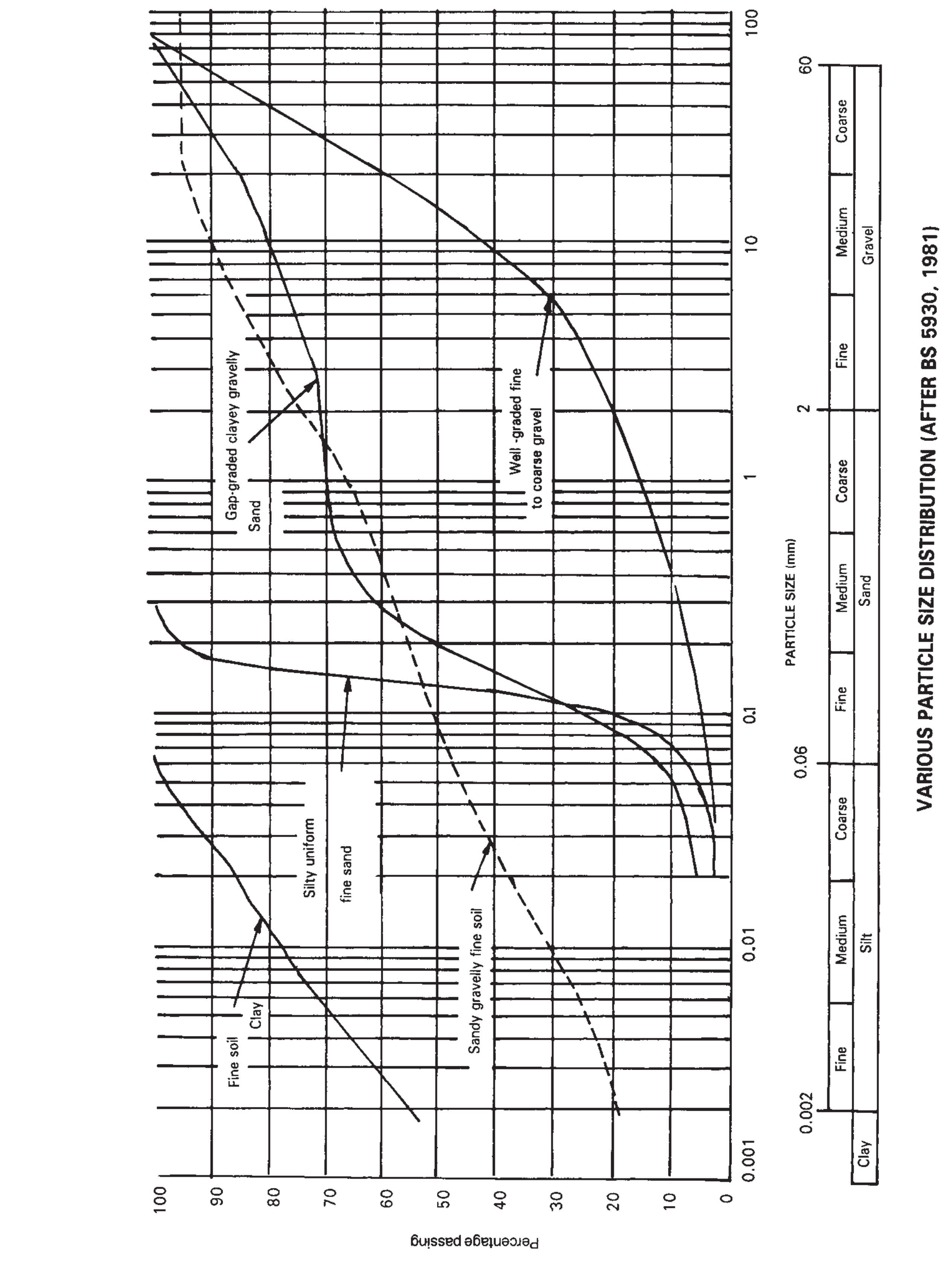


Fig. 4 VARIOUS PARTICLE SIZE DISTRIBUTION (AFTER BS 5930. 1981)

Clays are cohesive soils. Settlement of a clayey soil is a function of its water-content and stress-history. Usually the process of settlement of clay is protracted.

Clays tend to hold free water in addition to the adhered water. Draining of water from clayey soil is time-taking compared to granular soil which drains off water more quickly.

Clays are prone to shrinkage which may be as high as 20% by volume unlike granular soils which hardly shrink on drying.

3.2.3 Density of soil

Density of a soil depends on voids within it and is a function of the void-ratio. A dense soil is a strong soil. Compressibility of a soil depends in its density and water-content.

In Geotechnical Engineering, attainment of dry density of a soil is critical for its stability. In laboratory, it is the weight of a unit volume of a soil sample after drying it at 1050C. Dry density of a soil becomes the highest at a specific percentage of moisture content within it. This percentage of moisture content in a soil which produces the maximum dry density is called Optimum Moisture Content (OMC) of that soil. At a state of maximum dry density, a soil is less vulnerable to internal erosion. OMC is usually 8% for sands, 15% for silts and 15% - 20% for clays. Soils without having attained its state of maximum dry density, may cause clogging in JGT (See cl. 2.3.3 for clogging).

3.2.4 Permeability of soil

Permeability of a soil is a measure of the rate of flow of water through a soil. The flow depends on the hydraulic gradient and grading of soil (Fineness Modulus).

3.3 Definitions

Definitions of some important technical terms often used in Geotechnical Engineering are given hereunder to facilitate understanding of some salient soil characteristics.

A) Soil

- Angle of Internal Friction

The steepest angle to the horizontal at which a heaped soil-surface will stand under stated conditions.

- California Bearing Ratio (CBR)

Ratio of the resistance of a soil to a standard plunger of area 19.35 sq.cm. having penetration made to 2.5 mm to the corresponding resistance in crushed rock. A standard test developed by California State Highways Department, USA in 1929 used to denote the bearing capacity of a sub-grade, sub-base and base in a road-structure.

- Capillarity

The rising of fluid in capillaries above the static level of fluid in an open vessel. In soils, water rises between $^{1}/_{eD}$ and $^{5}/_{eD}$ cm. where e denotes Void Ratio and D effective diameter of the soil.

- Co-efficient of Permeability of soil (Ks)

The average velocity of flow (V) through the total area of soil (voids and solids) under unit hydraulilc gradient i.e., k_S = v/i where i is the hydraulic gradient. Also indicated by Hydraulic conductivity of soil.

- Uniformity Coefficient (CU) of soil

Ratio between the grain diameter corresponding to 60% by weight of finer particles in a soil sample to that corresponding to 10% by weight of finer particles ($C_U = d_{60}/d_{10}$).

- Compaction

Artificial increase of the dry density of a soil by decrease of air-voids through mechanical means like rolling, vertical drains, vibro-floatation and impact methods.

- Consistency limits (also called Atterberg limits)

Liquid Limit, Plastic Limit and Shrinkage Limit of a clay-sample which indicate its water content at different states of mouldability (See definitions for Liquid Limit, Plastic Limit and Shrinkage Limit under this section.)

- Consolidation of soil

The gradual reduction of water-content from voids of a soil at constant load.

- Darcy's Law

The relation is used for determining the velocity of percolation of water in a saturated soil. It states that velocity (v) = co-efficient of permeability (k) x hydraulic gradient (i).

- Effective grain size

The effective grain size of a soil is denoted by dn. It impliesn% of the particles are finer than the effective diameter of soil particles. For instance d_{50} means 50% of the soil particles are smaller than this diameter.

- Fineness Modulus

Indicator of the fineness of a soil which is calculated by determining the percentage residues on each of a series of standard sieves, summing them up and dividing the total by 100.

- Hydraulic gradient

The difference in water-level between two points divided by the length of the shortest soil-path between them.

- Internal Erosion

Loss of soil particles with a significant range of sizes within a soil-body, creating voids within it and making it vulnerable to collapse.

- Liquid Limit

Water-content of a re-moulded soil sample in transition between liquid and plastic states determined by a standard laboratory test.

- Piping

A sub-surface 'boil' or erosion - when the velocity of water flowing up through a soil is high enough to make it 'boil' or float.

- Plasticity Index

The difference between the water content of a clay at Liquid and Plastic Limits (PI = L.L. - P.L.).

- Plastic Limit

Water-content of a re-moulded soil sample in transition between plastic and semi-solid states determined by a standard laboratory test:

- Pore-water pressure

Pressure of water in the voids of a porous medium (e.g., soil, geotextile).

- Porosity

Ratio between volume of voids and total volume of soil.

- Shrinkage Limit of soil

Maximum water-content at which a reduction of water content will not cause any further decrease in volume of the soil.

- Suffusion of soil

Migration of the finest particles in a soil-body through the rest of the soil-matrix which remains more or less undisturbed.

- Void Ratio (e)

The ratio of the volume of voids to the volume of solids in a soil.

$e = V_V / V_S$

B) Geo-textile

- Apparent Opening Size (AOS)

The pore size of a JGT which admits the approximate largest particle of a soil-mass. Designated as O_n.

- Cross Machine direction (CD)

Direction in a fabric perpendicular to the direction of manufacture of a textile i.e. the weft way direction of a fabric.

- Drapability

Ability of a geotextile to make contact with the soil-surface without leaving any gap between the two. It is a measure of fabric - flexibility.

- Machine Direction (MD)

Direction in a fabric along the direction of the manufacture of a textile i.e. the warp way direction of a fabric.

- Open Area Ratio (OAR)

Ratio in percent between total area of openings and total covered area of a fabric-sample.

- Permittivity (Ψ)

Permittivity is the quotient of the co-efficient of hydraulic conductivity (also known as the Co-efficient of permeability) and the geotextile thickness.

$\Psi = k_g/t_g$ in units of s^{-1};

Where; k_g is the Co-efficient of permeability of geotextile and t_g is geotextile thickness.

The flow is usually measured under a head of 50 mm (Dh).

For Darcian flow, discharge rate $Q = \Psi \times Dh \times A$

Where; A = cross-sectional area through which flow takes place.

- Porometry

Measurement of Geotextile pore-size and its distribution.

- Transmissivity (θ)

It isalso called hydraulic transmissivity (θ). It is the product of the thickness of JGT (t_g) and co-efficient of in plane permeability (k_p). Strictly, transmissivity is $\theta = Q/wi$, where Q is discharge rate for Darcian flow, w is the width of JGT and i the hydraulic gradient across the JGT. It is measured in m2/s and should be qualifier by hydraulic gradient and normal stress curve.

- Wettability

Ability of a geotextile to become saturated under an extremely low water-head (usually a few millimetres).

4.0 TRANSPORTATION, STORAGE & HANDLING OF JGT

4.1 Transportation

JGT in the form of roll or balecan easily be handled and transported. Jute yarns are basically robust. But care is to be taken to keep it free from moisture (being hygroscopic) and fire. It can be shipped either as a bulk or a break-bulk cargo. A bale weighs around 340 kg. (680m^2) and may consist of a number of lengths (8 to 10) depending on the required individual roll length.

4.2 Site unloading

A fork lift or front-end loader fitted with a long tapered pole (carpet pole/stinger) is recommended for unloading JGT rolls. The carpet pole is inserted into the core of a JGT roll which is then unloaded from the truck. Nylon straps/ropes/roll pullers may also be used. Not more than three JGT rolls should be lifted and unloaded at a time. Use of chains & cables for unloading purposes is discouraged. A tarpaulin, a sheet of plastic or the like should be placed on ground for initial storage of JGT.

4.3 Storage

Prolonged storage of JGT in warehouse is discouraged as JGT is susceptible to microbial action and loss of strength. JGT should be provided with a water-proof cover for protection against rains and moisture. Its direct contact with soil during storage should also be avoided.

4.3.1 Humidity, temperature variation, lack of air-circulation and abnormal moisture absorption affect the quality of JGT. Storage of JGT therefore calls for attention. The main thrust should be on safe transportation and storage of JGT at site without damaging and unduly exposing the material to adverse climatic conditions.

4.4 Site Handling

As already stated, JGT rolls should be provided with a protective wrapping. It should be kept above the ground and should be covered with a tarpaulin or a thick plastic sheet.

4.4.1 Exposure of JGT to moisture/water may pose handling problems. As JGT can absorb water up to 5 times of its own dry weight, handling wet JGT becomes more difficult than handling a moisture-free JGT. The cores of JGT-rolls usually made of laminated paper are susceptible to damages on being exposed to moisture/ water and should therefore be kept dry.

4.4.2 JGT should not normally be stored for a long period. Protracted storage of JGT may impair its strength to some extent.

5.0 INSTALLATION OF JGT IN ROAD CONSTRUCTION, RIVER BANK PROTECTION AND SLOPE STABILIZATION

5.1 Installation of JGTfor Road Construction

Sequences in installation of JGT-

1. Sub-grade is to be excavated to the required level, cleared of all foreign materials and compacted to the OMC. Sub-grade should be done up with the specified profile. Vegetation, if any, should be uprooted and the area leveled with earth and rolled.

2. A thin cushion of local sand of about 25 -50 mm thick to be spread over the prepared sub-grade to facilitate better drainage and less chances of microbial attack.

3. JGT as selected should be laid by unrolling, ensuring proper drapability so that the fabric touches the sand layer at all points and stapled at an interval of about 750 mm with longitudinally overlaps of 150 mm. Staples should be preferably U-shaped nails (11 gauge) or suitable similar material.

4. A thin cushion of local sand of about 25 mm thick to be spread over the JGT to prevent puncture/damage due to rolling of the overlying sub-base/base-layer.

5. The first layer of aggregates in the base-layer should be spread with grading as recommended. No traffic should be allowed on an un-compacted base with less than 200 mm (300 mm for CBR greater than or equal to 3) thickness laid over JGT.

6. Any rut that may develop during construction should be filled in.

7. Parallel rolls of JGT should be overlapped by 100 mm and stapled (Fig. 5).

8. For application in curves, JGT should be folded or cut and overlapped in the direction of the turn. Folds in JGT should be stapled at an interval of 300 mm in curves (Fig. 6).

9. Before covering up the JGT, its condition should be assessed for any construction/ installation damage. Torn/damaged portions may be covered by pieces of JGT and duly stapled on all sides preferably at an interval of 300 mm. The extent of overlap should be such as to fully cover the damage/torn portion plus at least 75 mm beyond on all sides.

10. Often the sub-surface water is drained through the JGT and sand medium to the shoulders of a carriage way. In such cases, shoulder drains are required to be constructed either beneath the edge of the shoulder or immediately adjacent to its edge. In the event of existence of black cotton soil or expansive clay, porous drain pipes may also be inserted within the shoulder drain to augment drainage-efficiency.

11. Installation procedure is similar to what has been mentioned for open JGT-Encapsulated trench drains under the section.

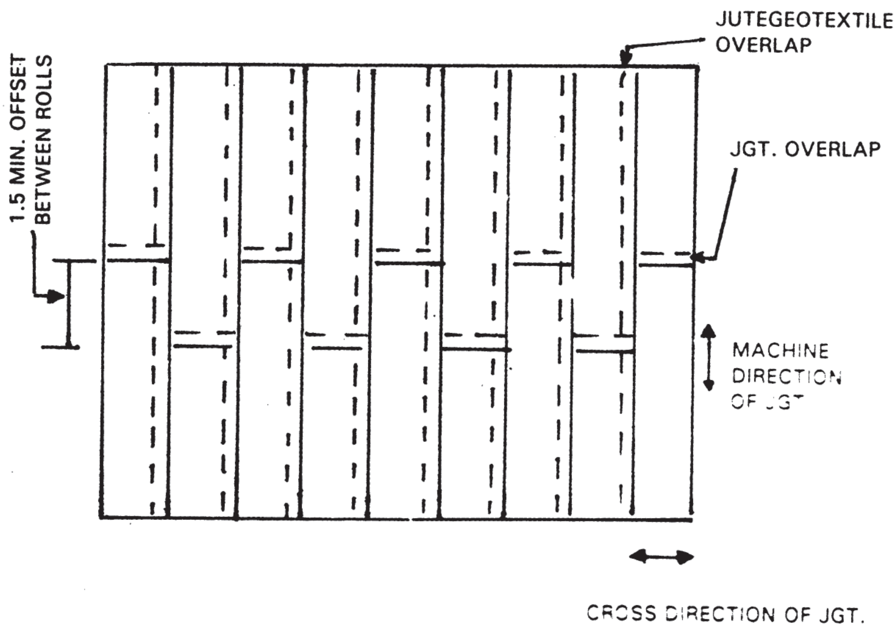


Fig. 5 OVERLAP PRINCIPLES OF JGT.

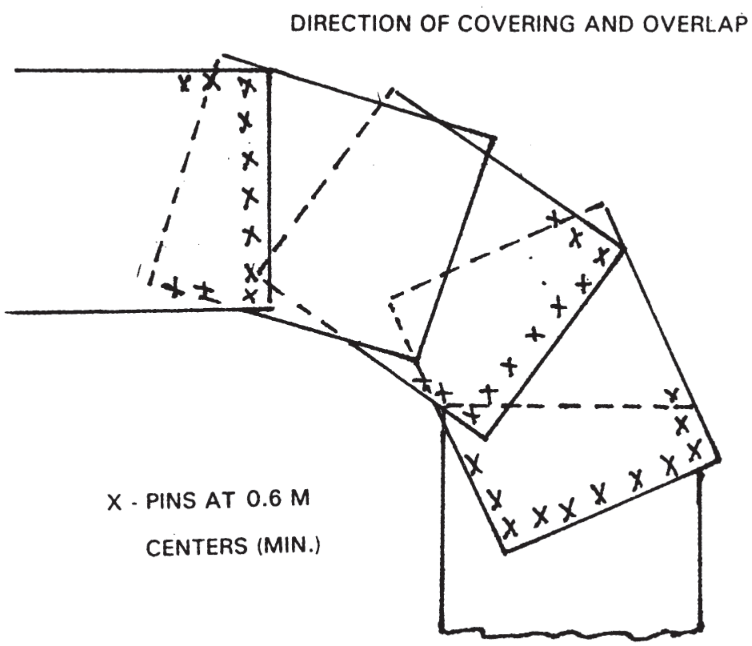


Fig. 6 FOLDING OF GEOTEXTILE IN CURVES

5.1.1 Monitoring & Maintenance

Performance of the pavement with JGT should be monitored closely, especially in regard to development of pot holes, subsidence, road side drainage, dispersion of sub-grade and the like. Frequency and extent of surface treatment and also re-sectioning needed are also to be noted. Special attention is necessary during and after the rains. Pot holes should be immediately restored. Surface drainage over the pavement should not be allowed to hinder due to malfunctioning of road side and shoulder drains.

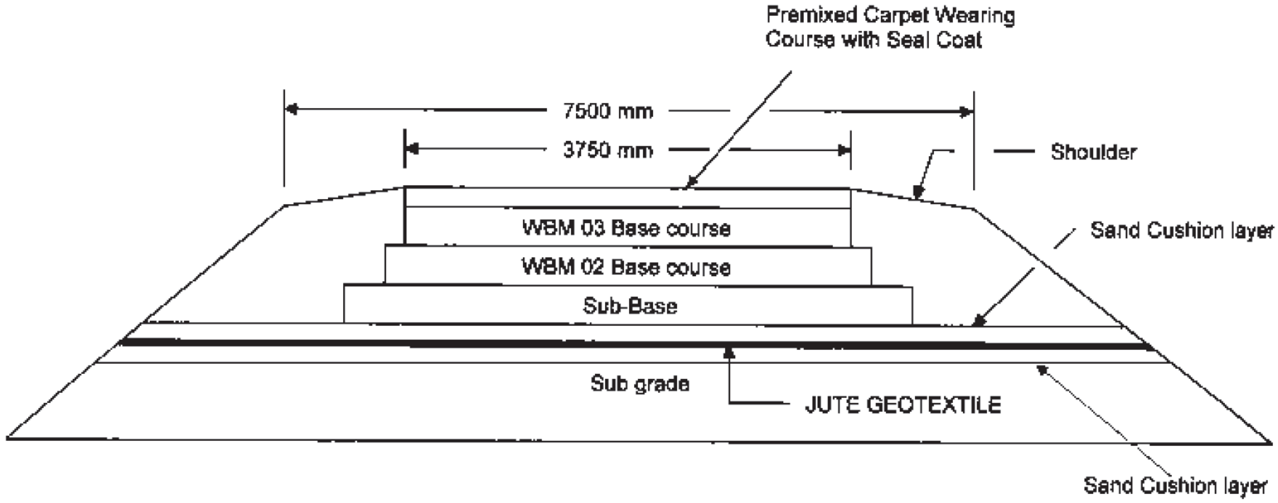


Fig. Typical Cross Section of a road with Jute Geotextile laid on the Sub-grade

5.2 Installation of JGTin River Bank Protection

Sequence in installation of JGT

1. The bank should first be cut to a stable slope preferably at the angle of internal friction of the bank soil. The surface shall be leveled and made free from angular projections, undulation, soil-slurry or mud.

2. Anchoring trench (usually rectangular) should be excavated at the top of the slope. Recommended dimensions of the trench-500 mm deep and atleast 250 mm wide at the bottom. The trench should be free from foreign materials, mud etc.

3. JGT should then be unrolled across the trench and along with slope from top to down side to the lowest water-level.

4. JGT should be stapled with U-shaped nails (usually 11 gauge) within the anchoring trench both at the sides and bottom at an interval of 300 mm along the length of the trench. There should be at least 2 staples both depth-wise and width wise in each cross-section.

5. JGT should be laid with the overlapping in the direction of water-flow. Care should always be taken to ensure that JGT does not suffer damage due to puncture, tear and installation stresses.

6. The recommended overlap is 150 mm (minimum). The overlapped portion should be stapled at an interval of 300 mm.

7. The anchoring trench should then be filled with stones/boulders for securing and protecting the JGT. Care should be taken to ensure that JGT touches the bank slope at all points (proper drapability).

8. Armour overlay of stone/boulder should then be placed on the JGT carefully and properly arranged. A thin layer of sand (25 mm) as a cushion on top of the JGT is recommended to avoid puncture of the fabric by granular armour.

Similar care in laying should be taken when a combination of granular filter and JGT is used under reversing flow-condition. There must be a beam at the toe of slope. This can be done by folding the JGT as per dimensions (usually 500 mm dia) with sand fill and duly stapled on the other side preferably at an interval of 75 mm.

Alternatively, an angular trench may be dug at the toe and the JGT placed on it ensuring full contact with the soil, duly stapled at a spacing of 75 mm and ballasted. Care should be taken to see that the overlapping layer is not displaced during installation. Suitable grass-seeds should then be spread on the treated bank. Alternatively, saplings of suitable plants that thrive in similar geotechnical and hydraulic conditions may be planted at close intervals through the interstices of the overlay, taking care to place them into the bank soil.

Note : the weight and specific gravity of each boulder shall be at least 25 kg - 30 kg with Specific Gravity of 2.8

5.2.1Monitoring and Maintenance :

The treated bank should be kept under watch for at least one full season-cycle. Frequent visits to sites during and after the rains or any natural calamity are necessary. Siltation may take place after about a month covering up the granular overlay gradually under favourable conditions. Maintenance involves, besides monitoring, re-arrangement of the overlay, if displaced, in position. No part of JGT should be allowed atmospheric exposure due to displacement of the overlay. The JGT-strength may be ascertained after one season - cycle and the overall performance analyzed.

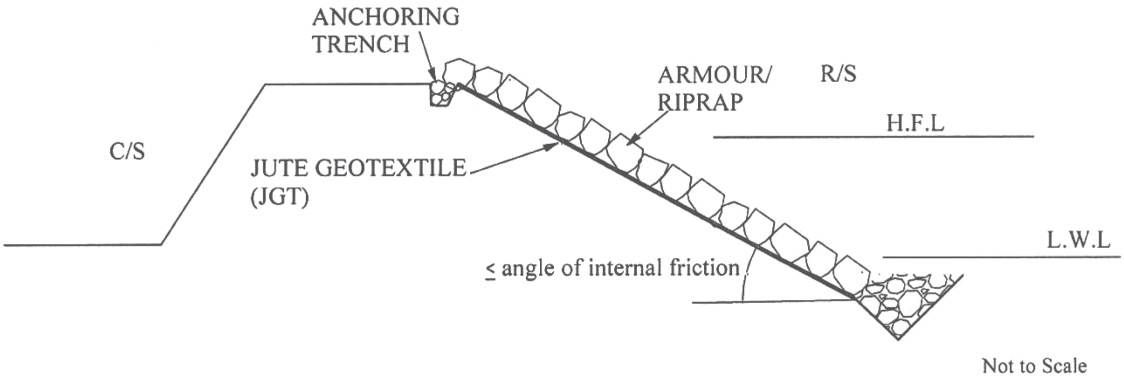


Fig. TYPICAL CROSS SECTION OF RIVER BANK PROTECTION WORK

5.3 Installation of JGT for Slope Stabilization

Sequences of laying of JGT on slopes for rain water erosion control

1 The slope should be made free from undulations, soil slurry, mud and sharp projections and compacted with additional earth where necessary.

2 Broadcasting of seeds of appropriate vegetation (locally grown seeds)

3 Anchoring trenches should be excavated at the top and toe of the slope along the length the embankment Recommended dimensions of the trench (usually rectangular) are 300 mm deep and 250 mm wide.

4 The selected JGT should be enrolled across the top trench and along the slope downward, caring to see that it touches the soil surface at all points.

5 Overlaps should be minimum 100 mm at sides and 150 mm at ends . The JGT at the higher level on the slope should be placed over the portion to its next at a lower level. Side overlaps of a JGT piece should be placed over its next at a lower level. Side overlaps of JGT piece should be placed over its next piece on one side and under the next piece on the other.

6 The JGT should fixed in position by steel staples usually of 11 gauge dia or by split bamboo pegs. Stapling should be done normally at an interval of 500 mm both in longitudinal and transverse directions. Special care should be taken to staple the JGT within the anchoring trenches both at the bottom and at the sides.

7 The anchoring trenches should be filled up with sand / brick-ballast / gravel etc. for keeping JGT in position. Care should be taken that the overlaps are not displaced during installation.

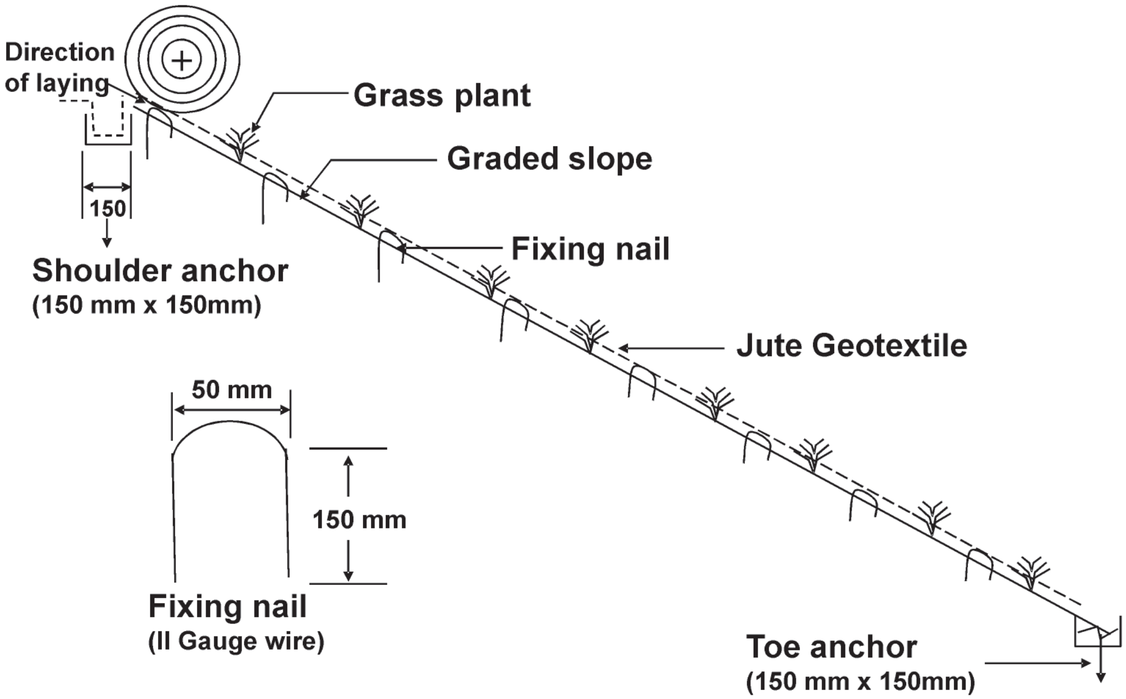
8 Care should be taken to ensure that the JGT is not damaged due to puncture, tear and other installation stresses.

9 Selection of type of vegetation is very important. Local experience should be the guide. Help of botanist, agronomist, local forest department in selection of species, timing of sowing/ planting/ broadcasting procedures, maintenance etc. are strongly advised.

10 In special circumstances, a second dose of seeds may be spread with dibbling of locally available grass.

11 Installation should be completed preferably before the monsoon to take advantage of the rains for quick germination of seeds and growth of vegetation.

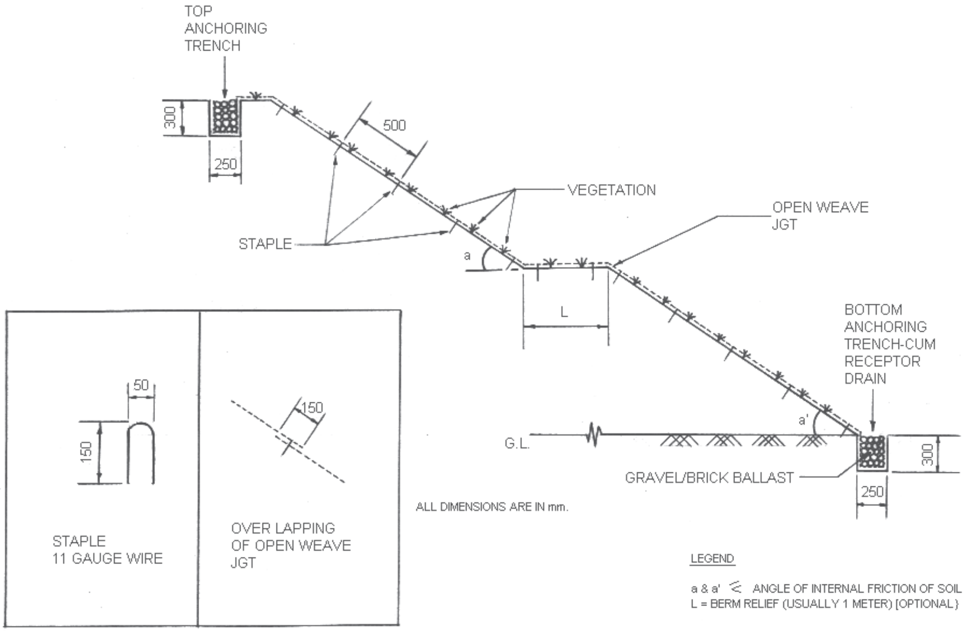
12 A second of seed broadcasting should be given over the laid JGT along with dibbling of locally available grass.



INSTALLATION OF JUTE GEOTEXTILE

5.3.1 Monitoring & Maintenance

Close monitoring should be carried out for at least one season-cycle. Displacement of JGT, if any, is to be noted and watched without disturbing it initially. Torn portion of JGT may be overlapped by fresh JGT-pieces stapled on all sides. Watering/ Maintenance of the plant-sappling may be done as per procedures suggested by the botanist/ agronomist/ Forest department as the case may be.



Typical Cross-section of Slope Stabilization

6.0 PROPERTIES OF JGT AND IMPORTANT TEST METHOD

Selection of the right type of JGT for a specific application is of vital importance. As there is hardly any difference between JGT and man-made Geotextiles functionally, the manual relies on the standards available for man-made Geotextiles. As the test standards of such Geotextiles are not uniform in developed countries, references have been drawn from the American Standards (ASTM standards) for the sake of uniformity, where Indian Standards are not available. The properties of JGT have also been drawn from "Jute Geotextiles - a survey made by International Trade Centre, UNCTAD/GATT" where deemed applicable.

6.1 The section is subdivided into three categories

- Physical Properties.
- Mechanical Properties.
- Hydraulic Properties.

6.2 Physical Properties

6.2.1 Physical properties mentioned in this subsection refer to JGT as presently manufactured. They are indicative only and not the critical design properties of the product.

6.2.2 Mass per unit area

This is an important property having a direct impact on the cost and mechanical properties. After 24 hours of conditioning at standard ambient conditions of temperature at 210C ± 20C and relative humidity at 65% ± 5%, the following nomenclatures for civil engineering applications may be adopted in case of untreated JGT in respect of mass per unit area.

6.2.3 Thickness

This is an important property in connection with transmissivity of JGT. It is measured between the upper and lower surfaces of the JGT at a specified pressure. ASTM D 5199/BIS-13162 part 3 stipulates that the accuracy should be at least 0.02 mm under a pressure of 2 kPa. Thickness of commonly used JGT ranges from 2 mm. to 8 mm.

6.2.4 Porometry

This is a critical property for permittivity and soil retention. JGT can be manufactured with open weave like nets (e.g. "Soil Saver" - usually with the pore-size of 2.84 cm2 for medium weight JGT) or as closely woven fabrics with a pore size of 100 micron or above. A finer pore-size of JGT treated with bitumen along with rot resistant chemical reduces OAR (Open Area Ratio) reducing/permittivity of JGT and inducing clogging.

6.2.5 Pore sizes can be measured by three different techniques

i) by using a calibrated microscope.

In the case of rectangular pores, the smaller dimension is taken as the pore size. A grading curve for the pore size distribution can then be represented on a semi-logarithmic graph which is similar to a particle size distribution graph for a soil. (Fig. 2, 3 & 4)

ii) by reverse dry sieving technique

Special glass beads (ballotini) of known size are vibrated on the JGT-fabric having unconfirmed mesh-size or porometry. The percentage of the glass beads passing through it is recorded and the test is repeated for successive smaller grades of glass beads. The pore size grading curve may be drawn on the basis of the findings.

N.B. : It may be noted that the weight of glass and the extent, duration and nature of vibration applied for this test are yet to receive universal acceptance.

iii) by wet sieving

The standards for this test vary widely and are therefore not stated.

6.2.6 Drapability

As stated under section 1.3 that JGT should have the ability to shape itself in keeping with the soil-surface-contours and to establish full contact with the surface. The extent of drapability is assessed by measuring the sag (D) in mm of the JGT in between two points (S) also in mm. (Fig. 7) and graph may be drawn with the values so obtained (see sketch). It is also a measure of JGT's "flex-stiffness"- i.e., bending of JGT under its own weight between two points (vide test method in ASTM D 1388). Drapability of jute is more when it is wet.

N.B. : *JGT possesses a better drapability than man-made and coir geotextiles.*

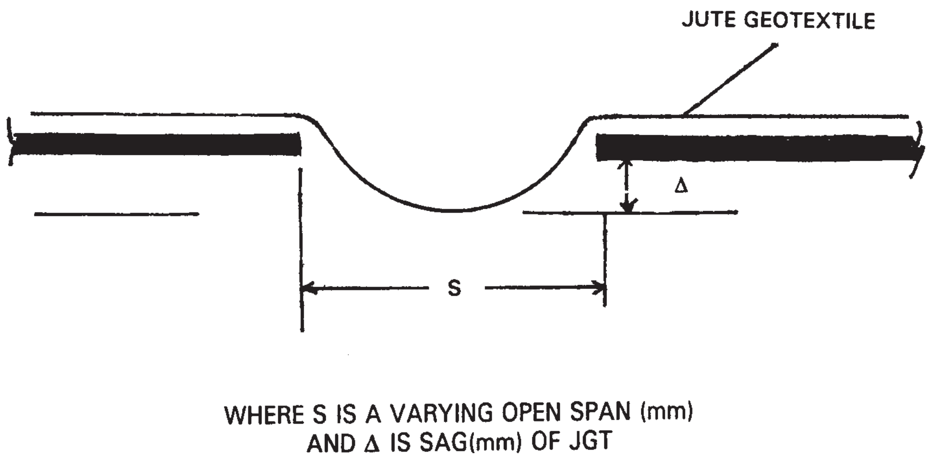


Fig. 7 DRAPABILITY TEST FOR JGT

6.3 Mechanical Properties

Mechanical properties of JGT are basically indicative of the product's resistance to mechanical stresses developed as a result of application of loads and/or installation conditions. The tests that may be used for determining mechanical properties of JGT are tensile strength, puncture strength, burst strength and tear strength. Test for frictional resistance (soil-JGT friction) is also important.

6.3.1 Tensile Strength

The test for Tensile Strength is performed as per ASTM D4632 or the relevant Indian Standards. The JGT specimen is stretched through one end but gripping it at two ends till its failure. While extending the sample, both load and deformation are to be measured and noted. Other tensile test methods are Narrow Strip Test (ASTM D 751) and Wide Width test (ASTM D 4595/BIS - 13162 Part 5). A sample of 200 mm and 100 mm width respectively will serve the purpose for the aforesaid tests. Maximum tensile stress is often referred to as ultimate strength. Woven JGT as of now has been developed upto maximum tensile strength of 40 kN/metre under normal manufacturing process.

6.3.2 Puncture Strength

A puncture rod is pushed through the JGT-sample clamped to an empty cylinder. Resistance to puncture is measured in N or kN per sq. cm. Woven JGT (heavy type) may be manufactured to possess a puncture strength of 400 N/sq.cm.

Ref. : Jute Geotextiles - A Survey of marketing and distribution systems in selected European Countries - prepared for International Jute Organisation by International Trade Centre. UNCTAD/GATT (1991)

6.3.3 Burst Strength

The test is known as Mullen Burst Test and is described in BS 4768 and ASTM D 3786. The JGT is given a shape of a hemisphere by inflating it by a rubber membrane. The sample bursts when no further deformation is possible. This is an index test and is used basically for quality control. The unit is kilo Pascal (kPa) (Fig. 8)

6.3.4 Tear Strength

JGT should be inserted into a tensile testing machine with an initial 150mm cut (Trapezoidal Tearing Strength Test). The load stretches the fabric before it tears. The test is described in ASTM D 4533/BIS 14293. The unit is kilo Newton (kN). (Fig. 9)

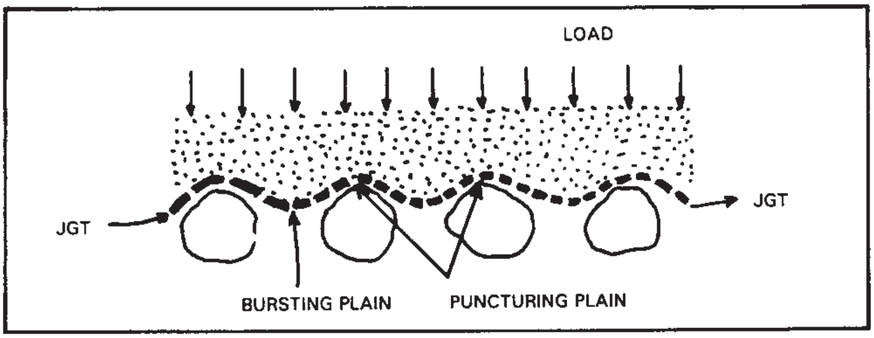


Fig. 8 PUNCTURING AND BURSTING OF JGT.

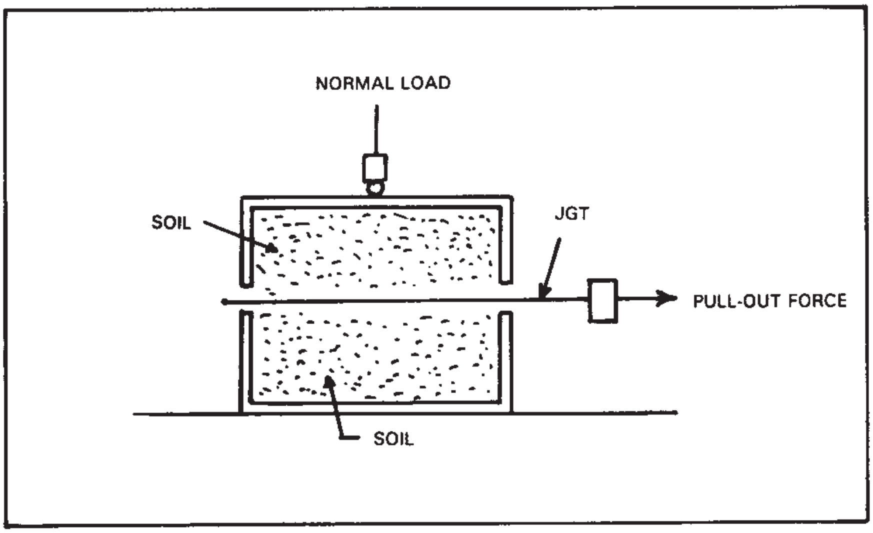


Fig. 9 PRINCIPLES OF THE PULL-OUT TEST

6.3.5 Frictional Resistance

This property can be determined either by the direct Shear Test using a shear box or the Pull out Test. The sample is placed between two parts of a shear box with its lower half fixed. The upper half filled with soil is moved horizontally relative to the lower half at a constant rate of displacement (Fig. 9). The maximum horizontal force required to move the top half is used to calculate maximum horizontal shear stress by dividing it by the specimen area.

In the pull out test, the JGT sample sandwiched between two halves of the box fitted with the soil is pulled by the jaws at a constant rate of displacement. The pull-out force is a function of JGT-extensibility, length of embedment, redrawal stress etc.

6.4 It may be noted that determination of values of different tests indicated above depends largely on the testing procedures like the method of gripping the sample, slippage of the sample, rate of deformation, sample-size etc. The stress-strain curve of JGT sample indicates the following

- Maximum tensile stress (ultimate strength)
- Strain at failure (i.e., elongation at break)
- Modulus of deformation (i.e., the slope of the initial portion of the stress-strain curve)
- Toughness (usually the area under the stress-strain curve)

6.5 Hydraulic Properties

6.5.1 Filter Cake Formation in One-way & Two-way Flows

The major hydraulic properties of JGT are permittivity and transmissivity. These properties act in conjunction with their soil-retention capacity. JGT helps stabilize the adjacent soil-structure by developing 'filter cake' under unidirectional flow conditions and together they control the ultimate flow-capacity of the system.

A) In unidirectional flow conditions, initially there is loss of fine soil parties through the pores of JGT leaving gaps in its soil-structure immediately contiguous to it. Larger particles bridge over these gaps as in arches as well as over the pores in JGT. Once larger particles rush to form the

so-called 'bridges', passage of smaller particles are blocked and a graded filter naturally develops in contact with the JGT. (Fig. 10)

Studies in this direction have confirmed that even fairly uniform sands can bridge a regular mesh-opening of two to three times the mean particle size (d50).

B) In reversing flow conditions (two-directional flow) similar 'filter cake' within the soil zones adjacent to JGT may also form provided there is sufficient cycle-time. In such cases of reversal of flow as in tidal rivers, a combination of JGT and granular filter is often considered necessary.

6.5.2 Formation of Filter Cake in Soil—Some Features

Formation of filter-cakes depends on compatibility of distribution of pore-sizes in JGT vis-à-vis grain size distribution of the soil. If the pore sizes in JGT are too large, there may be substantial initial loss of soil particles in a range of sizes. This is in effect a phenomenon of "internal erosion" (see section 3.3 for definition). When voids created by "internal erosion" are sizeable, the soil-body as a whole becomes vulnerable. (Fig. 11)

Suffusion is also a type of internal erosion, confined to finer particles in a soil matrix without shift of position of larger particles. Suffusion is less damaging than internal erosion as it does not contribute to destabilization of the soil-matrix as such (see section 3.3 for definition). (Fig. 12)

Pore size of JGT is important and should be judiciously chosen. Larger-than-the optimum pore size may lead to internal erosion while lower-than-the optimum pore size may cause clogging.

6.5.3 Permittivity vis-à-vis Porometry

As already stated, permittivity and porometry of JGT perform two contrasting functions.

Permittivity of JGT, apart from its porometry and thickness, is also a factor of permeability of the soil. Soil retention is obviously more effective with smaller pore-size of JGT which, in turn, reduces its permittivity. A judicious compromise is therefore called for in selecting JGT with proper porometry.

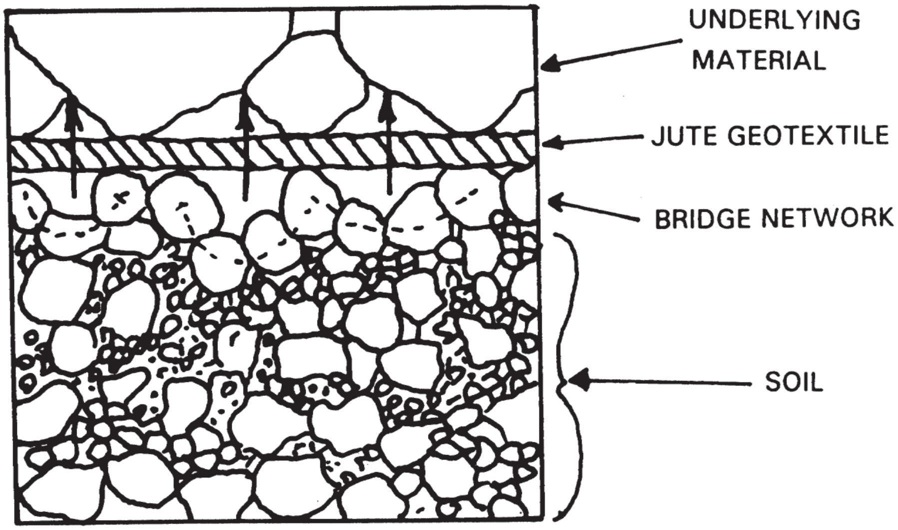


Fig. 10 BRIDGE NETWORK IN SOIL WITH JGT (AFTER ELMER, J.O. 1973)

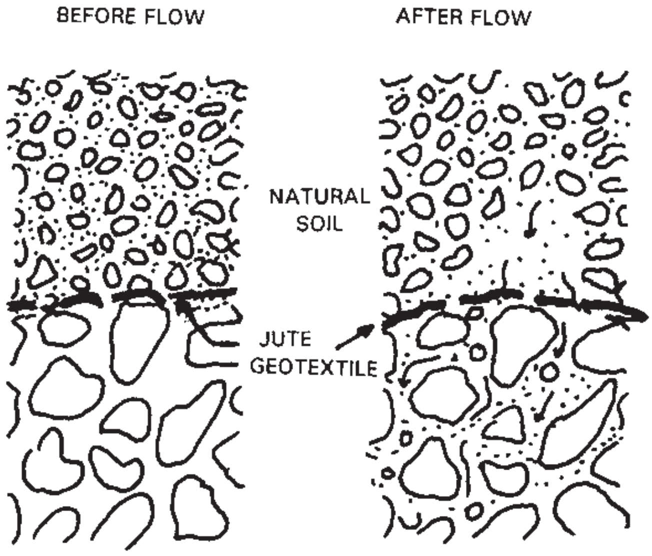


Fig. 11 INTERNAL EROSION – THE SOIL STRUCTURE IS DISTURBED

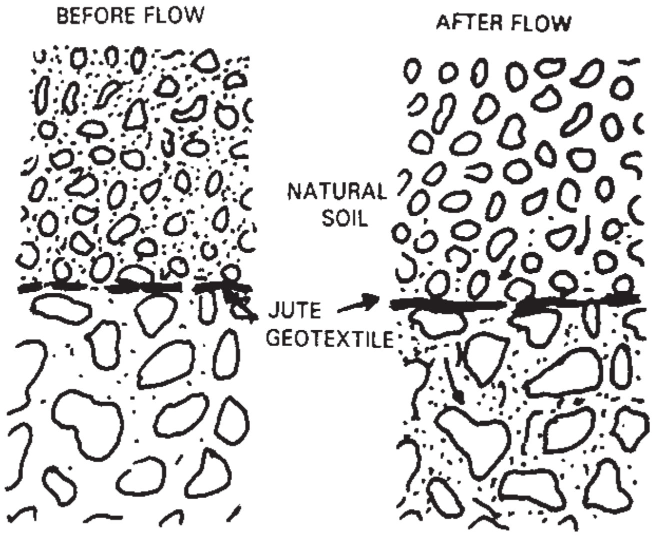


Fig. 12 SOIL SUFFUSION – ONLY SMALL PARTICLES MIGRATE

6.5.4 Soil Permeability (ks)

Permeability of the soil, also called hydraulic conductivity of soil, can be measured in a laboratory. Soil Permeability is indicative of flow capacity through a soil under a given hydraulic gradient and flow-area as per Darcy's Law. (Fig. 13)

$q = k_s \times i_s \times A$

Where q = unit flow rate (m^3/s), k_s = coefficient of permeability of soil (m/s)

i_s = hydraulic gradient (dimensionless). A = total cross-section of flow (m^2)

The equation can be expressed as

$q = k_s \times \Delta h_s \text{ X } A / L$

Or, $k_s = q \text{ X } L / \Delta h_s \text{ X } A$

Where -

Δhs = change in hydraulic head or head loss across soil

& L = length of flow path or soil thickness over which Δhs occurs.

Generally ks is expressed in cm/sec.

6.5.5 Permittivity of JGT (Ψ)

Permittivity is the measure of hydraulic conductivity of JGT across its plane in relation to the fabric thickness.

If permittivity of JGT is known, the flow capacity of JGT can be assessed for any given hydraulic gradient and flow area. It is expressed in reciprocal of time (sec-1) and is derived from Darcy's Law (Fig. 14)

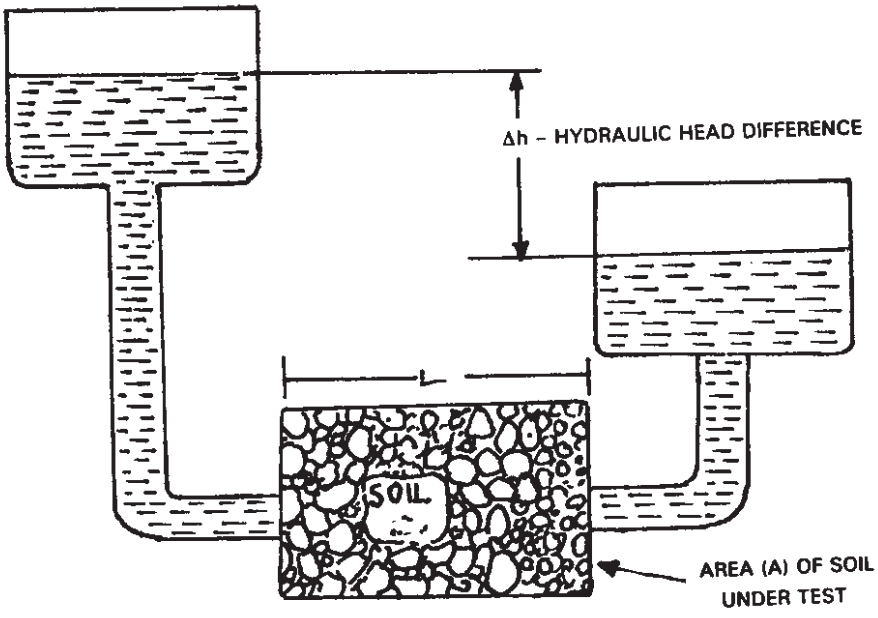


Fig. 13 SOIL PERMIABILITY

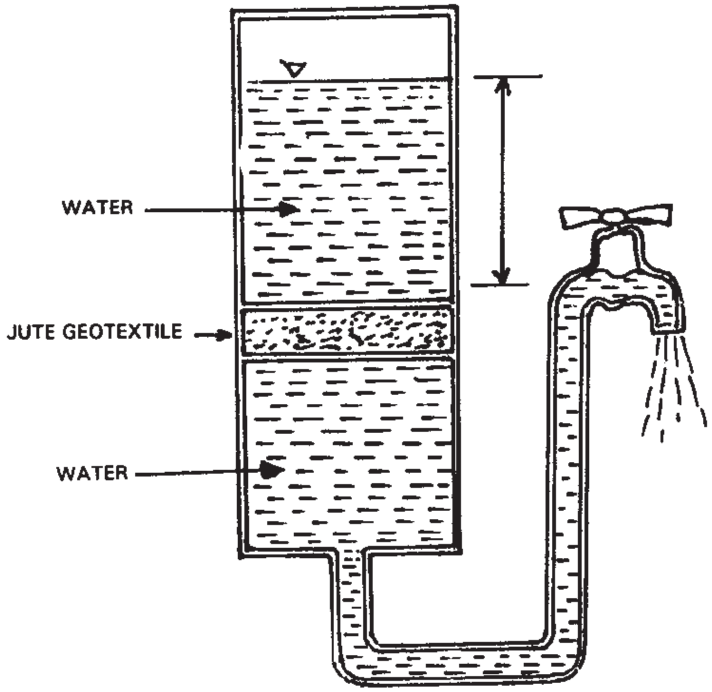


Fig. 14 JGT PERMITTIVITY TEST

$q = k_g \times i_g \times A$

$= k_g \times \Delta hg \times A / tg$

where k_g stands for coefficient of cross permeability of JGT (m/s)

i_g - hydraulic gradient ($\Delta h_g / t_g$) (dimensionless)

Δh_g = head loss across JGT (m) or in appropriate linear unit

A = JGT cross-section (m^2)

t_g = thickness of JGT (m) or same unit as of Δhg

The ratio K_g / t_g is termed as the permittivity of JGT (Ψ) and is therefore equal to $q / \Delta h_g \times A$

6.5.6 Transmissivity of JGT

Transmissivity is the property of JGT to transmit flow along its plane and is a function of its thickness and structure. In this case, the cross-sectional area of flow 'A' would be equivalent to $t_g \times w$, where t_g is the thickness and w is the width of JGT transmitting in-plane flow.

Rate of discharge Q would equal $t_g \times w \times k_p \times i$ where k_p is the co-efficient of normal permeability and i the hydraulic gradient.

The product tg x kp is called hydraulic transmissivity (θ).

Q then equals θ x w x i.

It is thus evident that transmissivity is directly proportional to the hydraulic gradient. It is pertinent to note that in certain types of non-woven JGT, high normal stress reduces transmissivity drastically.

With given values of hydraulic gradient and normal stress level, transmissivity can be deduced by dividing the flow rate (m^3/s/m) by the hydraulic gradient.

6.5.7 Determination of Clogging Potential of JGT

There are two test methods available to evaluate clogging potential of JGT - Gradient Ratio test and Hydraulic Conductivity Ratio (HCR) test. The first method does not simulate the field conditions in respect of compaction and confinement which the latter method does. ASTM D 5567 describes methods for the HCR test. ASTM D 5101 mentions about the Gradient Ratio method in which water is allowed to flow downwards through a vertical column of the soil placed over the candidate JGT. Hydraulic gradient is measured at two locations above the JGT. If the ratio of the flow exceeds a prescribed limit, it indicates the vulnerability of the JGT to clogging. (Fig. 15, Fig. 16)

The intention of either of these two methods is to ensure a long term flow-compatibility between soil and JGT. Clogging-proneness of a JGT is low when the flow rate test decreases with time and then attains a stable value over a time. Clogging-potential is high when theflow rate continues to decrease with time and does not stabilize. Piping-failure is indicated when the flow rate goes on increasing with time.

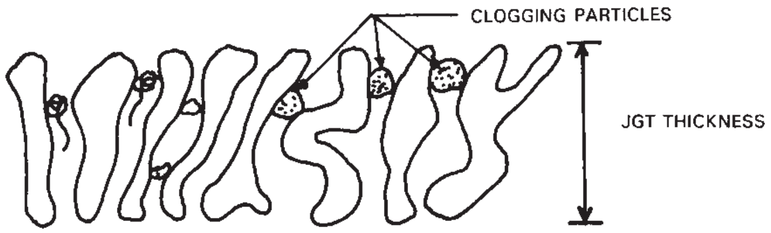


Fig. 15 TYPICAL CLOGGING IN JGT

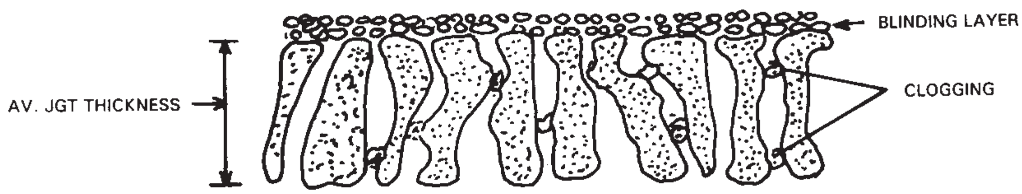


Fig. 16 BLINDING AND CLOGGING IN JGT

7.0 CIVIL ENGINEERING APPLICATIONS OF JGT

Considering the properties of JGT indicated in the preceding chapters, JGT have been applied in the following sectors of civil engineering -

a) Management of surficial soil erosion in slopes

b) Protection of banks of rivers / waterways

c) Stabilization of earthen embankments for highways, railways & flood control

d) Strengthening of road sub-grades

e) Management of subsidence of railway tracks

f) Consolidation of soft soil

7.1 Management of Surficial Soil Erosion

Surficial soil erosion in plains and slopes is primarily caused by precipitation and wind. In precipitation kinetic energy of raindrops first causes disintegration of surface-soil followed by transportation of the detached soil particles by surface run-off. The mechanism of surface-soil erosion is better understood by recounting the Universal Hydrologic Equation which, in simple terms, states that the total rain-fall gets distributed principally in three ways viz., through flow (infiltration into the soil body), surface run-off and on-land storage. Through flow is a factor of soil permeability i.e. hydraulic conductivity of soil. It is the surface run-off that acts as the main agency responsible for surface-soil erosion. Surface-soil erosion can therefore be effectively managed if the velocity of surface run-off can be reduced and overland storage augmented by extraneous intervention. (Fig. 17 & 18)

Open weave JGT precisely does the both to a good extent. Yarns (usually weft yarns) of JGT placed normal to the direction of surface run-off act as mini check-dams laid in series, curbing the velocity of surface run-off and preventing, to a good extent, migration of the detached particles beyond. Because of its high efficiency in absorbing water, yarns of JGT can affect storage of water on land as well. Incidentally, jute can absorb water to about 500% of its dry weight - much higher than other natural fibres such as Sisal (175%) and Coir (150%) and man-made polymers.

Use of JGT, in the next stage, is related to growth of vegetation on the erosion-affected soil. Considering the usual effective period of untreated JGT to be one season cycle, it is recommended that either of the following methods viz, to spread seeds, to implant plants / seedlings, to hydro-seed (a solution of seed, fertilizer and a mulching material) or to lay sods may be adopted. Pre-monsoon plantation is advisable to make the best use of monsoon showers for quicker growth of vegetation. Vegetation, once grown sufficiently, plays the role of JGT by curbing the velocity of surface run off, arresting detachment of top soil and migration of the disintegrated soil particles. (Fig.19)

In this connection, it is relevant to take note of the inter-relation between rainfall form and kinetic energy of rain drops.

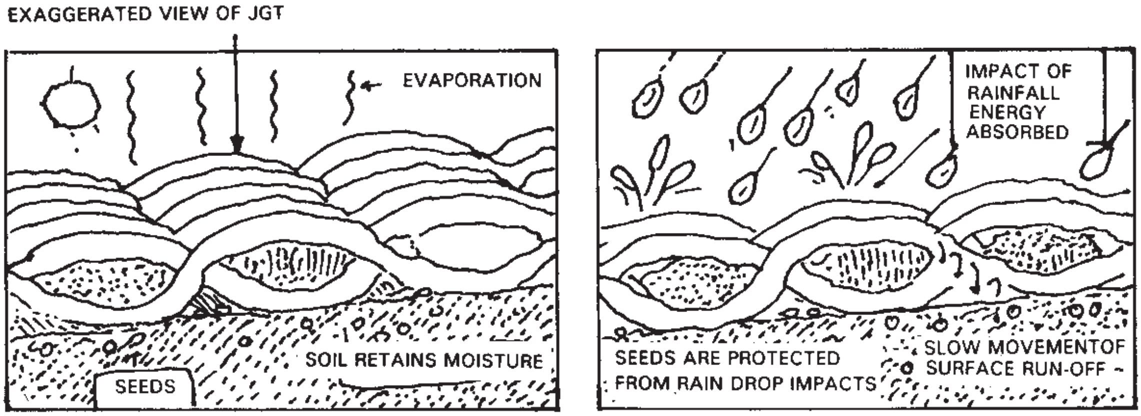
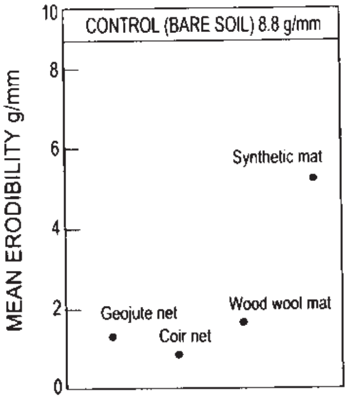
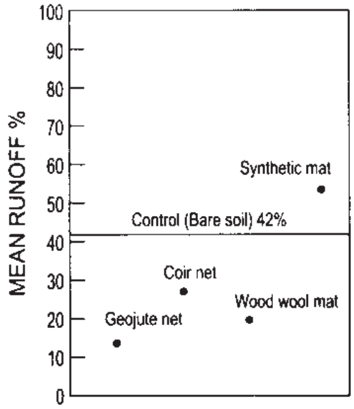


Fig. 17 HARMLESS SURFACE DRAINAGE
(AFTER RANKILOR, 1994)



MEASURED ERODIBILITIES FOR A SANDY
(AFTER INGOLD AND THOMSON, 1990)



MEASURED RUNOFFS FOR A SANDY LOAM
(AFTER INGOLD AND THOMSON, 1990)

Fig. 18

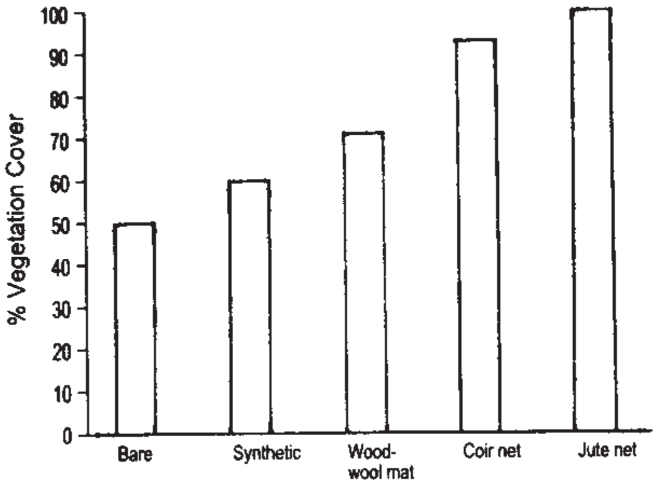


Fig. 19 VEGETATION ESTABLISHMENT DOT MIX-SANDY LOAM AFTER 82 DAYS
(AFTER RICKSON, 1998)

Inter-relation between rainfall form and kinetic energy of rain drops

Rainfall form	Intensity (mm/hour)	Diameter of rain drops (mm)	Kinetic Energy (j/m^2/hour)
Drizzle	< 1	0.9	2
Light	1	1.2	10
Moderate	4	1.6	50
Heavy	15	2.1	350
Excessive	40	2.4	1000
Cloudburst	100	2.9 to 6.0	3000 to 4500

Adapted from Geotextile & Geomembrane Manual – T. S. Ingold (1994) [Elsevier Advanced Technology, UK]

It may be noted also that JGT acts as mulch even on its biodegradation and leaves a residue of fibres that improves the soil-properties, specially the soil fertility & permeability. The fibrous residue of JGT, due to its roughness, acts in conjunction with vegetation as moderator of surface run-off and arrestor of detached soil-particles. Mulching effects of JGT help retain humidity in soil conducive to growth of vegetation. The extremes of temperature are also evened out by use of JGT. In fact JGT provides the cheapest of all bio-engineering solutions for quick growth of vegetation.

Nature of surface-soil erosion caused by wind is somewhat different from that caused by precipitation. Wind-induced erosion has a 'sweeping' effect unlike the phenomenon in case of rain fall which has "pointed" effects.

7.1.1 Areas of Application

- slopes of embankments of highways and railways, irrigation bunds, earthen dams
- degraded hill slopes, slopes in hill roads, road-berms
- slopes in bridge approaches made of earth
- stabilization of O.B. dumps in mines, PFA (pulverized fly ash), sand-dunes
- watershed management and afforestation in semi-arid zones

7.1.2 Design Aid

Choice of JGT for rain-induced surficial soil erosion depends on the intensity and duration of precipitation, on the soil-type and on the slope of the affected ground. Coverage provided by JGT (Open Area Ratio-OAR) plays an important role in maintaining Erodability Co-efficient of Soil to an acceptable degree.

For a flat ground, coverage of 60% provided by JGT (OAR), is considered adequate. Inclination of the ground to be protected calls for greater OAR as the velocity of surface run-off is greater in a slope. It is advisable to have OAR of minimum 40% for slopes up to 45°. Larger OAR is needed for slopes steeper than 45^{0}.

Another aspect that requires attention is the weight of open weave JGT, specially the diameter of weft yarns which are usually laid normal to the run-off direction. Yarns of diameter of the order of at least 4 mm are preferred to effect the desirable overland storage. It may be shown that a 500 gsm open-weave having 4 mm as weft-yarn diameter, numbering 45 in a metre length, can effect storage of 0.44 litre of water per sq.m. on a 1:2 slope which is exclusive of the extent of water absorption by the jute yarns. A 500 gsm JGT can absorb 2.43 litres (approx) per sq. metre of water (taking water absorbing capacity of Jute to be 475%). Thus on a 1:2 bare dry slope, 500 gsm open-weave JGT can retain 2.87 litres per sq. metre of surface run-off compared to an identical slope without any protective cover.

For wind induced surface-soil erosion, the pore-size should be significantly less, providing a greater coverage over the soil. Concurrently, rainfall pattern of the area and the maximum down pour has to be taken into account for deciding on the weight (gsm) of JGT to be used.

In addition, the following measures deserve consideration

- agronomic (biological)
- land/soil management
- mechanical

JGT is a useful tool for agronomic control by helping in rapid growth of vegetation. JGT facilitates land/soil management. Mechanical methods are, in fact, modification of the surface topography i.e. the ground contours by construction of terraces/benches or silt-fences. JGT may be used as a component of the silt-fence. Each or a suitable combination of the three methods is necessary for effective surface erosion control.

Introduction

Design concept in assessing contribution of open weave JGT for top soil erosion control is based primarily on its water-absorbing capacityfor overland storage and the fabric thickness across the direction of run-off caused by precipitation for effecting successive reduction of run-off velocity. Kinetic Energy of rain drops causing detachment of top soil particles has also been considered The aspect of inter-penetration of water into the soil has not however been considered in this case being dependent on the hydraulic conductivity and saturation of the soil which is apt to vary with the nature of slope fill. It is assumed that at some point on its path following the ground gradient, the velocity of run-off gets too weak to transport the detached soil particles. Thick strands of JGT (open weave) also trap and confine the detached soil particles partially.

The theoretical relations developed below will lead to design the appropriate JGT for the purpose. It may be seen that the most important component of the fabric is the thickness of weft yarns both for overland storage and successive reduction of velocity of the run-off. There are other factors also in play such as ground friction, saturation of JGT. In fact the phenomenon is complex calling for comprehensive simulation study. The major factors have only been analyzed in the following text individually.

7.1.2.1 Impact of Raindrops on Top Soil in Presence of OW JGT

To determine impact of kinetic energy per unit area E_k is expressed as

$$E_k = \frac{\rho i t v^2 \cos\theta}{2} \quad \text{[based onGaber \& Thomas, 2003} \frac{\text{mass}}{\text{area}} = \rho * i * t * \cos\theta\text{]}$$

Mass of water per unit area impacting a bare soil surface (Gaber & Thomas, 2003):

Where,

ρ is density of water (1000 kg/ m3),

i is rainfall intensity (m/s),

t is storm duration (s),

θ is hill slope.

v is terminal velocity (m/s) of rain drops caused by precipitation.

The relation is modified by introducing C_v, aerial coverage by JGT in percentage, considering the fact JGT will prevent impact of raindrops to touch ground in Eq. (9) to yield an *effective kinetic energy* E'_k impact of rain drops in presence of JGT:

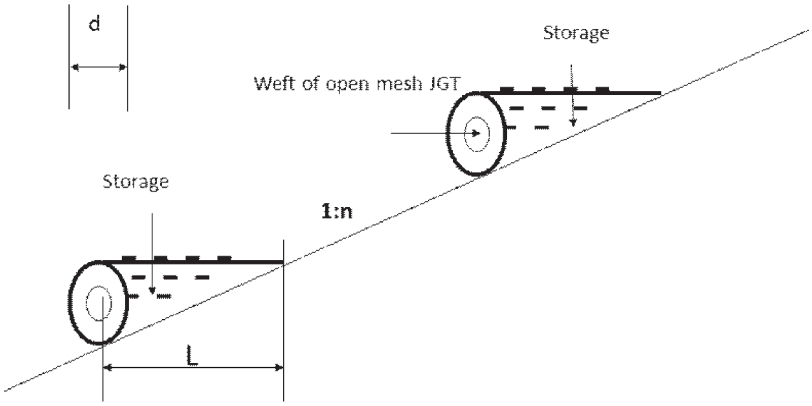
$$E'_K = \frac{\rho i t v^2 (1\text{-}0.01\ C_v)\ \cos\theta}{2}$$

Where, C_v is percentage of area covered by JGT.

Understandably, larger is the percentage of cover over soil, less will be (1) terminal velocity of rain drop, (2) the extent of detachment and migration of soil particles.

7.1.2.2 Overland Storage by OW JGT

Overland storage is interception of run-off. If a portion of the overland flow can be intercepted as storage, the erosive force will get somewhat reduced. It may be seen that the most important component of the fabric is the thickness of weft yarns both for overland storage and successive reduction of velocity of the run-off.



The aspect of overland storage has been analyzed by Sanyal (2006) which establishes the following relation for slope 1: n.

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

where, S = storage by weft yarns (mm^3/m^2)

d = Diameter of yarn (mm)

N = Number of weft yarns per meter

7.1.2.3 Reduction in Run-Off Velocity in Presence of OW JGT

Assumptions:

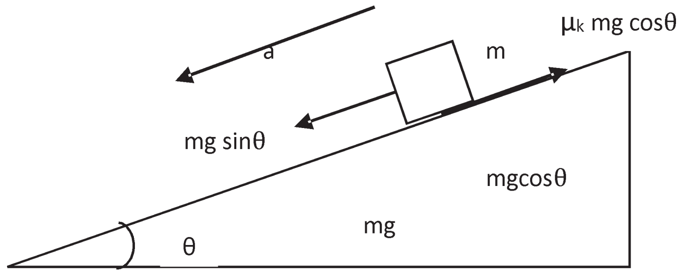
For estimating the Run-off velocity certain assumptions are stated below.

1) Run-off component of precipitation is considered only.
2) Neglecting storage of water by JGT.
3) Hydraulic conductivity of soil and percolation is neglected.
4) Weft yarns are considered as barrier imparting barrier constant.
5) Taking into account laws of dynamics, kinematics and gravitation.

Now consider an object of mass **'m'** moving down an assumed plain surface with acceleration **'a'** meeting a barrier on way posed by weft yarns of JGT in the instant case. Assuming no ground friction, the barrier effect (posed by jute yarns) denoted by **'μ_k'**may be found from the following relation

$$a = g \sin\theta - \mu_k g \cos\theta \quad (5)$$

As derived from free body diagram :- $\Sigma F_x = ma = mg \sin\theta - mg \cos\theta$



The component μ_k may be assumed to be equal to the number of barriers of JGT and its thickness along the length of slope.

$$\mu_k = N*h \quad (6)$$

where **N** is number of weft yarns of JGT & **h** is thickness/diameter of weft yarns of JGT (m).

Now for assessing the run-off velocity on meeting the micro-barrier posed by a JGT weft yarn running across the direction of flow, we revert to the basic relation

$$v^2 = u^2 + 2as$$

Assuming initial velocity (u) of run-off is zero,

$$v^2 = 2as \quad (7)$$

Substituting **'a'** from Eq.(5) & combining Eq.(6) and Eq.(7)

$$v^2 = 2\{g \sin\theta - Nhg\cos\theta\}s \quad (8)$$

wheres is distance between consecutive weft yarns (m).

For determining reduction in run-off velocity, assuming V_1 be run-off velocity before spilling over weft yarns and V_2 be run-off velocity after spilling over number of weft yarns over respective OW JGT shown in figure below.

Reduction in Run-off velocity in 1mt. along the slope (%) =

$$\frac{V_1^2 - V_2^2}{V_1^2} \times 100 = \mathbf{(Nh\ \cot\theta)\ x\ 100\%} \quad \dots \quad \dots \quad \dots \qquad \mathbf{(9)}$$

The approach is evidently theoretical based on certain assumptions. It requires corroboration with field data.

The added advantage of using JGT is its soil-nourishing properties. This is in fact a bio-remediation technique for top soil erosion control which is preferred for environmental reasons.

7.1.3 Recommended Guidelines for Selection of Open Weave JGT

Understandably the more is aerial coverage of the ground, the less will be the extent of impact of raindrops and associated soil dissociation. This aspect is partially taken care of by JGT in view of its open structure. The two other associated phenomena viz reduction of run-off velocity successively and ground storage can be tackled by open weave JGT. Heavier is the fabric and thicker is its weft yarns (i.e. its diameter), velocity reduction and ground storage are better assured. The added advantage of thicker weft yarns is that each space enclosed by two weft and two warp yarns acts as soil trap restraining movement of disintegrated particles with run-off. Besides soil loss, there are other aspects also such as extent of nutrient loss, interpenetration of water into slope fill, ground friction, saturation of JGT under a particular slope angle, soil type, intensity of rain fall also deserves consideration. These aspects have not been considered in the analysis.

From the experience gained in over 58 field applications the following suggestions regarding JGT choice are recommended in consideration of the intensity of precipitation.

Form of precipitation	Intensity (mm/hour)	Recommended type of OW JGT			
		Type	Weight	Thickness (mm)	Open Area (%)
Light	1	1	292 GSM	3	60
Moderate	4	2	500 GSM	4.5	50-65
Heavy	15	3	600 GSM	5.0	45-50
		4	700 GSM	5.5	40-45
Excessive	40	5	1000 GSM	6.0	25-30

7.1.4Monitoring& Maintenance

Close monitoring should be carried out for at least one season-cycle. Displacement of JGT, of any, is to be noted and watched without disturbing it initially. Torn portions of JGT may be overlapped by fresh JGT-pieces duly stapled on all sides. Watering/maintenance of the plant-saplings may be done as per procedures suggested by the botanists/agronomist/Forest department, as the case may be.

7.2 Bank Protection in Rivers and Waterways

7.2.1 The basic function of JGT in bank-protection in rivers and waterways is filtration as a more precise alternative to conventional granular filters.

Filter design with JGT for erosion-control in banks of rivers, canals and waterways should address three basic criteria :

i) Design of JGT

ii) Survivability of JGT

iii) Durability of JGT

The design basically involves selection of Jute Geotextile (JGT) which will ensure soil-tightness and proper permittivity of water to prevent differential over-pressures from developing across the fabric. It has already been stated that sand tightness i.e., retention of fines and permittivity are two contrasting functions. A judicious compromise has to be made in respect of selection of JGT so that both the functional demands are met.

Survivability means that JGT should possess sufficient strength against installation stresses.

Durability of JGT implies that the product should be effective throughout the design life of the treated surface.

7.2.2 Areas of application :

Protection of banks of rivers, canals and waterways.

7.2.3 Causes of Bank Erosion

The principal causes of river bank erosion are as follows :

i) Weak bank soil which is easily erodable.
ii) Strong current and eddies near the bank.
iii) Waves induced by wind and moving vessels.
iv) Large fluctuations in water-level.
v) Uplift pressures due to alternating hydraulic gradients.

7.2.4 Engineering Control of Bank Erosion

Bank erosion may be controlled effectively either by repulsion of flow away from the affected banks say, by construction of spurs or by providing a durable protection to the affected banks or by a combination of both these measures.

Repulsion of flow is a task of the concerned engineers and can be effected by construction of suitable regulatory measures at appropriate locations. Protection to the banks should be done as already indicated by a combination of conventional granular filter and armour.

The top of the bank protection work should have a cover of vegetation (e.g., quick - growing local grass, 'vetivar' grass, mangroves in saline inter-tidal zones).

7.2.5 Design Concept

The critical parameter for river bank erosion control is *the filtration capability* of the selected woven JGT. For filtration function to be effective under given hydraulic and geotechnical parameters, fabric design demands determination of optimal pore size of JGT that can retain the maximum soil particles ('soil tightness') on the one hand and ensure allowable permittivity to dissipate the pore water pressure in bank soil on the other. The design therefore should focus on AOS of woven JGT in relation to average grain size distribution of bank soil and permittivity of JGT vis-a-vis hydraulic conductivity of bank soil principally. There exist empirical relations for man-made geotextiles to address both the criteria. But then unlike man-made geotextiles JGT does not possess dimensional uniformity. Considering its lack of uniformity and for 'hairiness'of its yarns it is suggested that AOS of JGT should be given a *larger tolerance* (say 15%) over the design value.

Conceptually, designing a geotextile filter is no different from designing a graded granular conventional filter. For a geotextile to act as a filter, it is essential that a condition of equilibrium is established at soil-geotextile interface as soon as possible after its installation.

A filter should prevent migration of soil particles to an acceptable degree, while at the same time allow pore water to flow though and also along the filter layer to prevent development of overpressure in bank soil.

JGT filter should meet the following criteria:

(1) The apparent opening size (AOS) of JGT usually denoted by O_{95}, should be less than the average particle size of the soil to be retained.

(2) The permeability of JGT, K_{JGT} should be sufficiently more than the permeability of soil, KSOIL so that insignificant pore pressure can generate.

(3) The JGT must be capable of withstanding transportation and handling stresses.

SOIL RETENTION CRITERIA FOR DIFFERENT FLOW CONDITIONS

In *unidirectional* flow conditions larger soil particles usually form an arch-like configuration over JGT pores and restrain smaller particles which, in turn, successively contain smaller soil particles. The altered arrangement of soil particles in bank soil takes the shape of a graded filter structure ultimately (filter cake).

In *reversing* flow conditions, filter cake formation in bank soil is usually partial when the cycle time does not allow sufficient time to form a graded soil filter. In rapidly reversing flow conditions even partial filter cake formation in bank soil may not be attainable. In such conditions, granular filter is used in conjunction with JGT. Light weight JGT is adequate for unidirectional flow conditions, whereas thick GT should be suitable for rapidly reversing flow conditions. (D J Haore, 1984).

Geotextiles & Geomembranes Manual edited by T S Ingold states that permeability may be "operational". The recommendation is --'unlike static design where flow is unidirectional, flow through bank soil occurs under reversing, dynamic hydraulic gradients. Consequently the bank soil cannot be assumed to develop filter-cake and so the pore size required for retention will be smallerfor a dynamic flow regime than it might be for static flow.

Considering reversing flow conditions for mild to moderate rivers, the recommendation for retention criteria is as under which may be adopted for JGT.

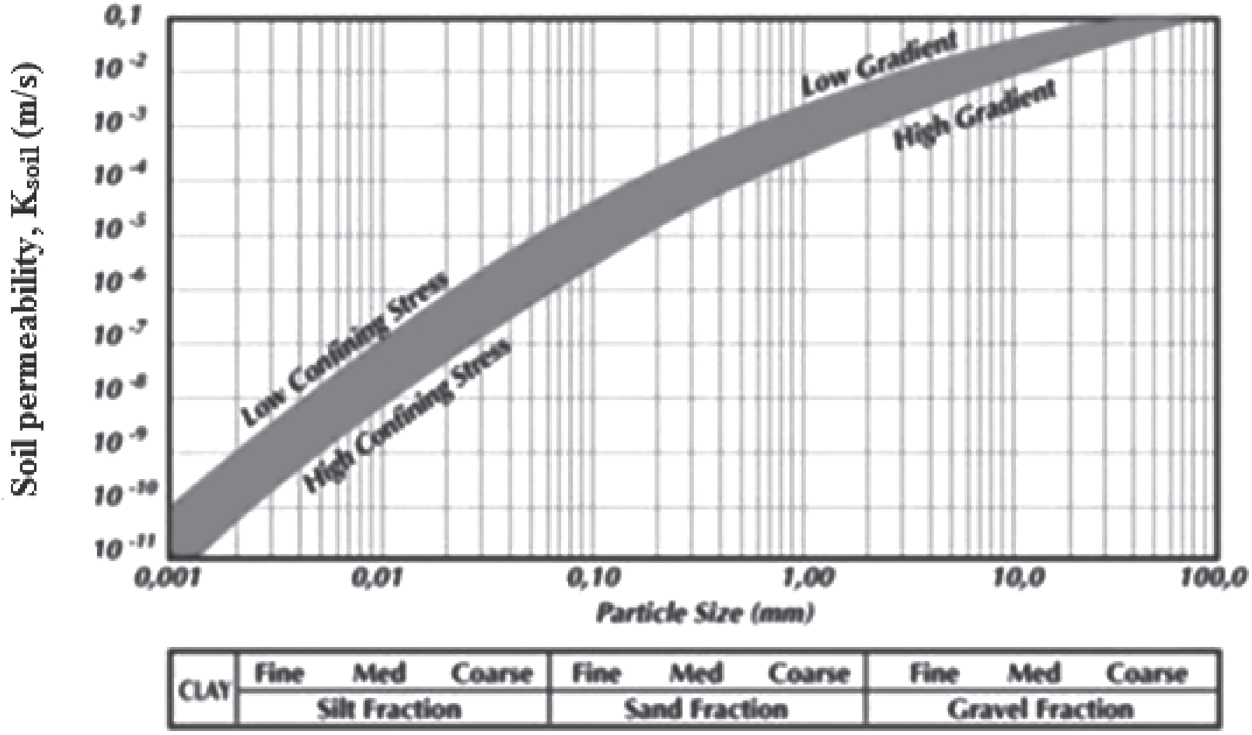
a) If d_{40} is ≤ 0.06 mm, then O_{95} should be less than $10d_{50}$ and 300μm separately

b) If d_{40} is > 0.06 mm, then O_{95} should be less than d_{50} and 500μm separately

PERMEABILITY CRITERION

General requirement of permeability criterion was described by Giroud in 1982 [1] as $k_{JGT} \geq k_{soil}$

The principle of all permeability criteria is that as long as the permeability of the geotextile (k_{JGT}) is greater than the permeability of the soil (k_{soil}) the flow of water will not be impeded at the soil/geotextile interface. Fig-1 shows permeabilities of different soil fraction under different hydraulic gradients and the relationships between permeability of JGT and soil have been derived from Netherlands Coastal Works Association (1981), Franzius Institute in Germany (1972) and Calhoun (1972).



Typical soil permeabilities

The recommended criteria for permeability of JGT is $\mathbf{k_{JGT} \geq 50k_{soil}}$

7.2.6. Transmissivity Criterion for Drainage Function

JGT acts as a drain allowing transmission of water along its plane. Values of transmissivity of 627 gsm woven JGT were measured in IIT Chennai under Prof K Rajagopal with a range of kPa values may be seen at the end. If the situation so demands, in very problematic bank soils, use of a thicker variety of woven JGT may be considered. Incidentally 627 gsm woven JGT is designed to possess tensile strength of 20 kN/m.

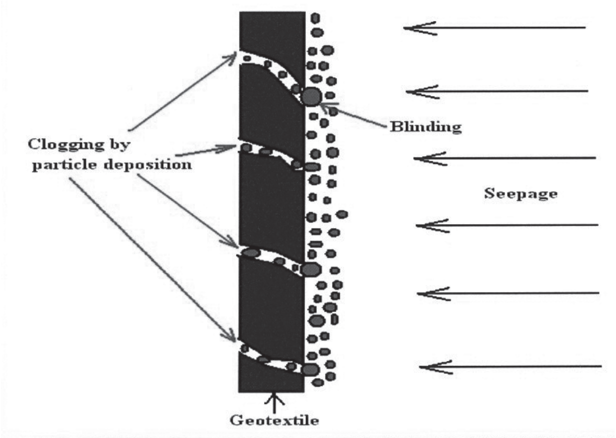
7.2.7 Survivability Criteria

For survivability JGT shall have the following minimum average roll values (MARV) for armour layer stone weighs about 50 kg with stone drop height of nearly 1m -

S.No.	Property	ASTM	Units	Values
1.	Wide Width Tensile Strength (kN/m)	D 4595	kN/m	20
2.	Puncture Strength (kN)	D 4833	kN	400 ($\pm$ 10%)
3.	Burst Strength (kPa)	D 3786	kPa	3100 ($\pm$ 10%)

7.2.8 Anti-Clogging Criteria

To obviate probability of clogging and blocking of JGT Gradient Ratio Test (GR Test) or Hydraulic Conductivity Test (HCR Test) should be conducted prior to deciding on the fabric porometry (AOS).



Method of clogging and blinding (After Bell and Hicks, 1980)

REFERENCE

[1] Giroud, J.P. 'Filter criteria for geotextiles', Proc. Second Int. Conf. on Geotextiles, Las Vegas 1982, Vol. 1, 103-108

7.2.9 Design of Riprap

The third aspect is based on assessing the tractive force (shear stress) imposed by flowing water and the ability of the armour-JGT combination to withstand the force. This implies determination of the thickness of the armour as well as its dead weight.

Design of Riprap Pitching consists of thickness of pitching and weight of boulders which can be determined as below -

i. Minimum Thickness of Pitching (T) as per IS code of 14262-1995

$$T \text{ (in metre)} = \frac{V^2}{2g(S-1)}$$

where, V = Maximum velocity during flood m/s

g = Gravitational constant = 9.81 m/s2

S = Specific Gravity of Riprap

ii. Minimum Weight of Boulders/Rocks (W) as per IS Code of 14262-1995

$$W\ (kg) = \frac{0.02323}{K} \times \frac{Sm}{(Sm-1)^3} \times V^6$$

Where, K = Slope Correction factor = $\sqrt{1-\left(\frac{\sin\theta^2}{\sin\phi^2}\right)}$

V = Maximum velocity during flood m/s

θ = Bank Slope

φ = 30⁰ = Angle of Repose

Sm = (1 - e)S

$$e = \text{Porosity} = 0.245 + \frac{0.0864}{(D50)^{0.21}}$$

Specification of Woven JGT

Nomenclature	Woven JGT 20 kN/m
Construction	1/1 DW Plain Weave
Weight (gsm) at 20% MR ≥	627
Width (cm) ≥	100
Ends x Picks / dm ≥	85 x 32
Thickness, (mm at 2 kPa)	1.7 ± 10%
Tensile Strength (kN/m) MD x CD ≥	20 x 20
Elongation at break (%) MDx CD ≥	12 x 12
Puncture Resistance(kN)	0.400 ± 10%
Burst Strength (KPa)	3100 ± 10%
Permittivity at 50mm constant head (/sec)	$350 \times 10^{-3} \pm 10\%$
A O S (micron) O_{95}	150 - 400

It has already been stated under para 2.3 on Filtration that geotextiles are supposed to perform two contrasting functions. The two criteria to be met are—

– the fabric must be fine enough to curb loss of soil fines

– the fabric must be permeable enough to prevent development of high overpressures.

While designing an appropriate JGT for bank protection of rivers and waterways, the protective arrangement should consist of an outer robust layer underlain by a core layer that is supposed to act as a filter layer. The function of the outer layer is to dissipate the dislodging effects of the current, besides preventing direct exposure UV radiation to JGT.

Design of JGT as the inner core of the protective arrangement i.e. filter is based on empirical studies carried out with man-made geotextiles in developed countries in particular. Several empirical relations have been developed establishing porometric criteria vis-à-vis the mean particle size of the bank soil. It is recommended to adopt the following criteria as recommended by the Netherlands Coastal Works Association on the basis of investigations.

a) for uniform non-cohesive soil (Uniformity Co-efficient < 5)

$O_{90} \leq d_{90}$

b) for well graded non-cohesive soil (Uniformity Co-efficient ≥ 5)

$O_{90} \leq 2\ d_{90}$

c) for cohesive soil

$O_{90} \leq d_{90}$ or $O_{90} \leq 10\ d_{50}$

The co-efficient of permeability of JGT (K_g) should be roughly 5 times larger than the co-efficient of permeability of the bank soil (Ks). The limiting criterion is $K_g = K_s$.

Wave action is not a usual feature in rivers and waterways excepting near the harbours. The weight of armour stones in rivers is decided on the basis of nature and magnitude of current velocity. It is safe to adopt the equivalent diameter of stone (specific gravity not less than 2.7) as 0.1 meter for turbulent current of the order of 1 meter/second. In rivers current velocity seldom exceeds 3 meter/second for which an equivalent diameter of 0.25 meter of armour stone is sufficient.

7.2.10 Choice of JGT

Critical aspects in choosing a JGT for this purpose are as follows—

a) Clogging of JGT

Chances of both mechanical & chemical clogging of JGT are pronounced as JGT is placed over a wet bank soil. Clogging-potential of JGT should be tested as per ASTM - D 5101 - 90 (Gradient Ratio test), or any other suitable method (Hydraulic Conductivity Ratio (HCR) test.)

JGT is expected to function with a low probability of clogging when the flow rate initially decreases with time and then stabilizes to a certain value over a time period.

b) Survivability of JGT

JGT needs careful storage, handling, transportation and installation. Details in this regard have already been mentioned under section 4.0.

It is preferable to lay a cushion of properly graded sand on top of JGT to guard against puncturing. Care should be taken to ensure that armour stones are placed 'softly' over the fabric.

JGT should not be laid on a surface of soil slurry as it may lead to clogging.

c) Durability of JGT

As already indicated that JGT, being biodegradable, possesses comparatively low longevity, but this should not be construed as a deterrent factor. JGT acts as change agent in formation of 'filter cake' within the base soil. In unidirectional flow, time of filter cake formation is usually one season cycle. JGT as already indicated helps in a very fast growth of vegetation due to its inherent characteristics such as creation of a congenial micro-ambience.

d) Longevity of JGT

In all bank erosion-control works it is imperative that the longevity of JGT should be at least 4 to 5 years. The purpose is two-fold. First, to allow sufficient time for stable formation of filter cake. Secondly, to ensure growth of a dense vegetative cover for holding the base soil naturally. The selected JGT should therefore be impregnated with suitable rot-resistant chemicals preferably eco-friendly additives that can delay the degradation of the fabric. In the field applications so far conducted industrial bitumen of suitable grade (90/15) was used as coating. Care may be taken to ensure that such application of rot-resistant additive/bitumen does not affect the porometry of JGT beyond a tolerance limit of 25%. Considering the inherent deficiencies of bitumen treated JGT researchers have developed natural, eco-friendly additive to enhance life of JGT. Such non-bituminous JGT have already been applied with success both in Bangladesh and India.

7.2.11 Monitoring and Maintenance

The treated bank should be kept under watch for at least one full season-cycle. Frequent visits to sites during and after the rains or any natural calamity are necessary. Siltation may take place after about a month covering up the granular overlay gradually under favourable conditions. Maintenance involves, besides monitoring, re-arrangement of the overlay, if displaced, in position. No part of JGT should be allowed atmospheric exposure due to displacement of the overlay. The JGT-strength may be ascertained after one season - cycle and the overall performance analysed.

7.3 Stability of Embankments for Highways, Railways and Flood - control

7.3.1. Role of Fill Material

Stability of embankments implies stability of the soil-body as a whole, apart from the stability of the exposed slopes. Road and railway embankments are subjected to moving loads which develop dynamic stresses within them. Flood-control embankments are supposed to withstand lateral thrusts of rising water which may seep into the embankment-body and enhance the moisture content within it.

Soils derive stability from their shear strength. The safe slope of an embankment depends on the shear strength of the fill. Non-cohesive granular soils possess high internal frictional resistance which helps develop increasing shear strength with the addition of load. This characteristic of non-cohesive soils allows construction of an embankment having stable and steeper angles than that of an embankment made with fine-grained cohesive fills.

Soil in general hardly possesses any tensile strength. It behaves differently according to its composition, structure and other geotechnical properties. As a result, embankments constructed with soils prone to volumetric variations suffer failure in the shape of vertical subsidence, lateral dispersion, down-slope migration, rotational slides etc.

7.3.2 Reasons of Slope Instability

Slope-instability in earthen embankments is caused mainly due to saturation of the soil with entrapped moisture/water. Draining out of water from the sub-surface is the solution. Trench drains along the toe of the slope and also across it help drain out the surface run-off. Moisture/water within the soil-body can be drained out by inserting pre-fabricated vertical jute drains (PVJD) that act like sand drains. Encapsulated drains are more effective when rubbles are encapsulated in JGT (usually non-woven JGT). Such JGT-encapsulated trench drains prevent ingress of erodable soil particles into the drain. The surface flow of water is unidirectional along slopes. Detachment and transportation of the upper layer of the soil on the slope due to rains/surface run-off are effectively tackled by open mesh JGT initially and by vegetation subsequently as already indicated under section cl. 6.1. The natural stability of the base soil remains unimpaired even after biodegradation of JGT unless there is an excessive geotechnical disturbance leading to instability of the slope and failure of the drainage system. Growth of vegetation on the slope renders stability to the slope naturally. PVJDs may be inserted at the terraces/benches of slopes for draining out entrapped moisture/water if the situation so demands.

The use of JGT for reinforcing the soil in the body of the embankment shall be based on the evaluation of improvement expected in regard to its stability because of such use. The improvement is a function not only of the fill-properties, but also of the JGT.

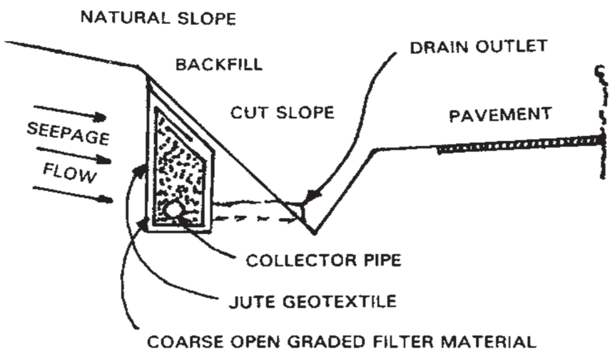
7.3.3 Application Areas

- stability of roads/railway tracks abutting hill-slopes.
- overburden (OB) dumps in open-cast coal mines.
- pulverized flyash (PFA) heaps in thermal power plants.
- all earthen embankments for highways, railways and flood-control.

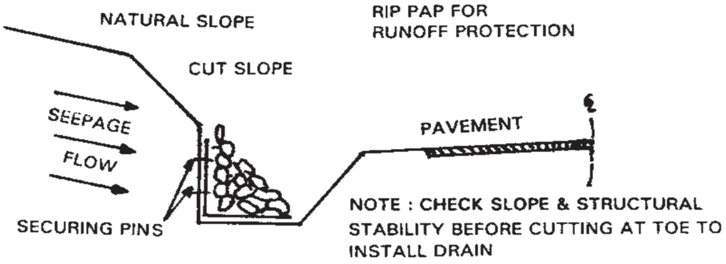
7.3.4 Design Approach

The remedial measures for slope in stability are similar to what has been recommended in the section on Surface Erosion Control excepting special provisions which are required to be made for draining out surface water run-off through a network of trench drains. (Fig. 24)

High permittivity and separation are the deciding factors in trench drains. Non-woven JGT, which has a higher permittivity than the woven type and less costly, is recommended. The coefficient of JGT permeability, (kg) should exceed the co-efficient of soil-permeability (ks) by a factor to allow for functional reduction in drainage efficiency due to clogging and other factors. Alternatively (?) the permittivity of a JGT (kg) should be higher than the calculated soil-permeability, ks by a prescribed margin of safety.

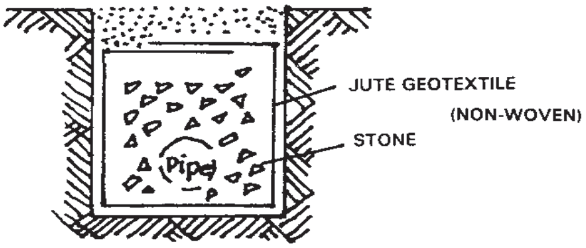


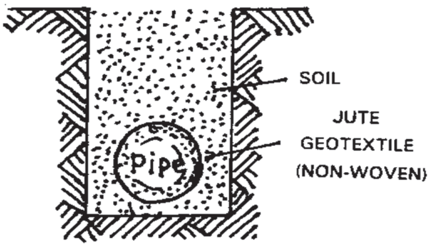
A. TRENCH INTERCEPTOR DRAN FOR CUT SLOPE SEEPAGE



B. ROCK TOE INTERCEPTOR DRAIN FOR CUT SLOPE

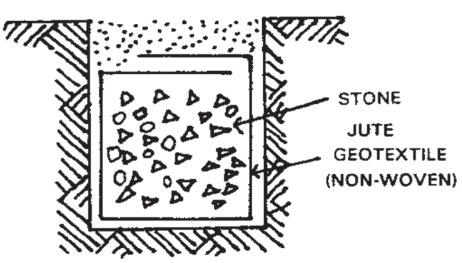
TRENCH AND TOE INTERCEPTOR DRAIN FOR CUT SLOPE SEEPAGE



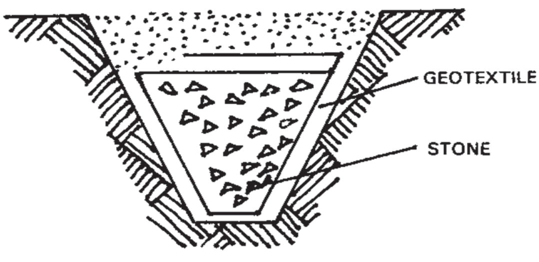


CONVENTIONAL PIPE UNDER DRAIN WITH AND WITHOUT JGT

(AFTER RAMASWAMY ET AL 1992)



GEOTEXTILE WRAPPED RUBBLE DRAIN (NO PIPE)
RECTANGULAR SECTION



GEOTEXTILE WRAPPED RUBBLE DRAIN (NO PIPE)
TARAPEZOIDAL SECTION

Fig. 24. **VARIOUS ARRANGEMENTS FOR TRENCH DRAINS**

Open i.e. unconcealed JGT-encapsulated aggregate-filled trench drains may also be used with rubble or sand cover. There is however a caveat. JGT-encapsulated open trench drains need special care in regard to their maintenance lack of which leads to malfunctioning of the drains as a result of blockage due to growth of vegetation, damage to JGT and other associated problems. Care is also to be taken to ensure that an open drain at the toe of a soil slope may not induce an element of instability of the slope. The sand or rubble cover will protect the main drain-structure. Such drains may be constructed as long 'ribs' along the toe of the slope with lateral outlets. The main drain may also be constructed with a porous pipe inside the drain-capsule in some cases. (Fig. 23C)

Reference may be made to Koerner (1990) for a suitable method of analysis or other text books on geo-synthetics, dealing with reinforced embankments. Generally, stability of the embankment subjected to moving loads may be ensured by JGT which can perform the following functions effectively :

A. Initial Reinforcement

An earthen embankment when subjected to moving loads, develops stresses and strains which may lead to its failure if the permissible limits are exceeded. JGT when placed at appropriate levels within an earthen embankment can absorb these stresses and strains to a substantial extent at the initial stages and control failure of the embankment. Soil-JGT friction acts as medium of transference of stresses and strain. JGT, when under tension, strengthens the soil-body.

JGT can directly reinforce an embankment only during its useful life-span (not more than 4 to 5 years after rot-resistant treatment). In fact, JGT may not serve the purpose of reinforcing an embankment fully for a long period. The initial reinforcing function of under dynamic loads tends to stabilize the earthen embankment gradually with the passage of time exerting a confining action.

B. Separation

JGT separate the natural ground from the fill materials of an embankment and thus prevent their intermixing. If the base-soil is weak and compressible, the first embankment layer can retain its geotechnical characteristics better as a result of the separation.

C. Filtration

When the first embankment layer is made of freely draining materials, JGT can intercept these materials while allowing passage of water through the fabric.

D. Drainage

JGT may serve as a draining layer (transmissivity) - a drain by itself within its own thickness when there is no localized out-flow of water.

All these functions in combination accelerate consolidation of the embankment. The basic design-criteria are similar to what has been stated under Section 6.2 (Bank Protection in Rivers and Waterways) in so far as porometry and permittivity are concerned.

It is imperative that both the grain size distribution and co-efficient of permeability of the fill and also of the base-soil are determined for choice of an appropriate JGT. Before construction of any new embankment, JGT treated with a suitable additive to enhance the fabric durability, may be laid on the base soil to prevent its intermixing. Additionally the fabric will also serve as a basal reinforcement for preventing rotational slides. If the soil material has a high Plasticity Index, it is recommended that JGT treated with suitable rot-resistant chemicals should be laid in successive layers above the base. The interval between layers will depend on the height and width of the embankment, the composition and geotechnical characteristics of the soil material and the type, frequency and extent of dynamic loading. There should be provisions for side-restraint if the soil-material has low internal friction. When permeability of the curb-material is less than 10-5 metre/sec, a combination of woven and non-woven JGT is recommended.

7.3.5 Installation of JGT

- The surface of the base should be levelled and cleared of any foreign materials.
- treated JGT should be placed at the interface of the base-soil and bottom of the proposed embankment with its ends filled with the fill material and folded (up to 1/8th of the base width of the proposed embankment (see portions of a + b + c of Fig. 25).
- more fill materials should be at the edges (portion d)
- the central portion is to be filled next (portion e)
- the height of the embankments is to be raised (portion f)
- complete filling the central portion in stages (portion g)

N.B. : i) The fill-material should not be an organic soil or with Plasticity Index (PI) more than 20 and Liquid Limit (LL) more than 40 when tested according to IS : 1720 (part 5).

ii) Filling behind abutments and wing walls of all structures should conform to the guidelines given in Appendix 6 of IRC : 78 (Standard Specifications and Code of Practice for Road Bridges - Section - VII) in respect of the type of material, the extent of backfill, its laying and compaction etc.

iii) The fill materials shall be laid in horizontal layers and compacted as per table 300-2 of the said Code of Practice.

iv) Backfilling should not be done in water or over a muddy surface. Water should be bailed out, mud scooped out and JGT laid on the prepared ground. It is recommended that granular material of maximum particle size of 75 mm and uniformity co-efficient (d_{60}/d_{10}) above 10 should be used in such cases.

v) Sufficient settlement period should be allowed to the new embankment before any construction is undertaken. Alternatively, methodology of pre-loading the new embankment may be considered.

vi) In case of very high embankments, treated JGT may be inter-posed at appropriate layers within the embankment-body.

N.B.: Installation procedure of JGT should be read in conjunction with Sec. cl. 6.1.4.

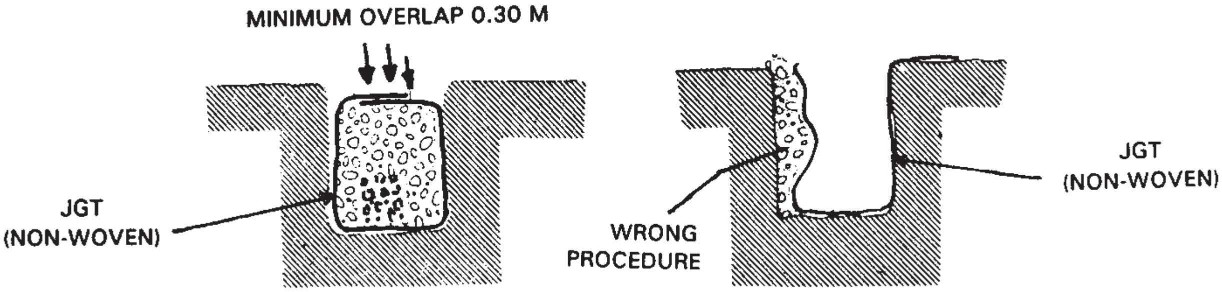


Fig. 25. CORRECT JGT-LAYING IN A TRENCH DRAIN

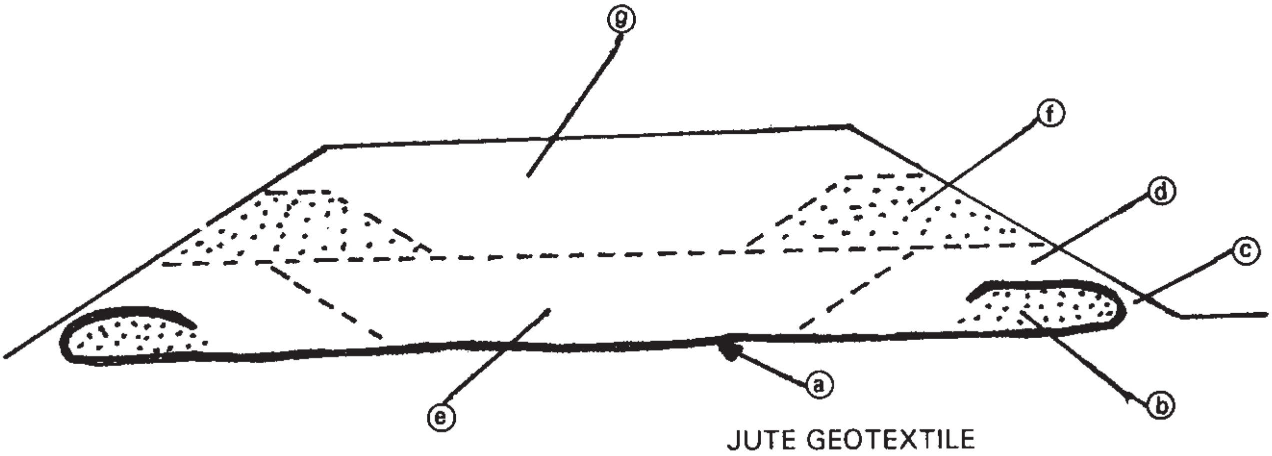


Fig. 26. RECOMMENDED EMBANKMENT CONSTRUCTION SEQUENCE

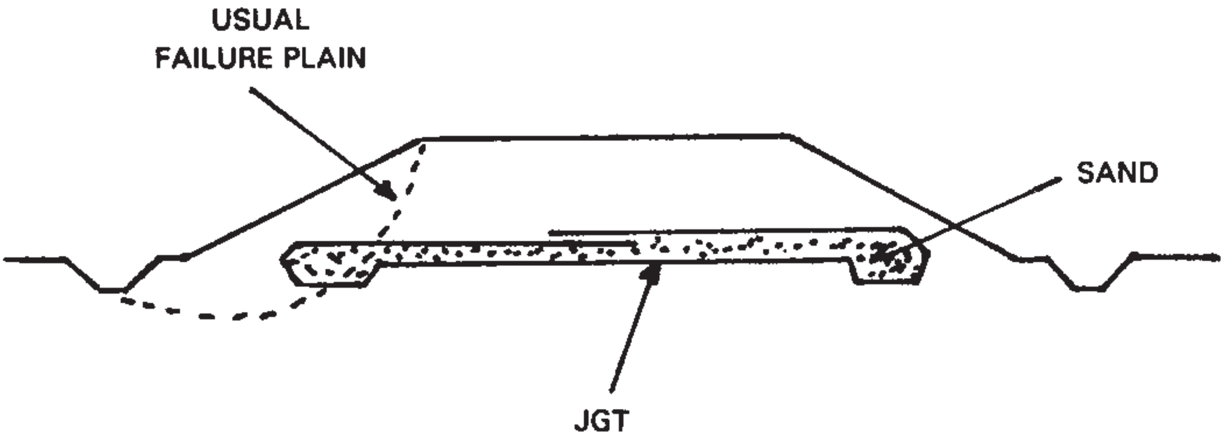


Fig. 27. TYPICAL BASAL REINFORCEMENT CONSISTING OF GRANULAR FILL ENCLOSED WITHIN A JGT

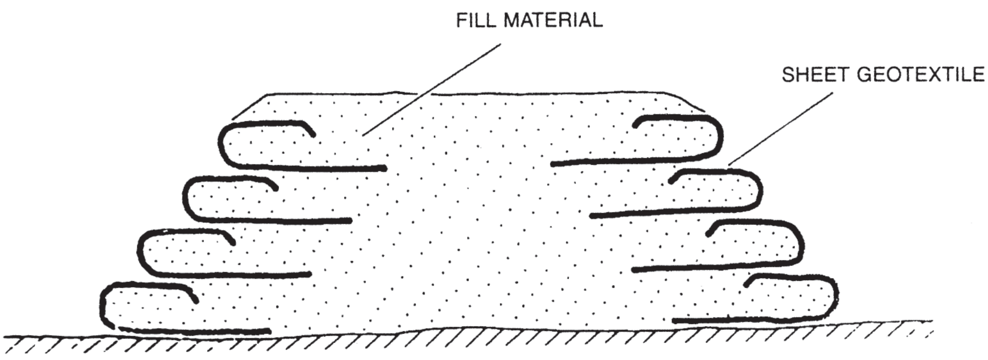


Fig. 28.

7.3.6Monitoring & Maintenance

Any newly constructed embankment should be monitored for two season-cycles for settlement and other distresses. The basic principle for a trouble-free stable embankment is to avoid ingress of water into it and to draw out water if there be any entrappedwater/moisture within it. Slope stability, specially, subsidence/settlement, is to be noted throughout the seasonat regular intervals and more frequently, during and after natural calamities and the rainy seasons. Drainage materials should not be normally disturbed unless there is an evidence of failure of the drainage-system. In the event of any disturbance, fresh materials may be laid, without disturbing/damaging the JGT.

7.4 Strengthening of Sub-grade in Roads

7.4.1 Reasons for Distresses in Roads

Poor sub-grade often causes pavement-failures when strains accumulated under repeated dynamic loads of traffic exceed the permissible value. It often happens that the materials in the base course of the pavement get intermixed with the sub grade, reducing the required depth of the pavement decided on the basis of class of loading rut depth and CBR (California Bearing Ratio) of sub-grade. A poor sub-grade may also cause its lateral displacement with the base-materials. Insufficient drainage of the surface water and also the entrapped moisture/water within the subsurface layers along with the seepage of water from the sides often lead to road-failures.

JGT can tackle all these problems effectively by segregating different layers of a road pavement, preventing movement of the sub-grade soil (sand-tightness) and facilitating penetration of water through its pores and dispersion of water along its plane. CBR value of the sub-grade gets enhanced due to concurrent functioning of separation, filtration and drainage.

7.4.2 Areas of application

– in road-construction in all types of soil including haul roads.

– car parks, storage yards, hard stands.

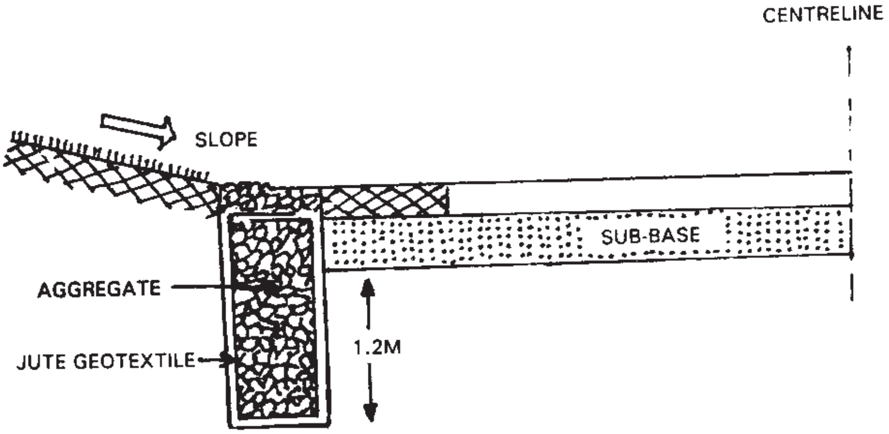


Fig. 29. A TYPICAL HIGHWAY CROSS-SECTION WITH EDGE-DRAIN

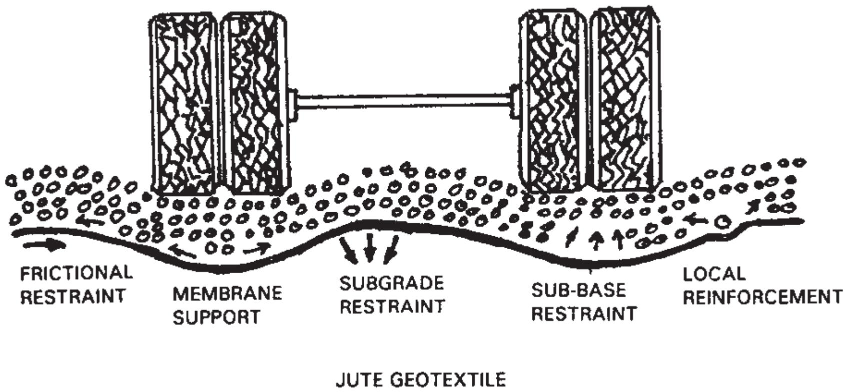


Fig. 30. JUTE GEOTEXTILE STABILIZATION OF AN UNPAVED ROAD

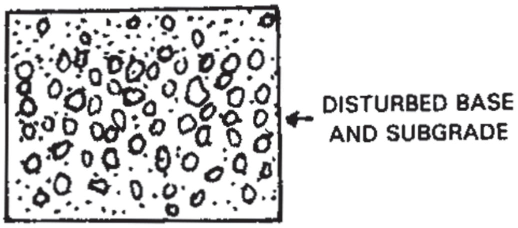


Fig. 31A. WITHOUT JUTE GEOTEXTILE

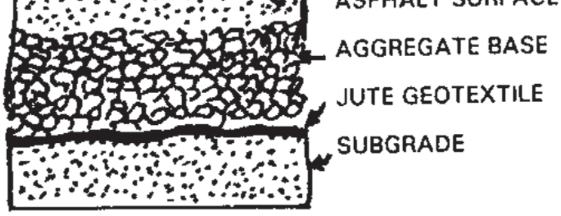


Fig. 31B. WITH JUTE GEOTEXTILE

7.4.3 Design Approach

INTRODUCTION

Design of road pavement includes determination of its total thickness and thickness of the individual layers, i.e. the thickness of improved subgrade, sub-base and base course layers.The total thickness of a pavement essentially depends on the strength of its subgrade, axle load and number of load cycles.

Design approach for geotextile reinforced road pavement may be found available in different codes and methods suggested by different researchers. One of the popular methods suggested by Giroud and Noiray (1981) for synthetic geotextiles, may also be adopted for jute geotextile (JGT) reinforced road pavement design. It may be appreciated that a JGT acts as an initial reinforcement until the initiation of its decomposition takes place. During this time, the strength of subgrade soil increases and presence of JGT becomes redundant for the future survibaility of the road. Increase in shear strength of original subgrade due to use of JGT has been recorded by direct measurement of California Bearing Ratio (CBR) at the field trial sites, both in Bangladesh and in India. From these test results, it is agreed that in less than twelve months time the CBR value of subgrade soil increases by at least 1.5 times its original value.The required pavement thickness should be determined on the basis of the governing case between the analytical approach and the increased CBR value approach. It should be noted that JGT will be effective only if subgrade soil deforms adequately. Therefore, it is recommended that the proposed design approach be implemented for a subgrade soil having CBR value less or equal to 50%.

ANALYTICAL APPROACH

The analytical approach for designing road pavement with geotextiles may be adopted as described by Giroud and Noiray 1981 [1].The approach is explained in relation with the figures 1(a), 1(b), 1(c) and 2. Figure 1(a) describes the thickness and stress distribution of a wheel load without geotextile. The thickness of pavement without geotextile is denoted by h0. Figure 1(b) describes the thickness of road pavement for a wheel load when geotextile is used. This thickness is denoted by h_G.

The equivalent contact area of a wheel on the road surface is taken as width B x length L. The relationships between these dimensions, the axle load P and the tyre pressure p_t are given in the following equations:

Normal highway vehicles including lorries:

$$B = \sqrt{P/p_t} \quad \textbf{(1)}$$

$$L = 0.707\ B \quad \textbf{(2)}$$

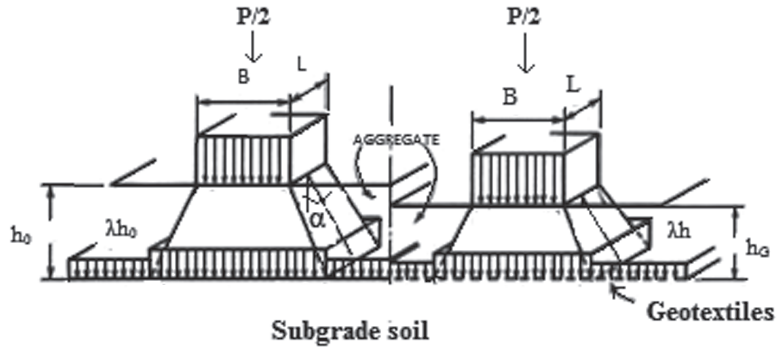


Figure 1(a) Figure 1(b)

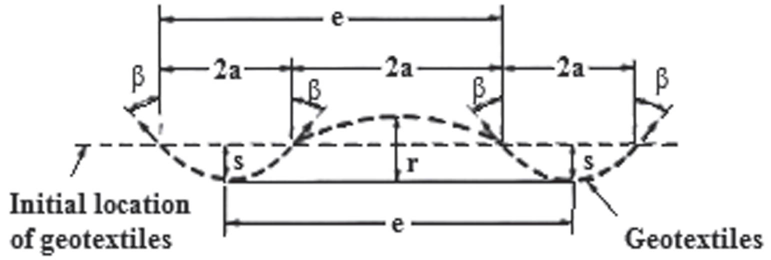


Figure 1(c)

Figure 1. Stresses in the subgrade and geotextiles (after Giroud and Noiray, 1981)

Referring to Figure-1(a), the stress p applied to the cohesive formation by a monotonic wheel load P/2 is:

$$p = \frac{P}{2(B + 2h \tan \alpha)\,(L + 2h \tan \alpha)} \qquad \textbf{(3)}$$

As the analysis is not very sensitive to the exact value of tan? and experiments indicate that tan? lies between 0.5 and 0.7, tan? may be taken as 0.6.

Hence, we may write—

$$p = \frac{P}{2(B + 1.2h)\,(L + 1.2h)} \qquad \textbf{(4)}$$

Giroud and Noiray make use of the net elastic bearing capacity (q_e) and the net ultimate or plastic bearing capacity (q_p) , Figure 2, defined as:

$$q_e = \pi\, c_u \qquad \textbf{(5)}$$

$$q_e = (\pi + 2)\, c_u \qquad \textbf{(6)}$$

Where, c_u is the undrained cohesion of the underlying soil.

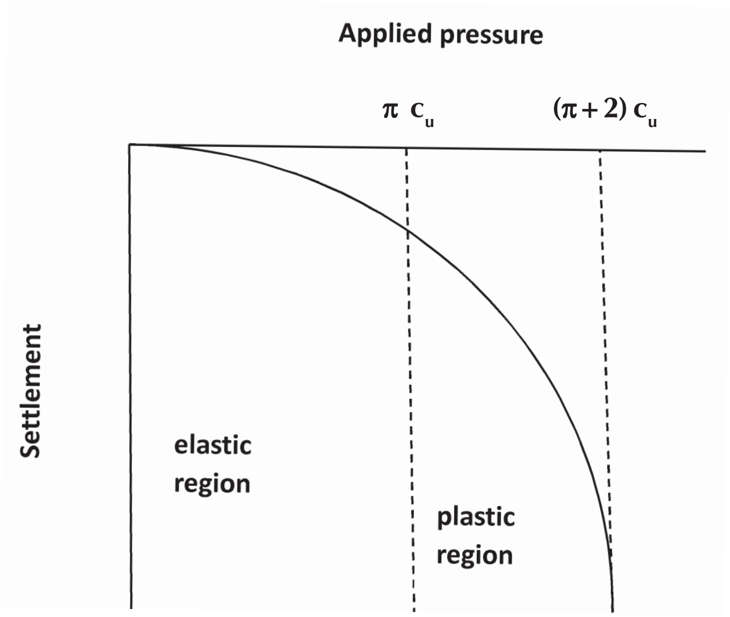


Figure-2: Settlement at the centre of a loaded plate

Substituting $p = q_e = \pi c_u$ in equation (4), gives:

$$\pi c_u = \frac{P}{2(B+1.2h_0)(L+1.2h_0)} \tag{7}$$

$$h_0 = \frac{-1.2(B+L)+\sqrt{1.44(B+L)2-5.76\left(BL-\frac{P}{2\pi c_u}\right)}}{2(B+1.2h_0)(L+1.2h_0)} \tag{8}$$

The value of h_0 obtained from the equation (8) is the minimum depth of aggregate required for one pass of the axle, without the presence of a geotextile. The value of h_0 remains valid for very light traffic.

However, the aggregate depth must be increased to h'_0 for heavy traffic (repetitive loading), using

$$h'_0 = \frac{[\,(125 \log N-294\,(r-0.075)}{c_u^{0.63}} \tag{9}$$

Where,

N is the number of passes of a standard axle (80kN)

r is the rut depth in m

c_u is undrained soil cohesion in N/m^2

h'_0 is the aggregate depth in m

If the loading is expressed in terms of a number of passes (N'), of an axle load (P') other than the standard axle load, then Giroud and Noiray suggest that it can be converted into an equivalent number of standard axle (N) using

$$N/N' = (P'/P)^{3.95} \qquad \textbf{(10)}$$

Giroud and Noiray suggest that the following two factors contribute to the extra stability arising from the presence of a geotextile in road base:

i) Greater spread of the loading.

ii) An uplift force due to the geotextile tension, Figure 1(c).

By assuming that the geotextile deforms to a parabolic shape, Figure 1(c), Giroud and Noiray derive the following expression for the geotextile uplift force (Fg):

$$F_g = \frac{J\varepsilon\,[1+(a/2s)^2]^{-(1/2)}}{a} \qquad \textbf{(11)}$$

Where,
J is the tensile stiffness of the geotextile,
ε is the geotextile strain
a is ½ (B + 1.2h) and
s is the settlement beneath the tyre (not as the same as rut depth r)

The tensile stiffness (J) of the geotextile is the ratio between the increment of force per unit width and the corresponding increase in strain and is usually measured in kN/m. Frequently this term is incorrectly referred to the elastic modulus of geotextile. The latter term is inappropriate because the elastic modulus is more correctly defined as the ration between the increment of stress and the corresponding increment of strain.

The effect of geotextile may be taken into account by using the ultimate or plastic bearing capacity as the limiting value. Substituting $p = q_p = (\pi + 2)c_u$, deducting $p_g = \frac{\sqrt{2}T_g}{B+1.2h_G}$ (for 627gsm and 724gsm JGT) and replacing $h = h_G$ in the equation (4), we obtain,

$$(\pi+2)c_u = \frac{P}{2(B+1.2h_G)\,(L+1.2h_G)} - \frac{\sqrt{2}T_g}{B+1.2h_G} \qquad \textbf{(12)}$$

$$h_G = \frac{-\left[1.2(B+L)+\frac{0.33T_g}{K}\right]+\sqrt{\left[1.2\,(B+L)+\frac{0.33T_g}{2\pi c_u}\right]^2 - 5.76\,(BL-\frac{P}{10.28c_u}+\frac{0.275T_gL}{c_u})}}{2.88} \qquad \textbf{(13)}$$

Where h_G is the required fill depth of geotextile for a monotonic wheel load, P/2. The saving in aggregate depth due to the presence of the geotextile (Δh) is given by

$$\Delta h = h_0 - h_G \qquad \textbf{(14)}$$

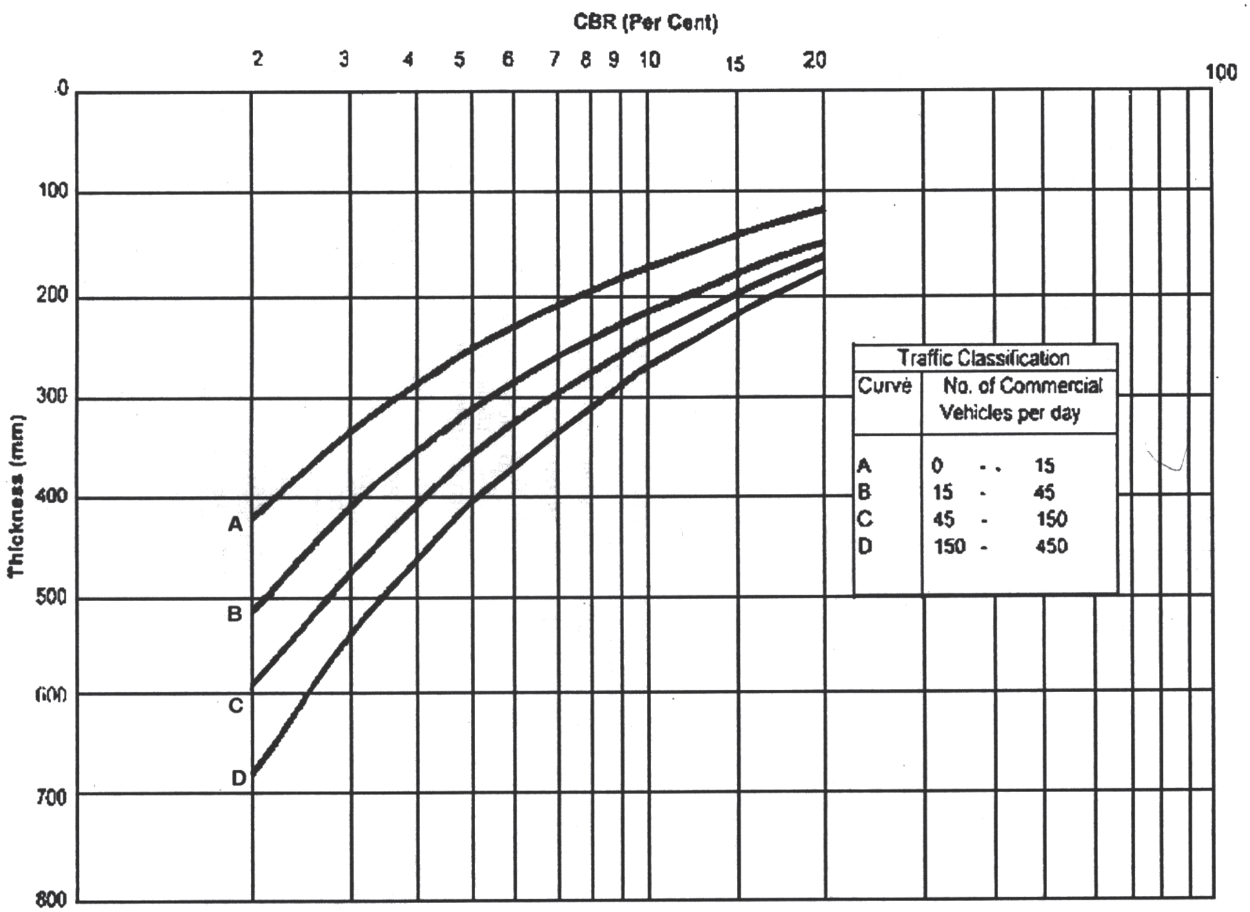
Where, h_0 is found from the equation (8) and h_G is found from the equation (13).

Thickness, h_G' of pavement using JGT, for repetitive loading, may then be determined from the following equation:

$$h_G' = h_0' - \Delta h \qquad \text{(Design approach prepared by BUET)} \qquad \textbf{(15)}$$

EMPIRICAL APPROACH

The design chart [2], Figure 3, produced by Inidan Roads Congress (IRC) is widely used for determining required thickness of road pavements. The chart includes design parameters such as, subgrade CBR value, equivalent standard axle load (ESL) and type of vehicles. Designers may enter the chart with a CBR value and read the required thickness without JGT. S/he can then enter the chart again with 1.5 times the earlier CBR value to determine the required thickness with JGT. The difference between the two values of thickness is the benefit due to using JGT.



IRC Design Chart

DESIGN THICKNESS

The design thickness shall be taken as the smaller of the outcomes from the analytical approach and from the empirical approach described in this document.

REFERENCE

[1] Giroud, J.P. and Noiray, L. Design of geotextiles reinforced unpaved roads. ASCE Proc., J. Geotechnical Engineering Div. 107, GT9 (1981) 1233-1254

[2] GOI (2008). A Manual on Use of Jute Geotextiles in Civil Engineering-2008. Jute Manufacturers Development Council (JMDC).

7.4.4 SELECTION OF JGT

After deciding on the pavement thickness, appropriate woven JGT has to be selected. Determination of choice of JGT is essentially an empirical exercise supported by practical experience. Retention criterion being the governing function of any geotextile, including JGT in case of road construction and tensile strength of JGT having been settled at 25 kN/m for most of roads, the design of JGT is about finalizing its porometric feature which is a factor of grain size distribution of sub-grade soil. The tensile strength of fabric has been kept at 25 kN/m as any greater value of tensile strength is usually not required for low volume roads. It is also been observed in field applications that fulfillment of retention criterion of JGT also concurrently achieves the desired value of permittivity. Parameters of deciding on the pore-size of JGT from functional stand point are indicated below.

a) Retention

To achieve maximum retention of top soil particles the following relationship may be used.

If $d_{85} \leq 75\mu$ then $O_{95} \leq 2 - 2.5\ d_{85}$

If $d_{85} \geq 75\mu$ then $O_{95} \geq d_{85}$

b) Filtration

Fabric permeability (or permittivity) vis-à-vis soil permeability can be determined considering the following relationship.

If $d_{85} \leq 75\mu$ then $\psi_{JGT} \geq 10\ k_{soil}$

If $d_{85} \geq 75\mu$ then $\psi_{JGT} \geq k_{soil}$

where, ψ_{JGT} is permittivity of fabric,d85 is 85% of soil particles finer than that size, O_{95} denotes fabric aperture in JGT 95% of which is less that size and ksoil is hydraulic conductivity of soil.

Specifications of Woven JGT for use in Weak Sub-grade Strengthening

Nomenclature	Woven JGT 20 kN/m (Untreated)
Construction	1/1 DW Plain Weave
Weight (gsm) at 20% MR ≥	724
Width (cm) ≥	100
Ends x Picks / dm ≥	94 x 39
Thickness, (mm at 2 kPa)	1.85 $\pm$ 10%
Tensile Strength (kN/m) MD x CD ≥	25 x 25
Elongation at break (%) MDx CD ≥	12 x 12
Puncture Resistance (kN)	0.500 $\pm$ 10%
Burst Strength (KPa)	3500 $\pm$ 10%
Permittivity at 50mm constant head (/sec)	350 x 10^{-3} $\pm$ 10%
A O S (micron) O_{95}	150 - 400

7.4.5 Shoulder Drains

Often the sub-surface water is drained through the JGT-medium to the shoulders of a carriage way. In such cases, shoulder drains are required to be constructed either beneath the edge of the shoulder or immediately adjacent to its edge (In USA, such drains are called "under-drains") [*Fig.* 27]. In the event of existence of black cotton soil or expansive clay, porous drain pipes are also inserted within the shoulder drain to augment drainage-efficiency.

Installation procedure is similar to what has been mentioned for open JGT- Encapsulated trench drains under the section 6.1.4.

7.4.6 Monitoring & Maintenance

The performance of the pavement with JGT should be monitored closely, especially in regard to development of pot holes, subsidence, road side drainage, dispersion of sub-grade and the like. Frequency and extent of surface treatment and also re-sectioning needed are also to be noted. Special attention is necessary during and after the rains. Pot holes should be immediately restored. Surface drainage over the pavement should not be allowed to hinder due to malfunctioning of road side and shoulder drains.

7.5 Management of Subsidence of Railway Tracks & Embankments

7.5.1 Settlement of Railway Tracks

Railway tracks often settle/subside - both longitudinally and cross-wise - due to inability of the sub-grade to withstand the repeated heavy vibratory loads of moving trains. In case of goods trains, duration of such heavy vibratory loads is prolonged. The sub-grade under a railway track is the embankment itself interposed by ballast layers which act as a cushion and a medium of transference of loads. It is the support incapability of the sub-grade that basically causes track subsidence.

Besides the insufficient bearing capacity of the sub-grade, rotational slides may be one of the causes of track subsidence. The situation can be tackled as indicated under 'Stability of embankment for highways, railways and flood control' (section 6.3)

The more common cause of subsidence of railway tracks is 'erosion pumping' (also called 'mud pumping'). The ballast layer, being an exposed open structure, allows rain water ingress which, in turn, may cause cycles of fluctuating pore-water pressure if the drainage is deficient. The entrapped water within the embankment forms a soil-slurry which gets pushed up into the ballast layer under repetitive heavy dynamic loads of moving trains. The situation impedes not only drainage of rain water through the ballast layer, but also facilitates penetration of ballasts into the sub-grade reducing its desired thickness.

The conventional remedial measure is to replace the disturbed and contaminated ballasts along with the sub-grade soil. The measure may not work if the fill is weak and if there are chances of entrapment of water within the embankment. The basic aim should be to drain out the entrapped water form the sub-grade and the soil below.

7.5.2 Application Area

– railway embankments built with compressive fill.

7.5.3 Design Approach

As already indicated the basic design-approach will be to eliminate water from the sub-grade. This is difficult without disturbing movement of trains.

In new railway embankment constructions, care should be exercised for the right type of fill materials, sub-grade separation, filtration and drainage. In existing embankments with compressive fill materials, especially in areas with moderate to high rainfall, Prefabricated Vertical Jute Drains (PVJD) can provide a lasting solution. The precondition is to assess the geotechnical properties of the sub-grade first, followed by assessment of the depth to which the PVJD needs be inserted into the soil. Drainage arrangement should also be provided laterally. The basic purpose is to ensure attainment of the desired degree of consolidation over a specified time period in relation to the subsoil conditions. The design-approach for deciding on the depth and spacing of JGT fibre drains have been indicated in the following section. A combination of woven and non-woven, JGT is recommended for laying on the subgrade to resist the dynamic stresses.

The approach in problematic compressible soil may be as follows :

– interposing, JGT (woven and non-woven) on the sub-grade. In case of existing railway tracks, the ballast layer should be scooped out completely supporting the rails on wooden blocks, levelling the subgrade, spreading a thin layer of sand on it, placing the JGT overlain by a cushion of sand and replacing the ballasts after cleaning them.

– constructing JGT-encapsulated rubble drains, placed laterally, to drain out entrapped water.

– inserting PVJD if there are signs of erosion-pumping.

– reshaping the embankment as per the design profile. (Fig. 31)

– protecting the exposed slopes with open mesh JGT and grass/turf sods.

7.5.4 Specification of PVJD

Prefabricated JGT drains developed by IJIRA (with the guidance of Prof.S.D. Ramaswamy) is shown in fig : 33.

The properties are :

- dimensions - 100 mm (wide) x 5 mm (thick) with coir/jute wicks inside the JGT-sheath.
- Weight/metre - 200 gm
- Tensile strength - 45 kN/metre
- Elongation at break - 5%
- Permeability at 50 mm water head - 0.41 mm/sec
- Discharge capability at 50 kPa under unit hydraulic gradient - 13.1 ml/sec.

N.B.: a) The design approach is similar to what is mentioned under the sub-section on 'Soft soil consolidation'(sub-section 6.6.4).

b) I.I.T. Delhi has also developed similar drains. The difference between the two is basically in the weave pattern of the JGT-sheath. PVJD developed by IIT, Delhi has a braided sheath.

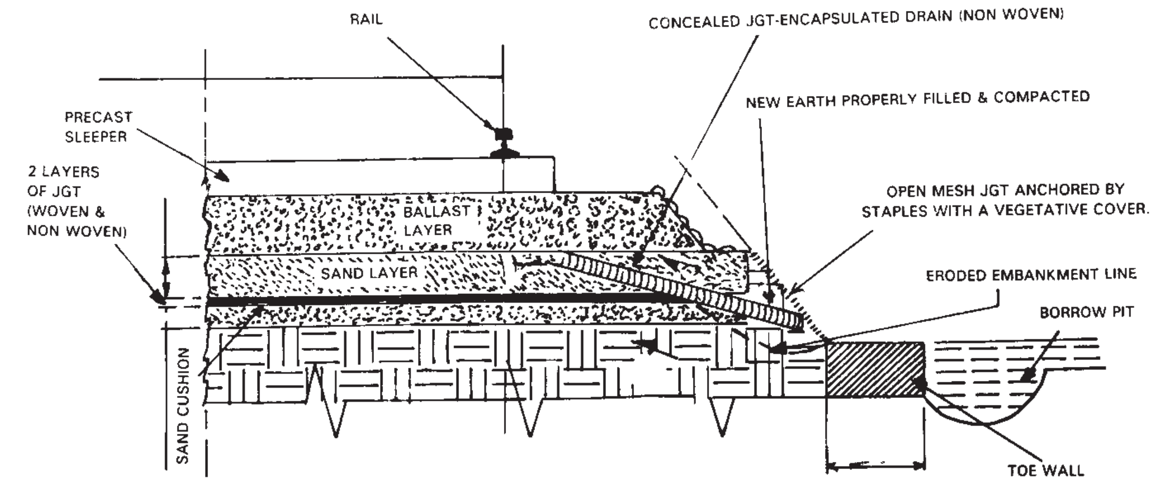
7.5.5 Installation of PVJD :

In absence of mechanical rigs, the following improvised method may be followed.

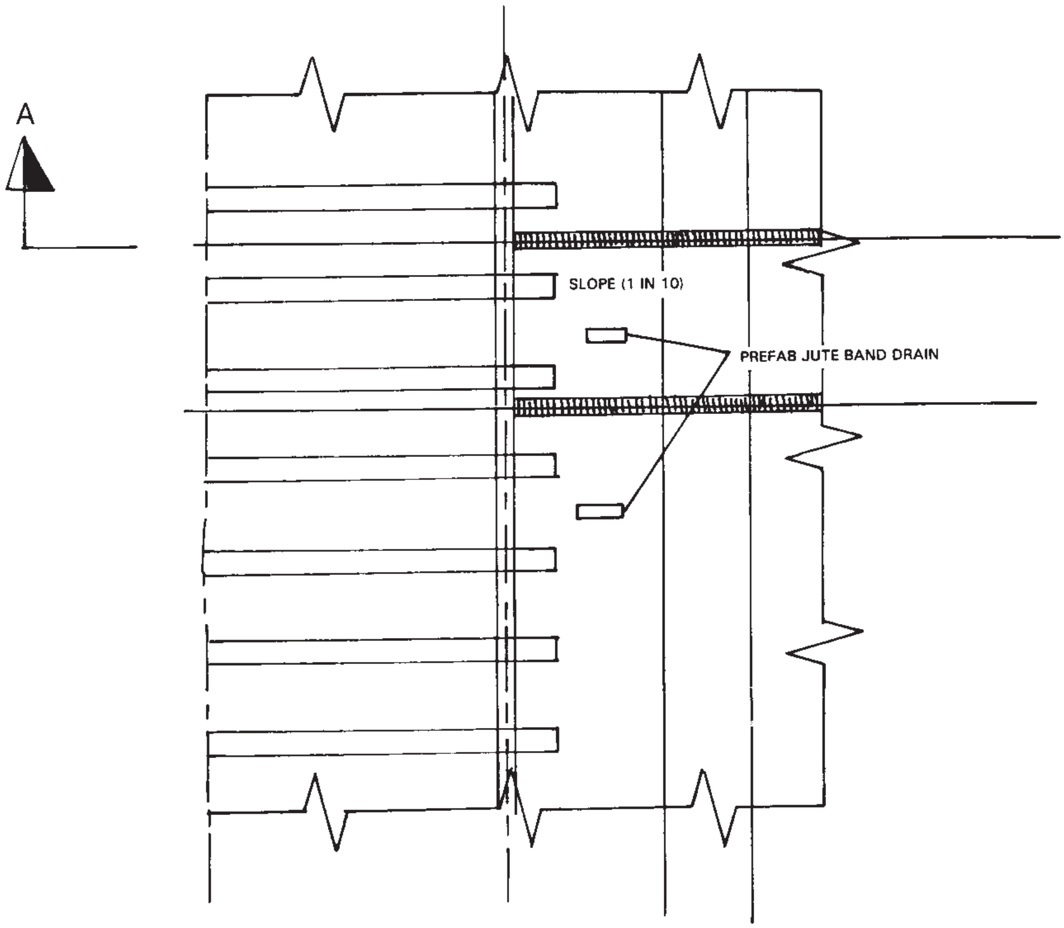
- drilling of holes (diameter 150 mm for 100 mm wide PVJD) up to the required depth with augers usually 2 metres below the bottom ballast level.
- taking out of all loose materials from the holes.
- insertion of PVJD inside the holes with help of split bamboo sticks, taking care to place it centrally.
- filling the side-space with sand/non-cohesive fine aggregates.
- the top of the JGT drains should be kept slightly proud of the bottom ballast level of the track. If there is a sand blanket under the ballast, the top of the fibre drains can be kept under the sand blanket.
- in case of JGT-wrapped porous pipes to be laid laterally, horizontal drilling may have to be done, loose materials removed and the pipe inserted keeping their outfall end laid on to the exposed surface of the embankment slope for ultimate drainage of the entrapped water.

7.5.6 Monitoring

Close monitoring should be done at least for two season cycles by noting the type and extent of subsidence of tracks. Clogging of the drainage outlet requires surveillance. Review of design (depth and spacing of JGT fibre drains) may have to be done in case erosion pumping failure persists.



SECTION -AA
(ASSUMING RIGHT SIDE TRACK IS AFFECTED)



JUTE BRAND DRAIN PLAN
(HALF SECTION)

PREVENTION OF RAILWAY TRACK SUBSIDENCE—INDICATIVE MEASURE

7.6 Consolidation of Soft Soil

7.6.1 Compressible soils pose problems for any type of construction on it due to their volume-variation with change in water-content. Effectiveness of JGT fibre-drains has been discussed in the preceding section. Consolidation of soft soil can be achieved if the water in the sub-surface layers can be drained out. Pre-fabricated Vertical Jute Drains (PVJD) can act as an extremely effective draining medium. The conventional method is to use vertical sand-drains and sand-wicks for such consolidation. Sand-wicks are essentially porous 'stocking's' filled with sand. Jute-fibre drains have been developed with jute/coir-wicks inside instead of sand.

7.6.2 Areas of Application

- cargo handling yards, airports, hardstands, embankments for all uses, unpaved roads.

7.6.3 Design Approach

The design approach is similar to what has been discussed in the preceding sections. Suitable spacing of band drains is the most critical part of the design after ascertaining the geotechnical features of the subsoil and deciding on the depth of vertical drains. The method developed by R. A. Barron (1948) and later adapted by W. Kjellman (1948) may be used. Kjellman's method on cardboard wicks involves determining the equivalent drain diameter (de) and the equivalent zone of influence (Ze). Kjellman's observation that effectiveness of a drain depends more on its circumference than on its cross-section is to be kept in mind.

Later, finite element analysis by Runesson et al (1977) confirmed that

$d_e = 2\ (B + t)\ /\ \pi(pi)$

Where B is the breadth of the band drain and t is its thickness.

If L is the drain spacing, then for a triangular grid of vertical drains shows Z_e to be equal to 1.05 L and to 1.13 L for a square grid.

Specifications of a standard PVJD have been mentioned in the preceding section.

A drainage blanket (usually of sand) should be laid to cover the PVJDs to facilitate drainage of the water drawn from the subsoil. Additionally, non-woven JGT (1000 gsm) may be laid underneath the drainage blanket for more efficient drainage and quicker consolidation.

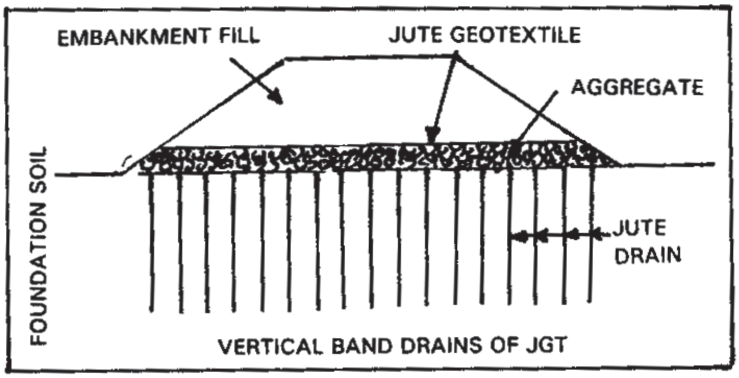


Fig.-33. VERTICAL BAND DRAINS COMBINED WITH BASAL BLANKET

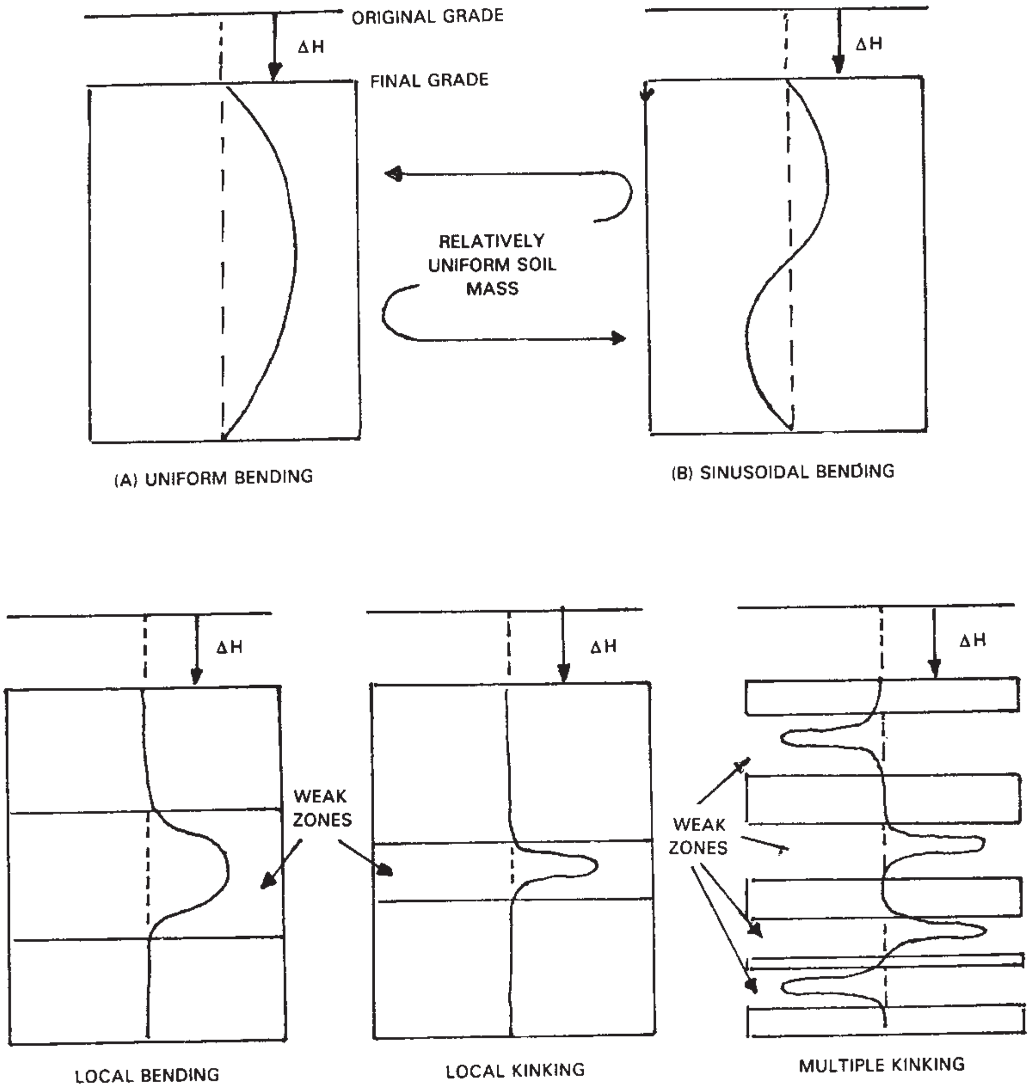


Fig.-34. KINKING PATTERNS OF PREFABRICATED DRAINS

(AFTER LAWRENCE AND KOERNER, 1998)

7.6.4 Installation

Installation of PVJD is similar to what has been stated in the preceding section. Special drilling equipments with rigs are needed for digging deep holes and removing the loose spoils.

7.6.5 Monitoring

Monitoring should be done at regular intervals for noting the rate of consolidation and settlement. One season-cycle is usually adequate for full consolidation.

7.7 New Areas of Application of JGT

Besides the areas mentioned in the preceding chapters, several new areas of application deserve consideration for laboratory investigation and field trial. The following areas may open up new end-uses of JGT.

i) In asphaltic overlays

Asphaltic overlay is used as a wearing course in highways. Bitumen-impregnated geotextile may be laid within the asphaltic wearing overlay as a reinforcing element. This may enhance the service life of the wearing course. Bitumen and jute have excellent thermal compatibility (190° C). JGT may also help in prevention of reflective cracking.

Studies are on to develop an impervious abrasion-resistant sheet with bitumen as binder reinforced by a combination of woven and non-woven types of JGT. This could be a cheaper alternative to mastic asphalt commonly used.

ii) In temporary haul roads

JGT can provide the desired reinforcing effects in temporary haul roads which are required to be constructed for access to sites for a limited period. Its initial stiffness and low extensibility may be effective in temporary high-duty roads.

iii) As fabriforms

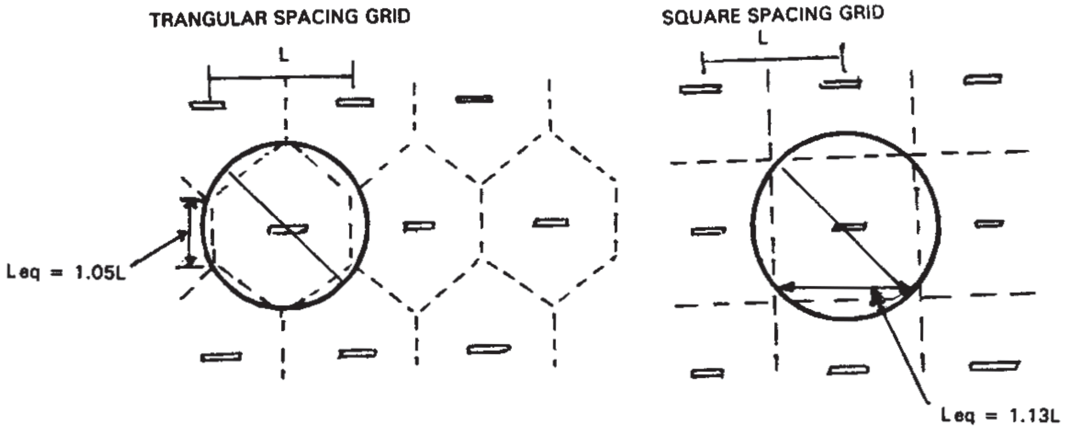
Fabriforms are used to mould wet concrete in a desired shape. JGT may be cut and stitched in accordance with the desired shape of concrete before being filled up with wet concrete. Fabriforms of JGT may be put to use for making revetment mattresses and remedial works for concrete structure. The function of JGT is to give and retain the desired shape of the concrete and its function ceases once the concrete hardens. Biodegradability of JGT is an advantage in such cases.

iv) As an ingredient of fibre-reinforced concrete

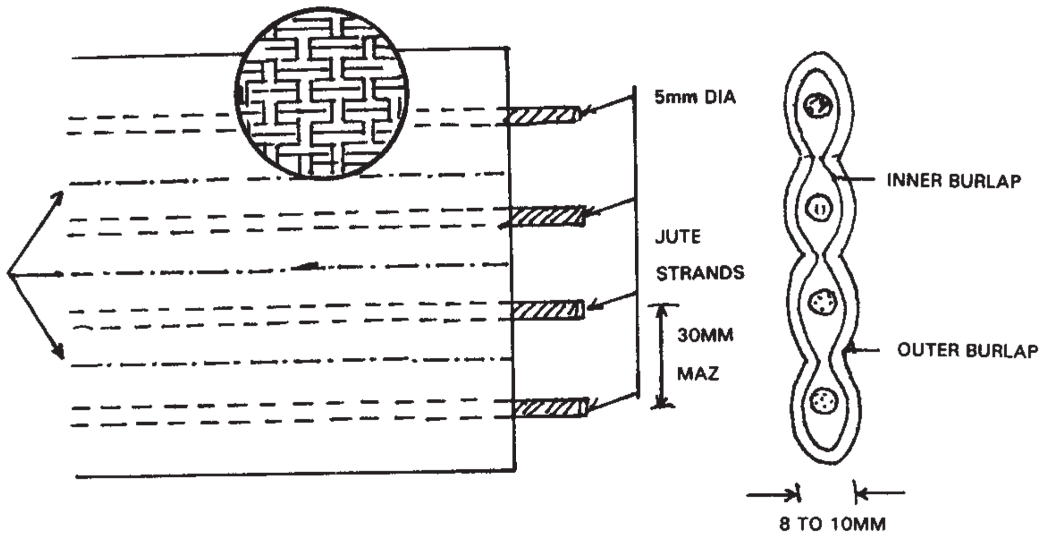
Jute fibres can be used to strengthen concrete as secondary reinforcement. Studies have been initiated in this direction.

v) Jute Geo Cell *

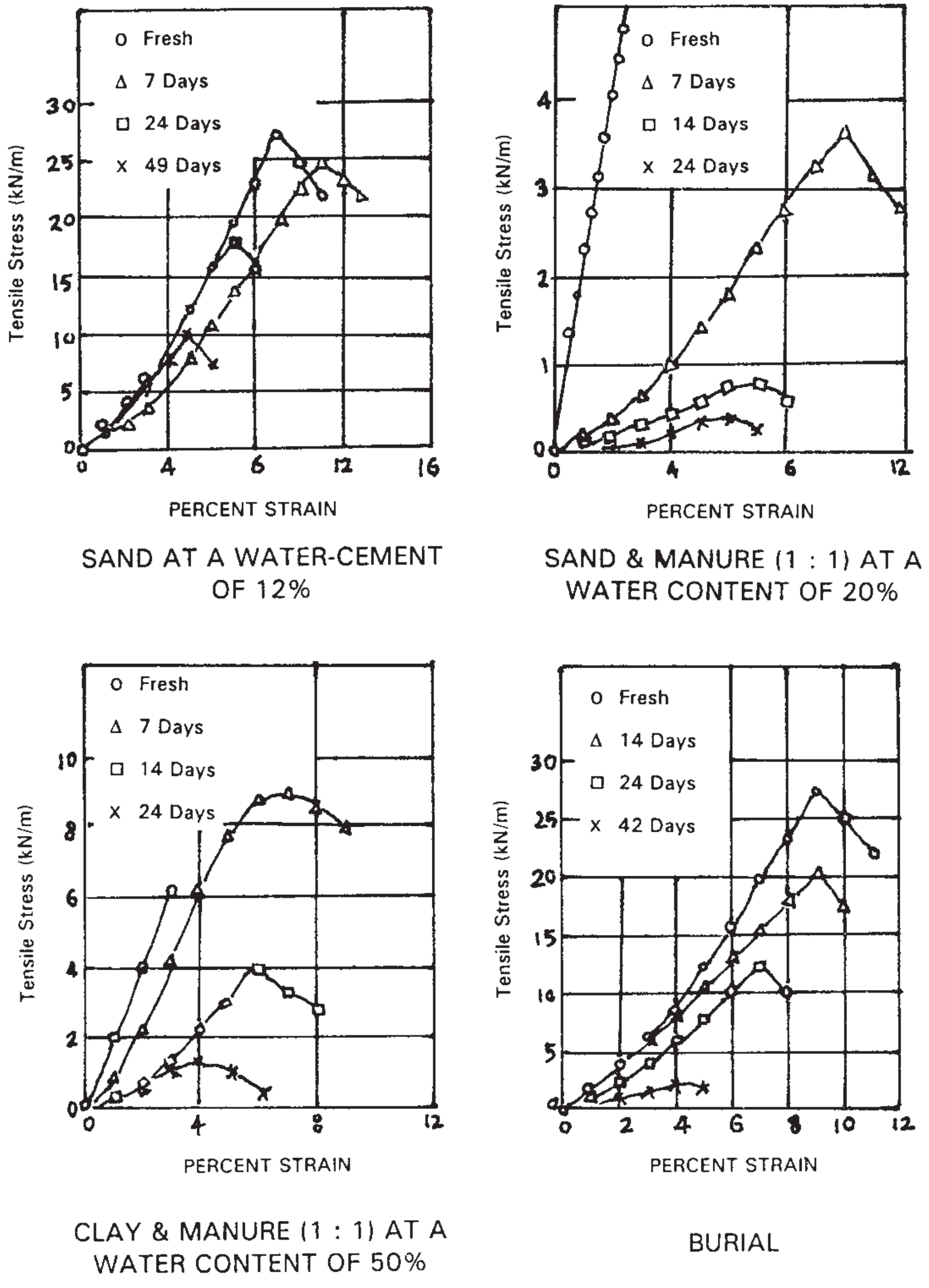
Use of Jute Geocells in low cost embankments and pavements construction on soft soil has been advocated by Mandal and Mhaiskar (1994). For design of low cost embankments with Jute Geocells, Mandal et al have recommended use of slipline theory (by H. Hencky - 1923) and for designing pavement on soft soils. Jute Geocells are innovative forms of JGT and are worth trying in the aforesaid areas.



THEORETICAL ZONES OF INFLUENCE FOR JUTE BAND DRAINS



ELEVATION *CROSS SECTION*



SAND AT A WATER-CEMENT OF 12%

SAND & MANURE (1 : 1) AT A WATER CONTENT OF 20%

CLAY & MANURE (1 : 1) AT A WATER CONTENT OF 50%

BURIAL

TYPICAL NARROW STRIP TENSILE STRESS-STRAIN CURVES AT DIFFERENT TIME INTERVALS FOR PLAIN WOVEN JGT (675 GSM) EMBEDDED IN DIFFERENT ADMIXTURES

(AFTER RAO AND BALAN 1996)

8.0 DURABILITY OF JGT *

8.1 It has been established after several laboratory tests on samples of JGT with varying linear density that its biodegradation depends on environmental factors. It has been observed that jute degrades faster in an acidic ambience having pH value less than 5.2. The rate of degradation of JGT is generally fast in the initial stages, but slows down subsequently. On the other hand, when pH is in a higher range (above 7) i.e., in an alkaline environment, the laboratory tests conducted by IIT, Delhi have initially revealed that higher is the linear density of yarns in a JGT, quicker is its degradation, though more elaborate studies are needed for this purpose to come to a definite conclusion.

8.2 Bacteria and fungi are two main groups of micro-organisms responsible for the microbial decomposition of any natural Geotextile. Moisture plays a key role in this respect. It has been reported that the minimum moisture requirements for the growth of bacteria and fungi in JGT are 20% and 17% respectively. Jute attains the aforesaid moisture contents when the relative humidity in the atmosphere is 90% and 80% respectively.

8.3 Temperature is also instrumental for bacterial and fungal attacks on jute. A temperature of 370C is the most favourable temperature for bacterial growth and 300C for growth of fungi in JGT. Both sunlight and rain causes quick degradation of JGT. The organic content of soil accelerates the decay of jute fibre.

8.4 The degradation studies on jute so far conducted indicate that the mechanism of its biodegradation is complex, being dependent on interaction of a number of influencing factors.

8.5 To prolong the durability of JGT, rot-resistant chemicals are presently used. The chemicals are essentially copper based compounds - usually Copper Napthalate and Cupramonium. The former is a non-leachable compound and costlier. The latter gets leached on continuous exposure to water. A branded product (COMPSOL) is also being used. It is a copper ammonium carbonate solution that meets the US and Canadian WHMIS (Workplace Hazardous Materials Identification system) standards. It is a stable additive completely soluble in water and does not cause hazardous polymerization.

Bitumen (90/15 grade) is also in current use as a coating on JGT for the same purpose in addition usually for its application in bank-protective work in rivers and waterways.

As a result of the application of rot resistant chemicals/bitumen, the life of a JGT can be prolonged to about 4 to 5 years, subject to the specific subsoil ambience.

* Ref. : Mandal J. N. and Mhaiskar S. Y. (1994) - Application of Jute Geocell for low-cost embankments and pavement construction on soft soil.

(Int. symposium on Bio-composites and Blends based on Jute & allied fibres - pp. 75-81).

Indian Institute of Technology, Kharagpur has recently been entrusted with a research project to develop an eco-friendly additive that will further enhance the durability of all types of JGT.

9.0 ENVIRONMENTAL ASPECTS OF JGT*

9.1 Jute, being an agricultural produce, poses no adverse environmental impact. Besides its cultivation, its processing and manufacture are essentially pollution free. A study by Dundee University reveals that jute processing has not caused any illness to workers engaged in the job for long twenty years.

9.2 Quantities of chemical pesticides/fungicides and fertilisers that are usually necessary for jute cultivation are far less than those required for cotton-cultivation. Jute cultivation facilitates multiple cropping pattern, enabling farmers to increase their field-outputs. Jute cultivation precedes paddy and pulse cultivation in that sequence. Leaves of jute plants enrich the soil-fertility.

9.2.1 As already mentioned in Section 1.0 fibres are extracted from jute-plants by retting. Water in retting tanks does not affect natural drainage nor does it pollute ground-water usually. In fact, the retted water can be used for irrigation for watering crop-fields.

Jute Manufactures Development Council (JMDC) initiated some time back a Life Cycle analysis of Jute through Price, Waterhouse & Coopers. The findings of the study do not indicate presence of any environmentally objectionable ingredient.

9.2.2 Studies conducted by Indian Jute Industries' Research Association (IJIRA) and Central Pollution Control Board show no adverse environmental impact of the effluent released from jute mills.

9.2.3 Hydrocarbon emission from jute batching oil (JBO) has also been rigorously studied by IJIRA. JBO is getting replaced by RBO (rice bran oil) which provides odour-free non-polluting technology.

9.2.4 During manufacture of jute yarns, other ingredients used like starch, natural gum are found to have no adverse environmental impact.

9.3 Environmental Protection Encouragement Agency (EPEA), Hamburg in Germany, a research and consultancy body, and the FAO Secretariat have made a comparative study between jute and polypropylene (PP) in respect of waste generation, water requirement, energy consumption and CO2 emission in their production. The table below is revealing.

9.4 Life Cycle Analysis (LCA) of Jute from cradle to grave is understandably a consultancy form of report confirms eco-compatibility of Jute.

Table : Comparison of Environmental Effects of Jute & PP fibres (per ton basis)

	Jute	PP	Ratio (PP/Jute)
Waste (t/t)	0.9	5.5	6.1
Water (m^3)	54-81	1.3	0.016-0.02
Energy (GJ/t)	5.4-14.35	84.3	5.9-15.6
CO_2 emission (t/t)	1.2-0	3.7-7.5	

*Ref: i) Ghosh, T. - Handbook of Jute, FAO Publication, pp. 175.

ii) Study Report of Environment Protection Encouragement Agency (EPEA), Hamburg, October 1992, pp. 89.

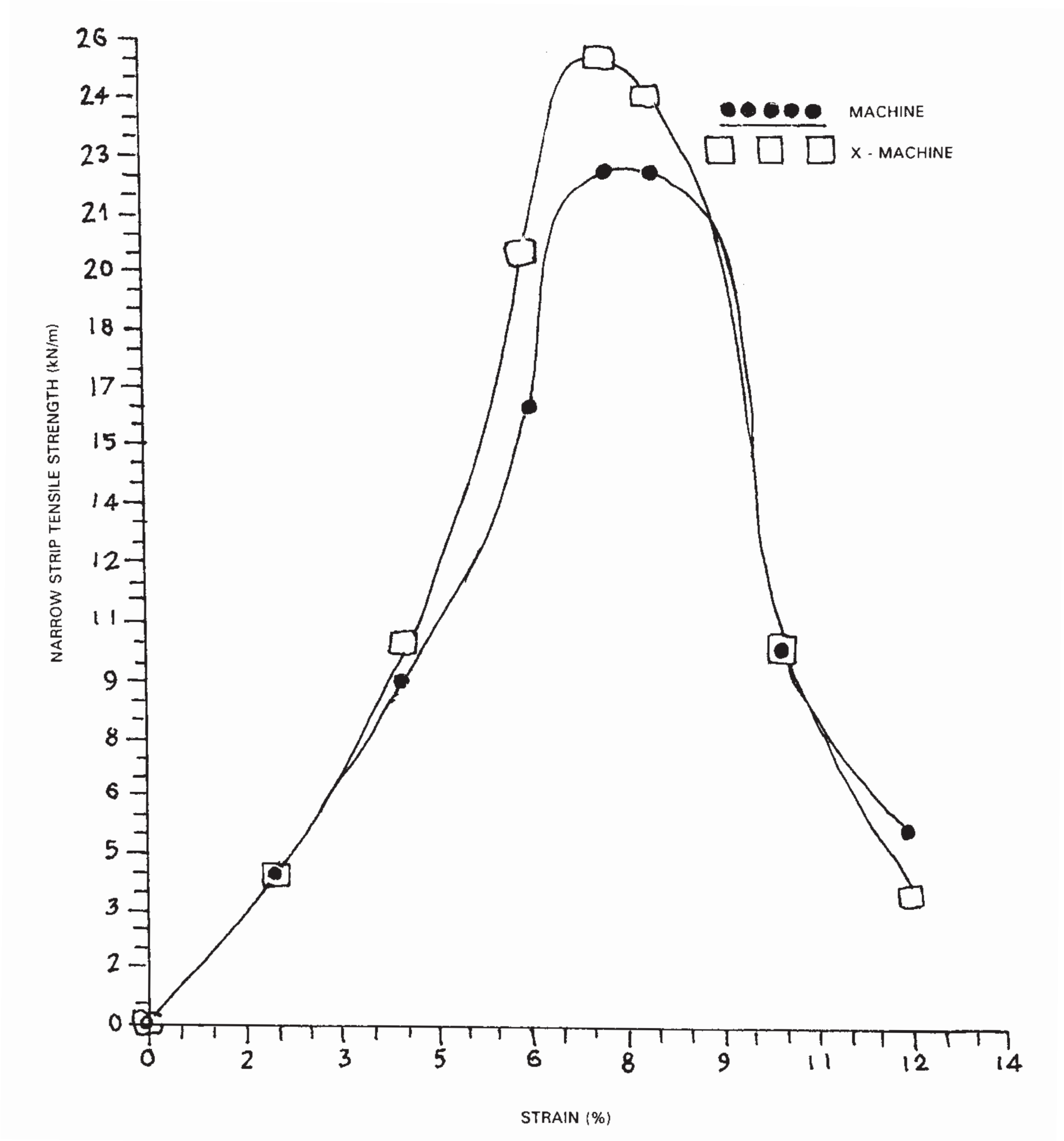
9.5 Jute Geotextiles (JGT) evidently pose no environmental threat. Being biodegradable, JGT ultimately coalesce with the soil on which it is laid, adding nutrients to it and retaining water for quicker growth of vegetation. Unlike man-made geotextiles which are not biodegradable, JGT poses no disposal hazards.

10.0 AVAILABLE STANDARDS

10.1 Though mostly references of various test methods have been drawn from American standards, some Indian standards on jute and allied products are available which may be consulted for ensuring quality control of JGT. The following references will serve as a guide.

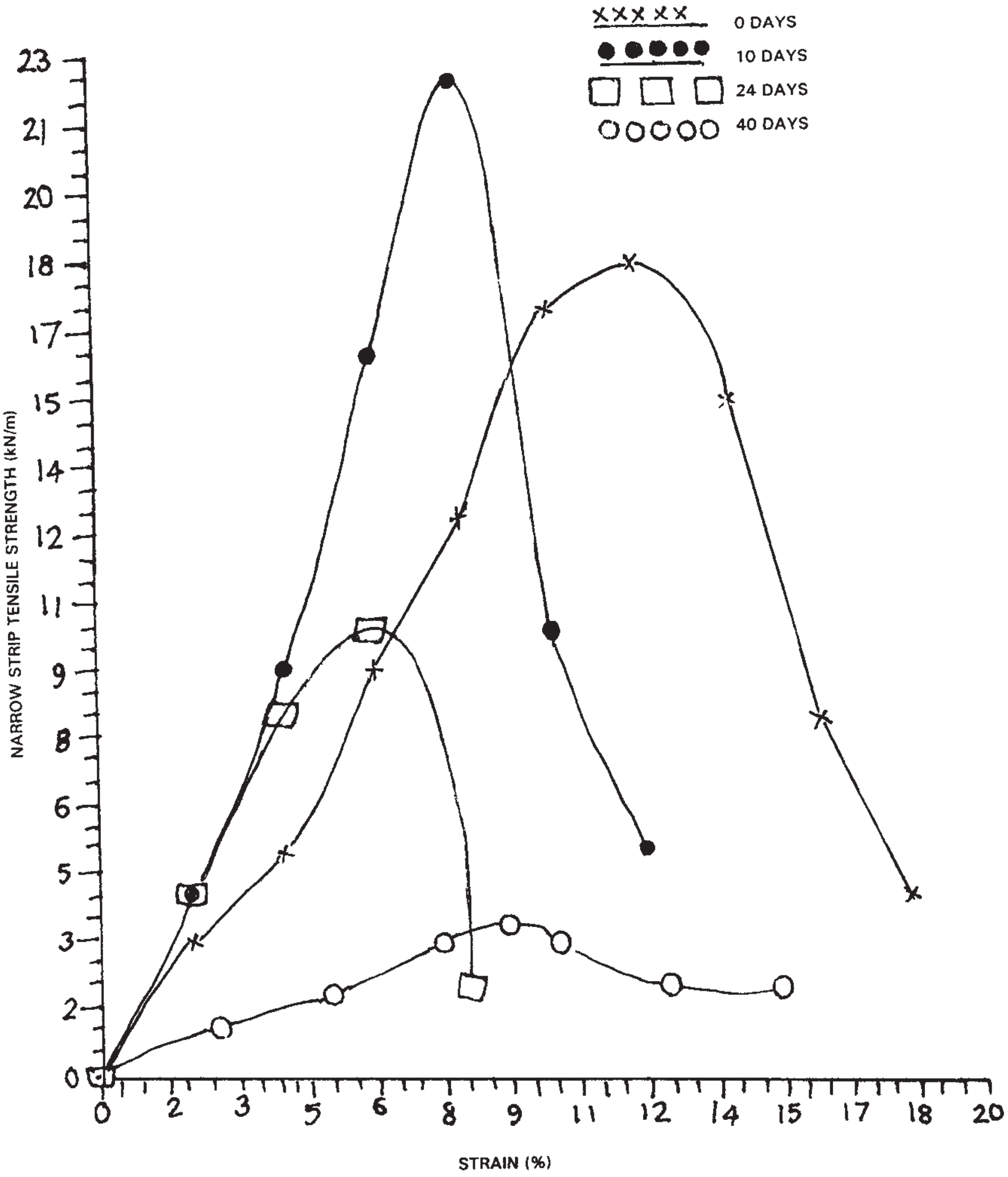
* Weight - IS : 2387 - 1969
* Width - IS : 1954 - 1969
* Thickness - IS : 7702 - 1975
* Threads/metre - IS : 1963 - 1981
* Bitumen - IS : 702 - 1988
* Rot-proofing - IS : 1623 - 1991
* Strength - IS : 1969 - 1985 and read with ASTM-D5035

Regarding permittivity and porometry, reference may be made to ASTM D 4491-35 and D 4716 - 87.



TYPICAL STRESS-STRAIN CURVE FOR JUTE GEOTEXTILE

(AFTER RAO & BALAN, 1994)



VARIATION OF STRESS-STRAIN BEHAVIOUR WITH TIME FOR JUTE GEOTEXTILE WHEN BURIED IN SOIL

(AFTER RAO & BALAN, 1994)

In addition, a further list of American and Indian Standards is given below for consultation :

i) ASTM D 4595 "Test method for Tensile Properties of Geotextiles by the Wide Width Strip Method" Annual Book of ASTM Standard Vol. 4.08 American Society for Testing and Materials, Philadelphia, P, 1992 pp. 880-890.

ii) ASTM D 4632 "Test Method for Breaking Load and Elongation of Geotextiles (Grab Method)" Annual Book of ASTM Standard Vol. 4.08 American Society for Testing and Materials, Philadelphia, P, 1992 pp. 339-342.

iii) ASTM D 4751 "Test Method for Determining Apparent Opening Size for a Geotextiles" Annual Book of ASTM Standard Vol. 4.08 American Society for Testing and Materials, Philadelphia.

iv) ASTM D 4533 "Test Method for Trapezoid Tearing Strength of Geotextile" Annual Book of ASTM Standard Vol. 4.08 American Society for Testing and Materials, Philadelphia.

v) ASTM D 276 "Test Method for Identification of Fibres in Textiles" Annual Book of ASTM Standard Vol. 4.08 American Society for Testing and Materials, Philadelphia.

vi) ASTM 5101 "Standard Test Method for Measuring the Soil Geotextile System Clogging Potential by the Gradient Ratio Method" Annual Book of ASTM Standard Vol. 4.08 American Society for Testing and Materials, Philadelphia, P, 1992 pp. 1190-1196.

vii) IS 13321 (Part 1)-1992, Glossary of Terms for Geosynthetics,

viii) IS 13162-1992 (1996) Geotextiles - Methods of Test - Part 5 "Determination of Tensile Properties using Wide Width Strip Method.

ix) IS 14293 - 1995 Geotextiles - Methods of Test - Determination of Trapezoid Tearing Strength.

x) IS 14294 - 1995 Geotextiles - Methods of Test - Determination of Apparent Opening Size (AOS).

xi) IS 14324 - 1995 Geotextiles - Methods of Test - Determination of Water Permeability - Permittivity.

xii) IS 14715: Part I: 2013 - Woven Jute Geotextiles - Strengthening of sub-grade in roads.

xiii) IS 14715: Part II: 2013 - Control of bank erosion in rivers & waterways

xiv) IS - 14986 : 2001 (Guidelines for application of Open Weave Jute Geotextile for rain watererosion control in road and railway embankments and Hill slopes)

xv) IRC : 56-1974 (reprinted 1991) - Recommended Practice for Treatment of Embankment Slopes for Erosion Control (The Indian Roads Congress Publication).

xvi) IRC : 56 - 1974 (reprinted 1991) - Recommended Practice for Treatment of Embankment Slopes for Erosion Control (The Indian Roads Congress Publication).

xvii) IRC : SP : 20 (Rural Roads Manual) - 2002

xviii) Guidelines for Earthwork in Railway Projects Guideline No. GE:G-1- July 2003

xix) Guidelines for application of Jute geotextile in Railway Embankments and Hill slopes.

No. RDSO/2007/GE: G0008- February 2007

xx) New Materials / Techniques Accredited by the Indian Roads Congress

Indian Highways, NOL 37 No. 7 - July 2009

Appendix - I

To determine tensile strength pore size and weight of fabric following formula / empirical relationship were used:

a) Warp way (MD)Tensile Strength of Fabric (kgf) = [(Warp count x QR) x Ends /dm x Utilization %] ÷ 2.204

b) Weft way (CD)Tensile Strength of Fabric (kgf) = [(Weft count x QR x Picks /dm x Utilization%)] ÷ 2.204

c) **Calculation of pore size and pore diameter of JGT fabrics :**

Particulars of Warp and Weft				**Method of calculation**
Warp/dm	102	Weft/dm	39	
Count of warp in ld/spyndle	9.75	Count of weft	28	
Diameter of yarn in inch	0.035	Diameter of yarn in inch	0.059	(√ count)/90
Diameter of yarn in cm	0.088	Diameter of yarn in cm	0.149	
Distance covered by the warp yarns in one dm (cm) (L1)	8.988	Distance covered by the weft yarns per dm (cm)	5.824	L1 = (Threads/dm) X diameter of the yarn (cm)
Gap (Open area) left by the warp yarns in one dm (cm) (L2)	1.011	Open distance left by the weft yarns per dm (cm)	4.176	L2 = 10 - L1
open distance between the warp yarns (mm)	0.100	Open distance between the weft yarns (mm)	1.099	L3 = L2 X 10 / (no of threads - 1)
Area of each open space (pore) in the fabric (Sq mm) (L3)	0.110			L3 of warp X L3 of Weft
Diameter of the pore (mm)	0.332			Assuming shape of the pore as square, the side of the square will be the pore diameter.
Diameter of the pore (micron)	332			

* Adapted from the paper entitled "Grasses and legumes for forage and soil conservation" (1984) by K. A. Shankarnarayanan and Vinod Shankar

d) Weight of Fabric (gsm) = 1.425 ($N_1G_1 + N_2G_2$),

where, N_1 = Ends /inch & N_2 = Picks /inch and G_1 = Warp count in lbs & G_2 = Weft count in lbs.

Appendix - I

SPECIFICATIONS OF STANDARD JGT

A. OPEN WEAVE JUTE GEOTEXTILES

Properties	Specification under BIS			Developed Under CFC Project			Test Method
	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	
Weight (gm/sq. metre)	292	500	730	500 (±10%)	600 (±10%)	700 (±10%)	ASTM D5261
Threads/dm (MD X CD)	12 x 12	6.5 x 4.5	7 x 7	≥6.5 x 4.5	≥ 8 x 7	≥ 8 x 8	IS1963
Thickness (mm)	3	4	6	4.50 (±10%)	5.25 (±10%)	5.50 (±10%)	ASTM D5199
Width (cm)	122	122	122	≥6.5 x 6	≥12 x 6	≥14 x 7	ASTM D4595
Open Area (%)	60	50	40	≤10 x 10	≤10 x 10	≤10 x 10	-
Strength (kN/metre) (MD X CD)	10 x 10	10 x 7.5	12 x 12	50-65	45-50	40-45	ASTM D4595
Water holding capacity on dry weight (%)	400	500	500	450-500	450-500	550-600	-

Usual areas of Application

- Slopes of embankments
- OB dumps in coal mines, PFA heaps
- Denuded lands

N.B. : Plantation of grass/vegetation on open mesh Woven JGT is strongly recommended.

Appendix - I (Continued)

B. WOVEN JUTE GEO TEXTILES

Construction → / Properties ↓	Grey (untreated)	Rot Resistant	Bitumen treated	DW Plain Weave for application in Rural Roads (grey-untreated)	DW Plain Weave for application in River Bank (grey-untreated)	Test Method
Weight (gm/sq. metre)	760	760+	1200	724 (±5%)	627 (±5%) (To be treated with suitable additive)	ASTM D5261
Threads/dm (MD X CD)	102 x 39	102 x 39	102 x 39	≥94 x 39	≥85 x 32	IS1963
Thickness (mm)	2	2	2	1.85 (±10%)	1.70 (±10%)	ASTM D5199
Width (cm)	76-200	76-200	76-200	≥200 cm	≥200 cm	IS1954
Strength (kN/metre) (MD X CD)	20 x 20	20 x 20	21 x 21	≥25 x 25	≥20 x 20	ASTM D4595
Elongation at break (%) (MD x CD)	10 x 10	10 x 10	10 x 10	≥12 x 12	≥12 x 12	ASTM D4595
Permittivity at 50 mm constant head (per sec)	350 x10-4	350 x10-4	350 x 10-4	0.35 (±10%)	0.35 (±10%)	ASTM D4491
Puncture Resistance (N/cm2)	380	380	400	0.500 (±10%)	0.400 (±10%)	ASTM D4833
Burst Strength (kPa)				3500 (±10%)	3100 (±10%)	ASTM D3786
Porometry (O90) micron	300	300	150	150-400	150-400	ASTM D4751

N.B. Width of the woven JGT may be fixed as agreed between buyer and seller subject to a lower limit of 100 cm

Usual areas of Application

- On Subgrades of roads & railways
- As a basal reinforcement of embankments
- For bank protection of rivers & waterways.

C. NON-WOVEN JUTE GEO TEXTILES

Properties	Type 1	Type 2	Test Method
Weight (gm/sq.m) at 20% M.R.	500	1000	ASTM D5261
Thickness (mm)	4	7	ASTM D5199
Width (cm)	150	150	IS 1954
Tensile Strength (kN/metre) MD X CD	4 x 5	5 x 6	ASTM D4595
Elongation at break (%) MD X CD	3.5 x 7	4 x 8	ASTM D4595
Water holding capacity (%)	250-300	300-400	ASTM D4751-99A
Co-eff. Of water permittivity (m/s)	2.9 x 10-3	2.9 x 10-4	ASTM D4491

Usual Application Areas

- in conjunction with woven JGT where better permittivity is necessary along with strength.
- as a cushion over woven JGT on railway sub-grades.
- as the outer permeable cover of encapsulated rubble drains in road sides, within embankments etc.
- in areas where drainage is the main criterion.

D. PREFABRICATED JUTE DRAINS

Material	Coir-wicks within jute sheath	Test Method
Width (mm)	100	IS 1954
Thickness (mm)	5	ASTM D5199
Tensile Strength (kN/100 mm)	45	ASTM D4595
Pore size (O90) [micron]	300	ASTM D4751
Discharge Capacity at 50 kPa (ml/s) hydraulic gradient	13	ASTM D4716

Usual Application Areas

- in all cases where sand drains are recommended for soil consolidation.
- in compressible soils for draining our entrapped water by capillary action.

N.B. :1.As per the current research status, durability of JGT can be ensured upto 4 years (Max) after treatment.

2. There is no difficulty in manufacturing JGT of the desired porometry.
3. As a special case, strength of JGT (woven type) may be improved upto 40 kN/metre.
4. Prefabricated jute drains may be made to a width of less than 100 mm.

Explanation :

CD - Cross machine Direction (see section 3.3)

Elongation at break - Elongation of JGT under the breaking load.

MD - Machine Direction (see section 3.3)

Open Area Ratio (OAR) - (see section 3.3)

Porometry - JGT pore sizes and their distribution in a JGT. Usually denoted by O90 which is the target JGT-pore. It corresponds to the size of the largest soil particle that can pass through a JGT.Puncture Resistance - Resistance offered by a test fabric, before failure to a specified puncturing object under a
certain load. Expressed in N/cm2.

Wise with Strip Tensile Test

A uni-axial tensile test in which the entire width of a 200 mm wide JGT specimen (or any geotextile) is gripped by clamping with a gauge length of 100 mm.

SALIENT PHYSICAL CHARACTERISTICS OF TYPICAL JUTE GEOTEXTILES

No.	Parameters	Woven			Open mesh		
1.	Weight (GSM)	760	724	627	292	500	730
2.	Construction	D.W. Twill	D.W. Twill	D.W. Twill	Plain	Plain	Plain
3.	Warp Count (Grist)	10	10	10	36	124	124
4.	Weft Count (Grist)	28	27	28	36	124	124
5.	Ends/dm	102	94	85	12	6.5	7
	Picks/dm	39	39	32	12	4.5	7
6.	Cover Factor	98			40	50	60
7.	Porometry (Apparent Opening Size- AOS in mm) (Aperture Size - mm)	0.15 -0.30	0.15- 0.40	0.15- 0.40	- 8×8	- 13×11	- 10×10
8.	Tensile Strength (kN/m)						
	Warp	20	25	20	10	10	12
	Weft	20	25	20	10	7.5	12
9.	Width Available (cm.)	76-200	76-200	76-200	122	122	122
10.	Min. Length (m) (cut length)	100	100	100	70	70	70
11.	Max. Length (m) (packing length/bale)	457 [IS : 2873]	457 [IS : 2873]	457 [IS : 2873]	820 Mill Practice	550 Mill Practice	550 Mill Practice
12.	Treatment Available	Rot resistant & Bitumen			No	No	No
13.	Water Holding Capacity- Grey						
	Dripping	400%			500%	500%	500%
	Squeezed	80-100%			NA	NA	NA
	Normal	8-20%			8-20%	8-20%	8-20%
14.	Recommended Use	Separetion & Filtration • Road • River/Canal Bank • Surfacing of			Erosion Control of Slopes • Afforestation in Semi-arid zone • Land Scaping	Erosion Control of Slopes • Mine spoil stabilization • Land Scaping	Erosion Control of Slopes • Mine spoil stabilization

Appendix - II

PLANTS FOR STABILIZATION OF BUNDS, TERRACE FACES, STEEP SLOPES AND GULLIES (After Tejwani and Mathur, 1974)*

State	Grass and legume	Yield (kg/ha)	Remarks
Gujarat (Vasad)	Dichanthium annulatum Amphilophis glabra	385/ha from land under bunds (verma et al., 1968)	Grass selected on the basis of yield of green forage and soil-binding capacity on bunds for alluvial soils (Srinivasan et al., 1962);
Uttar Pradesh	Cynodon dactylon Dichanthium annulatum Cenchrus ciliaris	4,355 6,805	Dichanthium annulatum was also found best for bench terrace risers
Western Uttar Pradesh (Saharanpur)	Pennisetum purpureum Eulaliopsis binata	1,585 33,430	Grasses selected on the basis of length of tap root, spread of root system and yield for alluvial soils near Agra
Rajasthan (black soil region Kota) Tamil Nadu (Madhavrao et al., 1968)	Dichanthium annulatum Cenchrus ciliaris Phalaris tuberose Festuca elatior Paspalum dillatutum	100/ha bunded area - - -	Near Muzaffarabad (Saharanpur district) 1 ha of bunded area can give Rs. 100. It has good binding capacity and is in good demand for paper and rope making - -
(Venkataraman et al., 1956)	Eragrostis curvula		Good soil-binders for terrace faces in hills for elevation of 1,500 m and above and rainfall of 80-100 cm. Good succulent fodder
	Cynodon dactylon var. Suwanne and var. Tiffin	-	
Andhra Pradesh (Ibrahim- patanam)	Pennisetum purpureum Chloris gayana	 - - -	-do- except for 50-70 cm rainfall Suited to high elevations,
Mysore (Velappan, 1964)	Urochloa sp. Cenchrus ciliaris Cenchrus glaucus Panicum antidotale	 -	good soil binders Moder-ate to heavy rainfall, hills of medium elevation and plains
	Tripsacum Laxum Bothriochloa glabra B. odorata	- - -	Low rainfall, hill of medium elevation and plains Good soil-binders for bunds, cme up in low rainfall areas Good for making Puerto Rico-type of terraces in the Nilgiri hills.
	Tripsacum Laxum (Guatemala grass)	 22,500	Good soil-binding capacity and suitable for stabilizing contour and field bunds Good fodder in tender stages, good green manure and good soil binder

Stabilization of steep slopes, waste lands, gullies class V and VII lands

Bihar (Upper	Stylosanthes gracilis	19,000	Perennial legume, very aggressive
Damodar Catch-		(green)	and suppresses other vegetation,
ment)			drought resistant, adds a lot of
			leaf litter (pandey and Teotia,
Bihar (Upper	Calopogonium	-	1969)
Damodar Catch-	orthocarpum		
ment)			Deep rooted, perennial, vigorous
			legume, provides a thick
			layer of leaf litter, plants start
Bihar State	Pennisetum	36,000 in 1	growth
	pedicellatum	cut (green)	in Feb-Mar and cover the land
			before onset of monsoon (Pandey,
Mysore (black)	Pennisetum		1966)
			Mukherjee and Prasad (1966))
Soil, semiarid	pedicellatum	6,800	have selected 3 promising strains
region) Punjab	Chrysopogon fulvus	(hay)5,2,50	for Bihar; this grass is
(Ambala, Siwalik	Eulaliopsis binata	-	reported also from Madhya
region) Uttar			Pradesh, South Rajasthan, and
Pradesh (alluvial	Chrysopogon fulvus	19,170	parts of Deccan (Blatter and Mc
soil, humid tropical	Eulaliopsis binata	16,290	Cann, 1935)
valley climate)	Pueraria hirsute	11,200 to	(Krishnamurthi, 1958)
		18,725	
		-	
Lesser Himalayas	Pennisetum		
(Mathur el	Purpureum	-	
al.,1969)	Apluda mutica		Perennial legume provides
		-	excellent cover before monsoon;
	Heteropogon contortus	-	very aggressive
	Chrysopogon fulvus	-	
	Eriophorum comsum		Up to an elevation of
			1,500 m
		-	Up to 1,500 m
Debadghao, 1964)	Chrysopogon fulvus		
	Themeda anathera	-	Up to 1,500 m
	(northern slopes)	-	Up to 1,500 m
	Arundinella		Up to an elevation
Tamil Nadu	nepalensis (warmer	-	of 1,500 m
(Madhavrao el al.,	slopes), Pennisetum		
1968)	orientale		1,500 to 2,600 m
		-	
	Trifolium repens		
		-	
	T. repens var. Dadino	-	
	T : incarnatum		

	T. subterraneum	-	Comes up on road-side cuts
	T. dubium	-	
	Vicia villosa	-	High rainfall, high Elevation
	V. angustifolia		
	V. Sativa		100 m and above
	Clitoria ternatea		
	Glycine javanica		Good pasture plants All legumes
	Pennisetum clandestinum (kikiyu grass)	12,500	Legume for dry areas Legume for high rainfall, warm climate
			Very good for covering steep unstable areas, forms a good cover but may run wild
Assam & N.E. Region	Vetiber		Suited for medium elevation, hills good soil binders Moderate to heavy rainfall.
Tamilnadu, Udhagamandalam (Ooty)	Cotula sp Poa annua Polygonum Alatum Coronopus sp		
Punjab, Shibalik	Carissa carandus Acacia spp. Adhatoda vasica Lanta camara Chrysopogon fulvus Caesalpinia seperia		

Appendix-III

LIST OF FIELD TRIALS WITH JUTE GEOTEXTILE (JGT)
(As on 21.03.2016)

A. EROSION CONTROL

Sl. No.	State	PIU	Particulars of work done	Year of application	Results
1.	Uttarkhand	Central Soil & Water Conservation Research & Training Institute (CSWCRTI).	Mine Spoil stabilization With open weave JGT- 6.5 x 4.5 - 500 g/m2 Area covered:10000 m2	1987	By 1990 erosion checked, water pollution decreased, slope covered with vegetation.
2.	West Bengal	Deptt. of Forest, Govt. of W.B	Hill slope protection With open weave JGT- 6.5 x 4.5 - 500 g/m2 Area covered: 5000 m2	1988	Slope protected and covered with vegetation after 6 months.
3.	West Bengal	Forest Deptt. ShankarpurGovt. of West Bengal	Sand Dune stabilization With open weave JGT- 6.5 x 4.5 - 500 g/m2 Area covered: 5000 m2	1988	80% area covered by vegetation after 6 months.
4.	West Bengal	Public Works Department, Iswar Gupta bridge Approach,Kalyani side, PWD, Govt. of West Bengal	Stabilization of slope of approach bridge with Open weave JGT- 6.5x4.5-500 g/m2 Area covered: 2,500 m2	1989	Erosion checked. Bridge approach stabilized, slope covered with vegetation.
5.	Assam	Tea Research Association	Control of top soil erosionWith open weave JGT-34 x 15 - 400 g/m2 Area covered: 5000 m2	1995	Soil loss reduced by 97%
6.	Assam	Tea Research Association	Control of top soil erosion With open weave JGT- 17 x 4,5 - 300 g/m2 Area covered: 5000 m2	1995	Soil loss reduced by 93 %
7.	Assam	Tea Research Association	Control of top soil erosionWith open weave JGT-34 x 15 - 300 g/m2 Area covered: 3000 m2	1995	95% reduction in soil loss
8.	Uttar Pradesh	CRRI & PWD of U.P. Govt.	Land slide management With open weave JGT- 6.5 x 4.5 - 500 g/m2 Area covered: 5000 m2	1996	Land slide checked, covered with vegetation.

Sl. No.	State	PIU	Particulars of work done	Year of application	Results
9.	West Bengal	Forest Deptt., Digha, Govt. of West Bengal.	Sand Dune stabilization With open weave JGT-34x15-400 g/m2 Area covered: 1000 m2 With open weave JGT-11x12-300 g/m2 Area covered: 1000 m2	1997	Washed away by high tide in Sept'97.
10.	Chhattishgarh	Western Coal Fields Ltd.	Mine spoil stabilization With open weave JGT-7 x 7 -730 g/m2 Area covered: 40,000 m2	2001	Spoil stabilized, sloped covered with vegetation
11.	Maharashtra	Western Coal Fields Ltd.	Mine spoil stabilization With open weave JGT 7 x 7 - 730 g/m2 - Area covered: 44,000 m2	2001	Covered with vegetation.
12.	Maharashtra	Western Coal Fields Ltd.	Mine spoil stabilization With open weave JGT-6.5x4.5-500 g/m2 Area covered: 40,000 m2	2001	Covered with vegetation.
13.	Uttar Pradesh	Northern Coal Fields Ltd.	Mine spoil stabilization With open weave JGT-7 x 7 - 730 g/m2 Area covered: 24,000 m2	2002	Spoil stabilized, covered with vegetation.
14.	Meghalaya	Sonapur, Border Roads Organization	Land Slide Management With open weave JGT-12 x 12 -292 g/m2 Area covered :30,000 m2	2003	Landslide controlled, slope was stabilized with full vegetative cover.
15.	Sikkim	National Hydro-electric Power Corporation TLDP - III	Land Slide Management & Steep slope stabilization With open weave JGT-7 x 7 - 730 g/m2 Area covered: 5,400 m2	2004	Land slide checked and slope was stabilized.
16.	West Bengal	National Hydro-electric Power Corporation TLDP - I	Land Slide Management & Steep slope stabilization With open weave JGT-7 x 7 - 730 g/m2	2004	Land slide checked, covered with vegetation.
17.	West Bengal	National Hydro-electric Power Corporation TLDP - II	Land Slide Management & Steep slope stabilization With open weave JGT-7 x 7 - 730 g/m2	2004	Land slide checked, covered with vegetation.

Sl. No.	State	PIU	Particulars of work done	Year of application	Results
18.	Assam	National Hydro-electric Power Corporation	Slope stabilization with Open weave JGT- 7 x 7 - 730 g/m2 Area covered :24,000 m2	2005	Slope stabilized and covered with vegetation.
19.	Himachal Pradesh	NTPC Limited, Kullu, HP	Slope stabilization with Open weave JGT- 7 x 7 - 730 g/m2 Area covered: 4,800 m2	2005	Slope stabilized and covered with vegetation.
20.	West Bengal	Forest Deptt., Jaldapara Govt. of West Bengal, Coochbehar Divn.	Slope protection with Open weave JGT- 7 x 7 - 730 g/m2 Area covered: 1,000 m2	2005	Entire slope stabilized and covered with vegetation.
21.	West Bengal	Public Works Department, Mundeswari, Govt. of West Bengal	Embankment Slope stabilization with Open weave JGT- 6.5x4.5-500 g/m2 Area covered: 3,500 m2	2005	Bridge approach stabilized, slope covered with vegetation.
22.	Himachal Pradesh	Kullu, NTPC Limited	Slope stabilization with Open weave JGT- 7 x 7 - 730 g/m2 Area covered :10,000 m2	2006	Slope stabilized and covered with vegetation.
23.	Himachal Pradesh	National Hydroelectric Power Corporation	Slope stabilization with Open weave JGT- 6.5x4.5- 500 g/m2 Area covered: 18,000 m2	2007	Slope stabilized and covered with vegetation.
24.	Himachal Pradesh	National Hydroelectric Power Corporation	Slope stabilization with Open weave JGT- 6.5x4.5-500 g/m2 Area covered: 18,000 m2	2007	Slope stabilized and covered with vegetation.
25.	Himachal Pradesh	National Hydroelectric Power Corporation	Slope stabilization with Open weave JGT- 6.5x4.5-500 g/m2 Area covered : 63,000 m2	2007	Slope stabilized and covered with vegetation.
26.	Nagaland	Border Road Organization	Slope protection of road embankment With open weave JGT-12 x 12 -292 g/m2	2007	Embankment is in good shape and slope stabilized.
27.	Port Blair	Border Road Tusk Force (GREF)	Slope stabilization with Open weave JGT-6.5x4.5-500 g/m2 Area covered: 3,000 m2	2007	Slope stabilized, vegetation established.
28.	Uttar Pradesh	NHAI	Slope stabilization with Open weave JGT-6.5x4.5 -500 g/m2 Area covered: 4,80,000m2	2007	Erosion checked, slope stabilized with vegetative cover.

Sl. No.	State	PIU	Particulars of work done	Year of application	Results
29.	West Bengal West Bengal	Transport Infrastructure Development Corporation Ltd. Raidighi	Embankment slope stabilization of Bridge approach road with Open weave JGT-6.5x4.5-500 g/m2 Area covered: 3,400 m2	2007	Bridge approach stabilized, slope covered with vegetation.
30.	West Bengal	Public Works Department, Govt. of West Bengal	Slope protection with Open weave JGT-6.5x4.5-500 g/m2 Area covered: 2,500 m2	2007	Slope of road embankment stabilized.
31.	Assam	National Hydro-electric Power Corporation	Slope stabilization with Open weave JGT-7 x 7 - 730 g/m2 Area covered: 24,000 m2	2008	Slope stabilized and covered with vegetation.
32.	Manipur	Border Road Organization	Slope protection of road embankment With open weave JGT-12 x 12 -292 g/m2 Area covered: 20,000 m2	2008	Embankment is in good shape and slope stabilized.
33.	Manipur	Border Road Organization	Slope protection of road embankment With open weave JGT-12 x 12 -292 g/m2 Area covered: 30,000 m2	2008	Embankment is in good shape and slope stabilized.
34.	Manipur	Border Road Organization	Slope protection of road embankment With open weave JGT- 12 x 12 -292 g/m2 Area covered: 20,000 m2	2008	Embankment is in good shape and slope stabilized.
35.	Manipur	Border Road Organization	Slope protection of road embankment With open weave JGT-12 x 12 -292 g/m2 Area covered : 20,000 m2	2008	Embankment is in good shape and slope stabilized.
36.	Manipur	Border Road Organization	Slope protection of road embankment With open weave JGT- 12 x 12 -292 g/m2 Area covered: 30,000 m2	2008	Embankment is in good shape and slope stabilized.
37.	Nagaland	Border Road Organization	Slope protection of road embankment With open weave JGT-12 x 12 -292 g/m2	2008	Embankment is in good shape and slope stabilized.
38.	Nagaland	Border Road Organization	Slope protection of road embankment With open weave JGT-12 x 12 -292 g/m2	2008	Embankment is in good shape and slope stabilized.

Sl. No.	State	PIU	Particulars of work done	Year of application	Results
39.	West Bengal	Forest Deptt. Govt. of West Bengal, Coochbehar Divn.	Slope protection with Open weave JGT- 6.5x4.5-500 g/m2 Area covered: 10,000 m2	2008	Entire slope stabilized and covered with vegetation.
40.	Himachal Pradesh	National Hydroelectric Power Corporation	Slope stabilization with Open weave JGT- 6.5x4.5-500 g/m2 Area covered : 24,000 m2	2009	Slope stabilized and covered with vegetation.
41.	West Bengal	National Highway Divn IX, PW ® Directorate	Slope protection with Open weave JGT- 6.5x4.5-500 g/m2 Area covered: 52,000 m2	2010	Land slide protected, vegetation started
42.	Panjab	CSWCRTI, Chandigarh	Hill Slope Stabilization with new type of Open Weave JGT 500 gsm-1467 sq.m 600 gsm-1467 sq.m 700gsm-1467 sq.m	2011	Slope Stabilized with growth of vegetation
43.	Uttarakhand	CSWCRTI, Dehradun	Hill Slope Stabilization with new type of Open Weave JGT 500 gsm-3660 sq.m 600 gsm-2440 sq.m 700gsm-2452 sq.m	2012	Slope Stabilized with growth of vegetation
44.	Tamilnadu	CSWCRTI, Ooty	Hill Slope Stabilization with new type of Open Weave JGT 500 gsm-2867 sq.m 600 gsm-3904 sq.m 700gsm-3294 sq.m	2012	Slope Stabilized with growth of vegetation
45.	J & K	Srinagar Uri Hydroelectric Power Project, HCC / KK Enterprise / Gloster	Slope protection with Open weave JGT- 7 x 7-730 g/m2 Area covered: 12,000 m2	2012	Slope reported to be stabilized
46.	Himachal Pradesh	Sutlej Jala Bidyut Nigam Ltd&National Hydroelectric Power Corporation	Slope stabilization with Open weave JGT- 6.5x4.5-500 g/m2 Area covered : 2,000 m2	2012	Slope stabilized, covered with vegetation
47.	J & K	Border Road Organization	Slope stabilization with Open weave JGT- 12 x12-292 g/m2 Area covered : 856 m2	2012	Slope stabilized, covered with vegetation
48.	J & K	Border Road Organization	Slope stabilization with Open weave JGT- 6.5x4.5-500 g/m2 Area covered : 200 m2	2012	Slope stabilized, covered with vegetation
49.	West Bengal	National Highway Divn IX, PW(R) Directorate and DM-Darjeeling	Slope protection with Open weave JGT - 7 x 7 -730 g/m2 Area covered: 14,000 m2	2012	Land slide protected, vegetation started

Sl. No.	State	PIU	Particulars of work done	Year of application	Results
50.	Gujarat	Narmada Fertilizer Co. by Mr. Jatin-09924250525	Water reservoir slopes tabilization with Open weave JGT- 6.5x4.5-500 g/m2 Area covered : 7,500 m2	2013	Installed in May,2013 No vegetation due to wrong species selection. Advised the solution in March,2013
51.	Himachal Pradesh	Forest Dept. Govt of HP	Slope stabilization with Open weave JGT- 8 x 8-700 g/m2(new) Area covered : 39,040 m2	2013	Slope Stabilized with growth of vegetation
52.	West Bengal	National Highway Divn IX, PW(R) Directorate and DM-Darjeeling	Slope protection with Open weave JGT- 7 x 7 -730 g/m2 Area covered: 13,000 m2	2013	Installation completed. Slope reported to be stabilized
53.	Khed Ki Aage Beat - Avari Block- Nirmand	Himachal Pradesh, Rampur Forest Circle, HP	Erosion of hill slope to be stabilized with 8 x 8 OW700gsm JAT - 11,060 m2	Installed in 2013	Slope stabilized. Slope covered with vegetation
54.	Khed Ki Aage Beat - Avari Block- Nirmand	Himachal Pradesh Rampur Forest Circle, HP,	Erosion of hill slope to be stabilized with 8 x 8 OW700gsm JAT - 5,434 m2	Installed in 2013	Slope stabilized. Slope covered with vegetation
55.	Alsed Khad Beat- Dehar Block-Kangoo	Himachal Pradesh, Mandi Forest Circle, HP	Erosion of hill slope to be stabilized with 8 x 8 OW700gsm JAT - 22,000 m2	Installed in 2013	Slope stabilized. Slope covered with vegetation
56.	Kalingchigahar	Himachal Pradesh Kullu Forest Circle, HP,	Erosion of hill slope to be stabilized with 8 x 8 OW700gsm JAT - 90,000 m2	Installed in 2013	Slope stabilized. Slope covered with vegetation
57.	Overseas	-	Slope stabilization with Open weave JGT- 9 x 8 - 850 gsm g/m2 (139 lbs yarn) Area covered : 13,500 m2	2014	Material procured from Birla Mills. Report yet to be received
58.	West Bengal	Public Works Department, Mundeswari Bridge Approach, Govt. of West Bengal	Embankment Slope stabilization with Open weave JGT- 6.5x4.5-500 g/m2 Area covered: 3,500 m2	2015	Erosion checked. Bridge approach stabilized, slope covered with vegetation.
59.	Madhya Pradesh	PWD (R), Ujjaini	Slope stabilization of road and bridge approach with Open weave JGT- 6.5x4.5-500 g/m2 Area covered: 10,000 m2	2015	Installation completed, result awaiting
60.	Assam	Assam Power Generation Corpn, Hatidubi Dam, langpi Hydel	Slope stabilization with Open weave JGT- 8 x 8 - 700 gsm Area covered : 4,500 m2	2016	Installation in March 2016

B. RIVER / CANAL BANK PROTECTION WORK WITH JUTE GEOTEXTILE (JGT)

Sl. No.	Site	Location	PIU	Particulars of work done	Year of application	Results
1	Nayachar (on river Hooghly),	West Bengal	Calcutta Port Trust	River Bank Protection Type of JGT used: DWT 8x12-800 gsm, treated with rot resistant chemicals & bitumen- Area covered: 33,000m2	1989	Bank is still in good shape.
2	Padma Hasanpur, Murshidabad	West Bengal	Irrigation Department, Govt. of West Bengal.	River Bank Protection Type of JGT used DWT 8x10-760 g/m^2, treated with rot resistant chemicals & bitumen - Area covered: 1000 m2	1995	Better than granular filter in terms of performance and cheaper in cost.
3	Phulahar, Ramayanpur, Maldah,	West Bengal	Irrigation Department, Govt. of West Bengal.	River Bank Protection Type of JGT used DWT 8x12-800 g/m^2, treated with rot resistant chemicals & bitumen - Area covered: 10,000 m2	1996	Better than granular filter in terms of performance and cheaper in cost.
4	Phulahar Valuka, Maldah,	West Bengal	Irrigation Department, Govt. of West Bengal.	Erosion Control of flood embankment Type of JGT used 6.5 x 4.5 - 500 g/m^2 - - Area covered: 1000 m2	1996	No damage by rains in 1996-97.
5	Hooghly, Kulpi, Kedarpur, Sunderban,	West Bengal	Sundarban Development Board, Govt. of W. B.	Protection of Jetty Type of JGT used DWT 8x12-800 g/m^2, treated with rot resistant chemicals & bitumen - Area covered: 500 m^2	1996	No damage by rains in 1996-97.
6	Majuli Island, Bramhaputra Assam,	Assam	SDO, Majuli & AVARD (NE)	River Bank Protection Type of JGT used DWT 8x12-800 g/m^2, treated with rot resistant chemicals & bitumen - Area covered: 500 m^2	1997	Bank is still in good shape and erosion checked.
7	Una; Himachal Pradesh.	Himachal Pradesh.	Irrigation & Public Health Deptt., Govt. of Himachal Pradesh.	River Bank Protection Type of JGT used DWT 8x12 -700 g/m^2 Area covered: - 500 m^2	1997	Highly encouraging performance.
8	Hooghly Barrackpore, 24-Pgs(N),	West Bengal	Irrigation & Waterways Department, Govt. of West Bengal.	River Bank Protection bathing ghat stabilization Type of JGT used DWT 8x12-800 g/m2, treated with rot resistant chemicals & bitumen - Area covered: 500 m^2	1997	Bank is still in good shape.

Sl. No.	Site	Location	PIU	Particulars of work done	Year of application	Results
9	Canal, Teesta Jalpaiguri, Teesta Barrage	West Bengal	Teesta Barrage Project, Govt. of West Bengal.	Protection of Canal Bank Type of JGT used DWT 8x12 -700 g/m^2 Area covered:- 30,000 m^2	1997	A portion damaged due to steep slope.
10	Ganga Murshidabad.	West Bengal	Anti-Erosion Division, I&WD Murshidabad Govt. of West Bengal.	River Bank Protection Type of JGT used DWT 8x10 - 760 g/m^2, bitumen coated Area covered: - 9,000 m^2	1998	Feedback not available
11	Mahananda. Embankment Division., Maldah, WB.	West Bengal	Irrigation & Water Ways Dte. Govt. of West Bengal.., Maldah Embankment Division.	River Bank Protection Type of JGT used DWT 8x10 - 760 g/m^2, bitumen coated Area covered: - 2,000 m^2	1998	Satisfactory.
12	Balurghat Irrigation embankment.	West Bengal	Irrigation & Water Ways Dte. Govt. of West Bengal..,	River Bank Protection Type of JGT used DWT 8x10 - 760 g/m^2, rot resistant Area covered:- 15,000 m^2	1999	Bank is in good shape and no sign of erosion is noticed
13	Mahananda. Embankment	West Bengal	Irrigation & Water Ways Dte. Govt. of West Bengal..,	River Bank Protection Type of JGT used DWT 8x10 - 760 g/m^2, bitumen coated Area covered: - 2,000 m^2	1999	Satisfactory
14	Contai Irrigation Division Govt. of West Bengal	West Bengal	Irrigation & Water Ways Dte. Govt. of West Bengal.	River Bank Protection Type of JGT used 102x39 - 760 g/m^2 (treated) Area covered:- 40,000 m^2	2001	Satisfactory
15	Kulik, Raigunj	West Bengal	Irrigation & Water Ways Dte. Govt. of West Bengal..,	River Bank Protection Type of JGT used 102x39 - 760 g/m^2 Area covered:- 35,000 m^2	2001	Satisfactory
16	Atrei, Balurghat	West Bengal	Irrigation & Water Ways Dte. Govt. of West Bengal..,	River Bank Protection Type of JGT used 102x39 - 760 g/m^2 Area covered:- 14,300 m^2	2001	Satisfactory
17	Nagar, Balurghat	West Bengal	Irrigation & Water Ways Dte. Govt. of West Bengal..,	River Bank Protection Type of JGT used 102x39 - 760 g/m^2 Area covered:- 35,000 m^2	2001	Satisfactory

Sl. No.	Site	Location	PIU	Particulars of work done	Year of application	Results
18	Atrei, South Dinajpur	West Bengal	Irrigation & Water Ways Dte. Govt. of West Bengal..,	River Bank Protection Type of JGT used 102x39 - 760 g/m^2 Area covered:- 25,000 m^2	2001	Satisfactory
19	Punarbhaba, South Dinajpur.	West Bengal	Irrigation & Water Ways Dte. Govt. of West Bengal..,	River Bank Protection Type of JGT used 102x39 - 760 g/m2 Area covered:- 25,000 m^2	2001	Satisfactory
20	Mahananda, Balurghat	West Bengal	Irrigation & Water Ways Dte. Govt. of West Bengal..,	River Bank Protection Type of JGT used DWT 8x10 - 760 g/m^2, bitumen coated Area covered:- 11,000 m^2	2001	Satisfactory
21	River Devi, Jagatsingpur,	Orissa.	Water Resource Deptt., Govt. of Orissa.	River Bank Protection (Flood embankment) Type of JGT used Open weave JGT 6.5 x 4.5 - 500 g/ m^2 Area covered: 30,000 m^2	2002	Very good shape. Vegetation started.
22	River Devi, Bhubaneswar	Orissa	Water Resource Deptt. Govt. of Orissa.	River Bank Protection (Flood embankment) Type of JGT used Open weave JGT 6.5 x 4.5 - 500 g/ m^2 Area covered: 30,000 m^2	2002	Very good shape. Vegetation started.
23	Phulahar, Panchananda-pur, Malda	West Bengal	Irrigation & Water Ways Dte. Govt. of West Bengal..,	River Bank Protection Type of JGT used DWT 102x39 - 760 g/m2, treated with rot resistance chemical & bitumen - Area covered: 20,300 m2	2002	Installation completed satisfactory.
24	Phulahar, Sankaritola, River Malda	West Bengal	I & WD, Govt. of W.B.	River Bank Protection Type of JGT used DWT 8x10 - 760 g/m2, bitumen coated Area covered: 28,750 m2	2003	Bank is still in good shape.
25	Sankaritola, River Phulahar, Malda	West Bengal	I & WD, Govt. of W.B.	River Bank Protection Type of JGT used DWT 8x10 - 760 g/m^2, bitumen coated - Area covered: 7,200 m^2	2004	Bank is still in good shape.

Sl. No.	Site	Location	PIU	Particulars of work done	Year of application	Results
26	Narmada Main Canal	Gujarat	Sardar Sarobar Narmada Nigam Ltd. Govt. of Gujarat	Canal Bank Protection Type of JGT used DWT 8x10 - 760 g/m^2, bitumen coated - Area covered: 5,000 m^2	2005	Bank is still in good shape and erosion checked..
27	Narmada Main Canal Embankment,	Gujarat	Sardar Sarobar Narmada Nigam Ltd. Govt. of Gujarat	Canal Bank Stabilization Type of JGT used Open weave JGT 7 x 7 - 730 g/m2 - Area covered : 5,000 m2	2007	Bank is still in good shape and erosion checked..
28	River Phulahar, Beside Sankaritola Malda	West Bengal	I & WD, Govt. of W.B	River Bank Protection Type of JGT used DWT 8x10 - 760 g/m^2, bitumen coated Area covered: 18,000 m^2	2007	Bank is still in good shape.
29	River Hooghly	West Bengal	Kolkata Port Trust	River Bank Protection Type of JGT used 1200 gsm bitumen treated woven JGT Area covered: 54,000 m^2	2008	Satisfactory
30	Chakruplaskar, Diamond Harbour	West Bengal	I & WD, Govt. of W.B	River Bank Protection Type of JGT used DWT 8x10 - 760 g/m^2, bitumen coated Area covered: 4,428 m^2	2009	Bank stabilized. No sign or erosion
31	Roytala, Diamond Harbour	West Bengal	I & WD, Govt. of W.B	River Bank Protection Type of JGT used DWT 8x10 - 760 g/m^2, bitumen coated Area covered: 2,200 m$_2$	2009	Bank stabilized. No sign of erosion
32	Ratneswarpur, Diamond Harbour	West Bengal	I & WD, Govt. of W.B	River Bank Protection Type of JGT used DWT 8x10 - 760 g/m^2, bitumen coated Area covered: 1,991 m^2	2009	Bank stabilized. No sign or erosion
33	Katiberia, Diamond Harbour	West Bengal	I & WD, Govt. of W.B	River Bank Protection Type of JGT used DWT 8x10 - 760 g/m^2, bitumen coated Area covered: 2,500 m^2	2009	Bank stabilized. No sign or erosion

Sl. No.	Site	Location	PIU	Particulars of work done	Year of application	Results
34	Mouse Haripura near Ghosh Khal sluice, Kakdwip	West Bengal	I & WD, Govt. of W.B	River Bank Protection Type of JGT used DWT 8x10 - 760 g/m2, bitumen coated Area covered: 4,085 m2	2009	Bank stabilized. No sign or erosion
35	Sitarampur, Patharpratima, Kakdwip	West Bengal	I & WD, Govt. of W.B	River Bank Protection Type of JGT used DWT 8x10 - 760 g/m^2, bitumen coated Area covered: 6,000 m2	2009	Bank stabilized. No sign or erosion
36	Basanti, Joynagar	West Bengal	I & WD, Govt. of W.B	River Bank Protection Type of JGT used DWT 8x10 - 760 g/m^2, bitumen coated Area covered: 4,000 m^2	2009	Bank stabilized. No sign or erosion
37	Kultali, Joynagar	West Bengal	I & WD, Govt. of W.B	River Bank Protection Type of JGT used DWT 8x10 - 760 g/m^2, bitumen coated Area covered: 6,000 m^2	2009	Bank stabilized. No sign or erosion
38	Vidya, Gosaba, Joynagar	West Bengal	I & WD, Govt. of W.B	River Bank Protection Type of JGT used DWT 8x10 - 760 g/m^2, bitumen coated Area covered: 15,000 m^2	2009	Bank stabilized. No sign or erosion
39	Hingalganj, Basirhat	West Bengal	I & WD, Govt. of W.B	River Bank Protection Type of JGT used DWT 8x10 - 760 g/m^2, bitumen coated Area covered: 4,000 m^2	2009	Bank stabilized. No sign or erosion
40	Charalkhali, Basirhat	West Bengal	I & WD, Govt. of W.B	River Bank Protection Type of JGT used DWT 8x10 - 760 g/m^2, bitumen coated Area covered: 6,700 m^2	2009	Bank stabilized. No sign or erosion
41	Nischintapur bank at Kulpi Reach of river Hooghly	West Bengal	Kolkata Port Trust	River Bank Protection Type of JGT used 1200 gsm bitumen treated woven JGT Area covered: 84,000 m^2	2009	Bank stabilized.
42	Ghoramara Island, Kulpi Reach of river Hooghly	West Bengal	Kolkata Port Trust	River Bank Protection Type of JGT used 1200 gsm bitumen treated woven JGT Area covered: 84,000 m^2	2009	Satisfactory

Sl. No.	Site	Location	PIU	Particulars of work done	Year of application	Results
43	Bhaluka Bazar right bank of river Fulahar, Malda	West Bengal	Mahananda Embankment Divn., I & W D, Malda	River Bank Protection Type of JGT used 1200 gsm bitumen treated woven JGT Area covered: 14.500 m2	2011	Bank Stabilized
44	Battali, right bank of river Punarbhava, Malda	West Bengal	Malda Irrigation Divn, I & W D	River Bank Protection Type of JGT used 200 gsm bitumen treated 1woven JGT Area covered: 12.000 m2	2011	Bank Stabilized
45	Uttarsurendra gunj, right bank of river Jagaddal, Patharpratima, South 24 Pgs	West Bengal	Kakdwip Irrigation Divn, I&WD	River Bank Protection Type of JGT used 1200 gsm bitumen treated woven JGT Area covered: 20,000 m^2	2011	Bank Stabilized
46	Cooch Behar I / W Divn River Dharla, Sitalkuchi Block	West Bengal	I & WD, Govt. of W.B	River Bank Protection Type of JGT used DWT 102 x 39 - 760 g/m2, bitumen treated Area covered: 10,000 m2	2012	Bank stabilized
47	Cooch Behar I / W Divn River Kaljani, Tufanjanj Block	West Bengal	I & WD, Govt. of W.B	River Bank Protection Type of JGT used DWT 102 x 39 - 760 g/m2, bitumen treated Area covered: 11,167 m2	2012	Bank stabilized
48	Mahi River bank protection, vadodara, Gujarat	Gujarat	Riverine of Mahi river ,Gujarat	Inside slope protection of riverine, 7 x 7 OW JGT 730 gsm- 15000 m2	2013	Installed in Januray13. Covered with vegetation
49	River Bhagirathi, Santipur, Nadia	WB	I/W Ways, Govt. of WB	River Bank Protection Type of JGT used: DWP85 x 32 -627 gsm, rot resistant & water repellant -17,000m2	May,2013	Bank treated with eco-friendly JGT is in good shape. No sign of erosion observed
50	River Mahananda (Right bank), Siliguri	WB	I/W Ways, Govt. of WB	River Bank Protection Type of JGT used DWT 102 x 39 - 760 g/m^2, bitumen treated Area covered: 10,000 m^2	February, 2014	Erosion Checked. Bank reported to be in stable condition

Sl. No.	Site	Location	PIU	Particulars of work done	Year of application	Results
51	River Jagatdal, Dakshin Surendraganj 24 Parganas (S)	WB	I/W Ways, Govt. of WB	River Bank Protection Type of JGT used DWT 102 x 39 - 760 g/m^2, bitumen treated Area covered: 13,000 m^2	January, 2015	work has been completed in June 2015
52	River Mahananda (Right bank), Siliguri	WB	I/W Ways, Govt. of WB	River Bank Protection Type of JGT used DWT 102 x 39 - 760 g/m^2, bitumen treated Area covered: 6,800m^2	February, 2015	Work completed in July 2015 (Buddhadeb Adhikari-9679289860)
52-66 (15 sites)	Rivers under Jaynagar Divn	WB	I/W Ways, Govt. of WB	Aila affected country side bank protection with 500 gsm OW JGT	November 2015	Work partially completed
67-91 (25 sites)	Rivers under Kakdwip Divn	WB	I/W Ways, Govt. of WB	Aila affected country side bank protection with 500 gsm OW JGT	November 2015	Work partially completed
92-104 (13 sites)	Rivers under Basirhat Divn	WB	I/W Ways, Govt. of WB	Aila affected country side bank protection with 500 gsm OW JGT	November 2015	Work partially completed
105	Canal bank protection	Manipur	PWD, Govt., of Manipur	Eroded bank of Kangla Fort outer moat at Imphal treated with 627 gsm woven treated JGT- 2500 sq.m	February, 2016	Installation completed

C. ROAD CONSTRUCTION

Sl. No.	Site	Location	PIU	Particulars of work done	Year of application	Results
1.	Kankinada, Port connecting Road	Andhra Pradesh	CRRI and Kankinada Municipality	Road Pavement Construction Type of JGT used DWT 8x10-760 g/m^2, rot resistant Area covered:- 25,000 m^2	1996	No damage of the treated portion while the untreated road damaged severely by a cyclone.
2.	Hanuman Setu	Delhi,	CRRI	Filtration & drainage during construction of roads. Type of JGT used Nonwoven 500 g/m^2 - - 1000 m^2.	1996	Satisfactory
3.	Joshimath ; Malari Road,	Uttarkhand	CRRI & PWD of U.P. Govt.	Drainage and filtration of trench drain for roads. Type of JGT used Nonwoven JGT 500 g/m^2 - - 1000 m^2.	1996	No damage of the stretch after one year.
4.	Oklha Fly Over,	Delhi,	DDA.	Filtration & drainage during construction of roads. Type of JGT used Nonwoven 500 g/m^2 - - 1000 m^2.	1997	Satisfactory
5.	Kandla Port,	Gujrât,	CRRI & Kandla Port Trust.	Road Pavement Construction Type of JGT used DWT 102x39- 760 g/m^2, rot resistant - 15,000 m^2	1997	No subsidence reported.
6.	Ponta Sahib,	Himachal Pradesh,	CRRI & PWD, Govt. of H.P.	Road side slope protection Type of JGT used Open weave JGT- 6.5 x 4.5 - 500 g/m^2 - 5000 m^2	1997	Reported to be satisfactory
7.	Kandla Port Trust,	Gujarat.	CRRI & Kandla Port Trust.	Road embankment construction Type of JGT used DWT 102x39- 760 g/m2, rot resistant - 15,000 m^2	1998	Satisfactory

Sl. No.	Site	Location	PIU	Particulars of work done	Year of application	Results
8.	Munsirhat-Rajput Rd, Howrah	West Bengal	P.W (Roads) Dte. Govt. of West Bengal.	Road Construction Type of JGT used DWT 102x39- 760 g/m^2, rot resistant - 7,500 m^2	1999	Satisfactory.
9.	Garia Station Road, Alipore	West Bengal.	Public Works Department. Govt. Of West Bengal.	Wearing Course in Roads Type of JGT used 12 x 12 - 300 g/m^2 - 10,000 m^2.	1999	No pot holes and cracks developed after 3 yrs of application of JGT.
10.	Kalyani,	West Bengal.	PWD Construction Divn. No.VI, Govt. Of West Bengal.	Wearing Course in Roads Type of JGT used 12 x 12 - 300 g/m^2 - 3000 m^2.	1999	Satisfactory.
11.	Halipad Road, Jaigaon, Jalpaiguri.	West Bengal.	Public Works Department. Govt. Of West Bengal.	Wearing Course in Roads Type of JGT used 46 x 32 - 248 g/m^2 - 37,500 m^2.	1999	No reflective crack reported.
12.	Border Roads, Karimganj - Silchar	Assam	Border Roads Organization	Slope protection of road embankment Type of JGT used Open weave JGT- 6.5x 4.5- 500 g/m^2 Area covered: 1,00,000 m^2	2003	Highly satisfactory
13.	Odlabari - Kranti Road	West Bengal.	Public Works Department. Govt. Of W.B.	Slope protection of road embankment Type of JGT used Open weave JGT- 6.5x 4.5- 500 g/m^2 3,500 m^2	2003	Slope stabilized & covered with vegetation.
14.	Andulia (Kalupukur More) to Boyratala, North 24 Parganas	West Bengal.	Panchyat & Rural Development Department, Govt. Of West Bengal.	Road Construction Under PMGSY Total length of road- 3.50 km: Type of JGT used:- 20 kN/m-17,605 m^2	2005	Road in good shape, CBR increased by three times

Sl. No.	Site	Location	PIU	Particulars of work done	Year of application	Results
15.	Jeliakhali (Bagdipara More) to Barmajur, Gazikhali Road North 24 Parganas,	West Bengal.	Panchyat & Rural Development Department, Govt. Of West Bengal.	Road Construction Under PMGSY Total length of road:-7.00 km Type of JGT used:- 20 kN/m-35,210 m^2	2006	Road is in good shape, no sign of depression / deflection noticed in the JGT treated zone
16.	Port Blair, Andaman	Andaman	BRO	Slope protection of road embankment with open weave JGT- 12 x 12 -292 g/m^2	2007	Slope fully stabilized & covered with vegetation
17.	U T Road to Jorabari/ Barnagaon, Darrang ,	Assam	Public Works Deptt., Govt. of Assam.	Road Construction under PMGSY Pilot Project Total length of road:- 4.60 KM. Type of JGT used 15 kN-13370 m^2 30 kN-3200 m^2 20 kN/m-6440 m^2 O.W. 3430 m^2 B.T-8350 m^2 N.W.-12870 m^2	2007	Road in good shape.
18.	Rampur Satra to Dumdumia. Nagaon - Assam,	Assam	Public Works Deptt., Govt. of Assam	Road Construction under PMGSY Pilot Project Total length of road:- 4.20 KM Type of JGT used 15 kN-5800 m^2 30 kN-11400 m^2 20 kN/m-2900 m^2 O.W. 71900 m^2 B.T-11530 m^2 N.W.-5880 m^2	2007	Road in good shape. CBR improved by three times
19.	Khairjhiti to Ghirghoisa Road, Kawardha,	Chattisgarh,	Chattisgarh Rural Roads Development Agency, Govt. of Chhattishgarh	Road Construction under PMGSY Pilot Project Total length of road:- 5.50 KM Type of JGT used 15 kN-6800 m^2 20 kN 6800 m^2 30 kN-10040 m^2 B.T. - 3240 m^2 O.W - 11240 m^2	2007	No distress observed

Sl. No.	Site	Location	PIU	Particulars of work done	Year of application	Results
20.	Kodavabani to Khursi, Bilaspur,	Chattisgarh,	Chattisgarh Rural Roads Development Agency, Govt. of Chhattishgarh	Road Construction under PMGSY Pilot Project Total length of road:- 4.80 KM Type of JGT used 15 kN-14910 m^2 20 kN 6430 m^2 30 kN-8930 m^2 O.W - 18670 m^2 N.W.-3000 m^2	2007	No distress observed
21.	Berasia to Semrakalan Approach Road, Bhopal,	Madhya Pradesh,	M.P. Rural Roads Development Agency, Govt. of Madhya Pradesh	Road Construction under PMGSY Pilot Project Total length of road:- 5.10 KM Type of JGT used 15 kN-16960 m^2 20 kN/m-3570 m^2 30 kN-10710 m^2 O.W - 10530 m^2 N.W.-3570 m^2	2007	Satisfactory . No sign of distress observed
22	Gehlawan Village to PMGSY Road, Raisen,	Madhya Pradesh	M.P. Rural Roads Development Agency, Govt. of Madhya Pradesh	Road Construction under PMGSY Pilot Project Total length of road:- 3.14 KM Type of JGT used 15 kN-9290 m^2 30 kN-6250 m^2 O.W - 3260 m^2 N.W.-3130 m^2	2007	Distress observed. Road constructed without any treatment of BC soil by the MPRRDA
23	NH 3 by-pass, Guna, MP	Madhya Pradesh	Guna Infrastructure Ltd. (M.P.)	Highway embankment slope protection Open weave 6.5 x 4.5, 500gsm - 24000 sq.m	2007	Slope stabilized & covered with vegetation.
24	Jadupur to Mahanangal, Kendrapara,	Orissa,	Rural Works Deptt., Government of Orissa.	Road Construction under PMGSY Pilot Project Total length of road:- 5.50 KM Type of JGT used 15 kN-14910 m^2 20 kN 6070 m^2 30 kN-11960m^2 O.W - 24520 m^2 N.W.-- 6750 m^2	2007	No Distress observed till date

Sl. No.	Site	Location	PIU	Particulars of work done	Year of application	Results
25	MDR 14 t0 Chatumar, Jajpur	Orissa	Rural Works Deptt. Government of Orissa.	Road Construction under PMGSY Pilot Project Total length of road:- 4.00 KM Type of JGT used 15 kN-4280 m^2 20 kN 21770 m^2 30kN-44200m^2 N.W.-- 2140 m^2	2007	Road in good shape. No distress noticed.
26	Sikkim	Sikkim	BRO	Slope protection of road embankment With open weave JGT- 12 x 12 -292 g/m^2	2007	Slope stabilized & covered with vegetation.
27	Notuk to Dingal, West Midnapore,	West Bengal.	P & RD, Govt. o WB	Road Construction under PMGSYPilot Project Total length of road:- 4.80 KM Type of JGT used:- 15 kN-3700 m^2 20 kN/m-3700 m^2 30 kN-3700 m^2 B.T. -4620 m^2 O.W. 24780 m^2 N.W.-3880 m^2	2007	Road in good shape.
28	Andhra Pradesh	Andhra Pradesh	BRO	Slope protection of road embankment With open weave JGT-12 x 12 -292 g/m^2	2008	Slope fully stabilized & covered with vegetation
29	Chattisgarh,	Chattis-garh,	BRO	Slope protection of road embankment With open weave JGT-12 x 12 -292 g/m^2	2008	Slope fully covered with vegetation
30	Madhya Pradesh	Madhya Pradesh	BRO	Slope protection of road embankment With open weave JGT-12 x 12 -292 g/m^2	2008	Slope stabilized & covered with vegetation.
31	Maharastra	Maharastra	BRO	Slope protection of road embankment With open weave JGT-12 x 12 -292 g/m^2	2008	Slope stabilized & covered with vegetation.
32	Nagaland	Nagaland	BRO	Slope protection of road embankment With open weave JGT-12 x 12 -292 g/m^2	2008	Slope stabilized & covered with vegetation.

Sl. No.	Site	Location	PIU	Particulars of work done	Year of application	Results
33	Tripura	Tripura	BRO	Slope protection of road embankment With open weave JGT-12 x 12 -292 g/m^2	2008	Slope stabilized & covered with vegetation.
34	Agartala-Mohanpur-Chebri Road at Tripura	Tripura	PMGSY Road, Tripura	200 m Road Construction Type of JGT used DWT 102x39- 760 g/m^2, 825 m^2	2009	Excellent performance. Work carried out by Mr. Moloy Dev
35	Udal to Chakrabrahma, Dakshin Dinajpur	West Bengal	P & RD, Govt. of WB	Road Construction Under PMGSY Total length of road:-4.75 km Type of JGT used:- 25 kN/m, 724 gsm, 76,472 m^2	2011	Road is in good shape. No sign of distress observed
36	Nihinagar to Hazaratpur, Dakshin Dinajpur	West Bengal	P & RD, Govt. of WB	Road Construction Under PMGSY Total length of road:-7.9 km Type of JGT used:- 25 kN/m, 724 gsm, 45,980 m^2	2011	Road is in good shape. No sign of distress observed
37	Panchbhaga to NH 60, Bankura Bypass	West Bengal	PWD, Govt. of WB	Reconstruction of road through re-sectioning and widening Total length of road:-4.5 km Type of JGT used:- 25 kN/m, 724 gsm, 30,000 m^2	2011	Road is in good shape. No sign of distress observed
38	Krishnabali to Saranjabari, Dakshin Dinajpur	West Bengal	P & RD, Govt. of WB	Road Construction Under PMGSY Total length of road:-6.15 km Type of JGT used:- 25 kN/m, 724 gsm, 59,530 m^2	2011	Road is in good shape. No sign of distress observed
39	Chengishpur to Durgapur, Dakshin Dinajpur	West Bengal	P & RD, Govt. of WB	Road Construction Under PMGSY Total length of road:-2.0 km Type of JGT used:- 25 kN/m, 724 gsm, 19,360 m^2	2011	Road is in good shape. No sign of distress observed
40	Rajarhat Test Track	West Bengal	NJB	20 kN/m-627 gsm DW Plain weave-500 m2 25 kN/m-724gsm DW Plain weave JGT-500 m^2	2012	Road is in good shape. No sign of distress observed
41	Pramodnagar to Muga-chandrapara, Agartala	Tripura	TRRDA,PWD, Govt. of Tripura through NBCC	Road Construction Under PMGSY 6.99 km 94 x 39 DWP JGT 25 kN/m, 724 gsm, 26,000 m^2	Work commenced in Sept, 2012	Road is in good shape. No sign of distress observed

Sl. No.	Site	Location	PIU	Particulars of work done	Year of application	Results
42	Nihinagar to Hazaratpur, Dakshin Dinajpur	West Bengal	P & RD, Govt. o WB	Road Construction Under PMGSY Total length of road:-4.5 km Type of JGT used:- Ganges/ Samnagar north-18MT, 25 kN/m, 724 gsm, 24,860 m2observed	2012	Road is in good shape. No sign of distress observed
43	Bedakumda-T-03, Bidar	Karnataka	KRRDA	Road Construction Under PMGSY 2.38 km 25 kN/m, 724 gsm,	2013	Road is in good shape. No sign of distress observed
44	Honnadi-Bagdal, Bidar	Karnataka	KRRDA	Road Construction Under PMGSY 5.20 km 25 kN/m, 724 gsm,	2013	Road is in good shape. No sign of distress observed
45	Halgorta-T-10, Bidar	Karnataka	KRRDA	Road Construction Under PMGSY 4.00 km 25 kN/m, 724 gsm,	2013	Road is in good shape. No sign of distress observed
46	Bagdi-marimulo Barada Nagar to Damkal kheya Ghat, Mathurapur	West Bengal	WBSRDA Govt. o WB	25 kN/m, 724 gsm, 48,299 m^2	2013	Road is in good shape. No sign of distress observed
47	V-Koracharahatti-T-10, Davanagere	Karnataka	KRRDA	Road Construction Under PMGSY 4.02 km 25 kN/m, 724 gsm,	2013	Road is in good shape. No sign of distress observed
48	Devarhospet-Gundur, Haveri	Karnataka	KRRDA	Road Construction Under PMGSY 12.59 km 25 kN/m, 724 gsm,	2013	Road is in good shape. No sign of distress observed
49	Devagondan akatti- T-07, Haveri	Karnataka	KRRDA	Road Construction Under PMGSY 2.98 km 25 kN/m, 724 gsm,	2014	Road is in good shape. No sign of distress observed

Sl. No.	Site	Location	PIU	Particulars of work done	Year of application	Results
50	Chandapur-T-12, Haveri	Karnataka	KRRDA	Road Construction Under PMGSY 6.75 km 25 kN/m, 724 gsm,	2014	Road is in good shape. No sign of distress observed
51	Kanksa to Bati, Jiaganj Block 8.6 km road	Murshi-dabad	WBSRDA, Govt. of WB	Road Construction Under PMGSY 8.02 km 94 x 39 DWP JGT 25 kN/m, 724 gsm, 44,176 m^2	2013	Road is in good shape. No sign of distress observed
52	Raiganj-Karimganj to Buniadpur PWD Road	North Dinajpur, WB	PWD, North Dinajpur, Raiganj	Rehabilitation of damaged 2 km road of 5.5 m wide 94 x 39 DWP JGT 25 kN/m, 724 gsm, 10,920 m^2 7.5 kg/10m2 x2 tack coat both at top and below JGT -75 mm BM then 25mm Semi Dense BM	2013	No sign of pot holes and reflection cracks observed till date.
53	Taldi to Jharur More	Canning 24 Par ganas (S)	PMGSY	Road Construction Under PMGSY 1.5 km 25 kN/m, 724 gsm, 9,000 m^2	Completed in October, 2014	Performance under observation.
54	Hiremaganur to T-11 Haveri	Karnataka	KRRDA	Road Construction Under PMGSY 3.35 km 25 kN/m, 724 gsm	Completed in june 2013	Performance under observation
55	Munsitanda to T-06 Gulbarga	Karnataka	KRRDA	Road Construction Under PMGSY 3.88 km 25 kN/m, 724 gsm	Completed in Jan 2014	Performance under observation
56	Bomraldoddi to T-06 Gulbarga	Karnataka	KRRDA	Road Construction Under PMGSY 5.96 km 25 kN/m, 724 gsm	Completed in Jan 2014	Performance under observation
57	Ayatti to L-026 Dharwad	Karnataka	KRRDA	Road Construction Under PMGSY 6.77 km 25 kN/m, 724 gsm	Completed in 2014	Performance under observation
58	Saidapur to T-03 Dharwad	Karnataka	KRRDA	Road Construction Under PMGSY 5.96 km 25 kN/m, 724 gsm	Completed in 2014	Performance under observation
59	Nandi Bevurutanda to T-01 Davanagere	Karnataka	KRRDA	Road Construction Under PMGSY 3.17 km 25 kN/m, 724 gsm	Completed in Dec-2013	Performance under observation
60	Honnapura to T-06 Davanagere	Karnataka	KRRDA	Road Construction Under PMGSY 4.74 km 25 kN/m, 724 gsm	Completed in June-2013	Performance under observation

Sl. No.	Site	Location	PIU	Particulars of work done	Year of application	Results
61	Saragondlu to T-05 Kolar (Chickballa-pura)	Karnataka	KRRDA	Road Construction Under PMGSY 2.38 km 25 kN/m, 724 gsm	Completed in Oct-2013	Performance under observation
62	Thimmayagar ahalli to Approacch road (T-04) Kolar (Chickballapura)	Karnataka	KRRDA	Road Construction Under PMGSY 1.86 km 25 kN/m, 724 gsm	Completed in Dect-2013	Performance under observation
63	Naralahalli to Bellavalahalli (T-01) Kolar (Chickballapura)	Karnataka	KRRDA	Road Construction Under PMGSY 2.26 km 25 kN/m, 724 gsm	Completed in Mar-2014	Performance under observation
64	Pasapalodduto Approacch road (T-09) Kolar (Chickballapura)	Karnataka	KRRDA	Road Construction Under PMGSY 1.14 km 25 kN/m, 724 gsm	Completed in Dec-2013	Performance under observation
65	Lingarajnagar Sirsangi to T-05 via Basidoni Gorbal Belgaum	Karnataka	KRRDA	Road Construction Under PMGSY 7.25 km 25 kN/m, 724 gsm	Completed in Jan-2014	Performance under observation
66	Hiretadasi to T-03 Belgaum	Karnataka	KRRDA	Road Construction Under PMGSY 6.40 km 25 kN/m, 724 gsm	Completed in Jan-2014	Performance under observation
67	Balpai-Jhalapara Rd, Sabaong, Paschim Medinipur	WB	WBSRDA, Govt. of WB	Road Construction Under PMGSY 4.7 km 25 kN/m, 724 gsm,	Application commenced in May, 2015	Installation of JGT in progress
68	Daskalgram-Ruipur Rd, Nanoor, Birbhum	WB	WBSRDA, Govt. of WB	Road Construction Under PMGSY 5.63 km 25 kN/m, 724 gsm,	Likely to be undertaken in April,2015	Awaiting placement of order
69	Paschimchak=-Gokulchak, Pingla Paschim Medinipur	WB	WBSRDA, Govt. of WB	Road Construction Under PMGSY 4.7 km 25 kN/m, 724 gsm,	Likely to be undertaken in September, 2015	Awaiting placement of order
70	Ruinan - Chakdamusen, sabang Paschim Medinipur	WB	WBSRDA, Govt. of WB	Road Construction Under PMGSY 4.7 km 25 kN/m, 724 gsm,	Likely to be undertaken in September, 2015	Awaiting placement of order

D. RAILWAYS

Sl. No.	Site	Location	PIU	Particulars of work done	Year of application	Results
1.	Lamding, Assam,	Assam,	Chief Engineer, N.F. Rly.	Hill Slope protection on Railway Track Type of JGT used:- Open weave JGT- 6.5 x 4.5 - 500 g/m^2 - Area covered: 4000 m^2	1997	Hill slope is stabilized
2.	Jammu Tawai Link,	Jammu & Kashmir	Northern Railway.	Railway Slope protection Type of JGT used:- Open weave JGT- 6.5 x 4.5 - 500 g/m^2 Area covered:- 15000 m^2	2000	Slope is in perfect shape.
3.	Keonjhar, S. E. Railway,	Orissa.	South Eastern Railway	Railway slope Protection Type of JGT used:- Open weave JGT- 6.5 x 4.5 - 500 g/m^2 Area covered:- 4000 m^2	1998	Slope is in perfect shape.
4.	Madhusud unpur (E.R)	West Bengal	Howrah Divn., Eastern Railway	Control of Track subsidence JGTs used:- 102x39 -760 /m^2, (bituminized) - 6,000 m^2, 1000 gsm Non woven- 6,000 m2& 500 gsm OW- 6000 m^2	2001	No subsidence occurred till date. Settlement level reduced from 70 mm to 13 mm
5	Shibaichandi, Howrah-Burdwan chord line (E.R)	West Bengal	Howrah Divn., Eastern Railway	Control of Track subsidence JGTs used:- Woven 760 gsm-treated 25kN- 18,920 m^2 1000 gsm Non woven - 18,920 m2& OW 500 g/m^2- 15,000 m^2	2008	No subsidence occurred till datebeing monitored.
6	Baltikuri - Dankuni-Ballyghat (E R)	Bally, Howrah, WB	Howrah Div. Eastern railway	Control of track settlement JGTs used:- Woven treated 760gsm-8745sq.m, Nonwoven 1000 gsm -8745 sq.m & OW-6.5x4.5 - 500 gsm - 17,000 sq.m	2013	Out of 1.5 km 600 m completed in December. 2013. Track is in good shape
7	Solapur	Gujrat/ Maharastra	Central Railway	Controlling of track settlement. Quality and quantity of JGT yet to be determined (10,000 sq.m.)	Enquiry of Atul Jani 2014	Decision pending
8	Thingon Rly Alingment, Manipur	Manipur	N F Railways	Erosion control of railway embankment and stabilization of down hill slope, 7 x 7, 730 gsm OW JGT- 80,000sqm	2014	Work undertaken in December' 14 through Maccafferri
9	Bishramgarh-Agartala Sabroom Project, Tripura	Agartala, Tripura	N F Rly	Slope stabilization of Cutting on either side of track and 6.5 x 4.5, 500 gsm OW JGT- 40,000sqm out of 10 lac sq.m	2015	Work undertaken in April,2015 by Tribeni construction through Maccafferri (supplier)

E. APPLICATIONS IN AGRI-HORTICULTURE & FORESTRY(JUTE AGROTEXTILE)

Sl. No.	Site	Location	PIU	Particulars of work done	Year of application	Results
1.	Arunachal	Arunachal Pradesh.	Govt. Of Arunachal Pradesh.	Seedlings to saplings Type of JAT used:- Jute sleeves 9"x8" - 5,000 pcs.	1998	Feedback not available
2.	Arcuttipore T.E., Cachar,	Assam;	Indian Tea Research Association.	Weed control in tea cultivation Type of JGT used:- .Non woven JAT- 500 g/m^2 ; Area covered:- 5000 m^2.	1995	Significant reduction of growth of weeds.
3.	Borbetta Tea Estate	Assam;	Indian Tea Research Association.	Weed control in tea cultivation. Type of JGT used:- Non woven JAT-750 g/m^2 ; Area covered:3000 m^2	1996	60% reduction of weeds.
4.	Andrew Yule Tea Estate.	Assam	Indian Tea Research Association.	Seedlings / saplings Type of JAT used:- Jute Sleeves 9"x8" - 1,000 pcs.	1997	Degraded within 3 months and more expensive.
5.	Indian Tea Association	Assam	Indian Tea Research Association.	Seedlings / saplings Type of JAT used:- Jute Sleeves 9"x8" - 500 pcs.	1997	Degraded within 3 months and more expensive.
6.	Forest Deptt.,	Himachal Pradesh	Forest Deptt., Govt. of Himachal Pradesh	Preservation of costly fauna from extinction. Type of JAT used:- Non woven JAT- 500 g/m^2 ; Area covered: 1200 m^2	1997	Feed back not available.
7.	Horticulture Deptt.,	Himachal Pradesh	Horticulture Deptt., Govt. of Himachal Pradesh	Seedlings growth of / saplings Type of JGT used:- Jute Sleeves 9"x8"- 10,000 pcs.	1997	Not suitable under the climate.
8.	Hijli & Porapara, Midnapore	West Bengal	ForestDeptt., Govt. of West Bengal.	Afforestation & Erosion Control Type of JAT used:- 1. Open weave JAT-34 x 15 - 250 g/m^2 Area covered:- 1000 m^2 2. Open weave JAT-11x 12 - 300 g/m^2 Area covered: - 1000 m^2	1997	Growth of the trees in the treated area significantly higher. No sign of erosion.
9.	Hunsur,	Karnatak,	C.T.R.I. (ICAR)	Mulch on seed bed of Tobacco nursery. Type of JAT used:- Open weave JAT- 6.5 x 4.5 - 500 g/m2 Area covered:- 500 m2.	1988	Number of seedlings and survival rate increased by 5%.

Sl. No.	Site	Location	PIU	Particulars of work done	Year of application	Results
10.	Hunsur,	Karnatak,	C.T.R.I. (ICAR)	Mulch on seed bed of Tobacco nursery. Type of JAT used:- Open weave JAT- 11 x 12 - 250 g/m2 Area covered:- 300 m2.	1990	Number of transplantable seedlings and survival rate increased by 5%.
11	Barapani, Meghalaya	Meghalaya	ICAR	Soil Conservation Type of JAT used:- Open weave JAT- 400 g/m2	2002	Soil loss significantly reduced
12	Pushkar	Rajasthan	Agriculture Deptt., Govt. of Rajasthan	Soil Conservation & agromulching Type of JAT used:- 6.5 x 4.5 open mesh- & 500 gsm nonwoven- Area covered:200 sq.m	2007	Soil loss significantly reduced
13	Jaipur	Rajasthan	Agriculture Deptt., Govt. of Rajasthan	Soil Conservation & agromulching Type of JAT used:- 500 & 6.5 x 4.5 open mesh- & 500 gsm nonwoven- Area covered:200 sq.m	2007	Soil loss significantly reduced
14	Chewang Nursery	Sikkim	Forest & Environment Deptt. Govt of Sikkim	Seedlings growth of / saplings Type of JGT used:- Jute Sleeves 9"x6"	2001	excellent performance in growth and survival
15	Tarang Nursery	Sikkim	Forest & Environment Deptt. Govt of Sikkim	Seedlings growth of / saplings Type of JGT used:- Jute Sleeves 9"x6" performance in growth and survival	2001	excellent
16	Phedang Nursery	Sikkim	Forest & Environment Deptt. Govt of Sikkim	Seedlings growth of / saplings Type of JGT used:- Jute Sleeves 9"x6"	2001	excellent performance in growth and survival
17	Namprikdang Nursery	Sikkim	Forest & Environment Deptt. Govt of Sikkim	Seedlings growth of / saplings Type of JGT used:- Jute Sleeves 9"x6"	2001	excellent performance in growth and survival
18	Menshithang Nursery	Sikkim	Forest & Environment Deptt. Govt of Sikkim	Seedlings growth of / saplings Type of JGT used:- Jute Sleeves 9"x6"	2001	excellent performance in growth and survival

Sl. No.	Site	Location	PIU	Particulars of work done	Year of application	Results
19	Bop Nursery	Sikkim	Forest & Environment Deptt. Govt of Sikkim	Seedlings growth of / saplings Type of JGT used:- Jute Sleeves 9"x6"	2001	excellent performance in growth and survival
20	Shimphere Nursery	Sikkim	Forest & Environment Deptt. Govt of Sikkim	Seedlings growth of / saplings Type of JGT used:- Jute Sleeves 9"x6"	2001	excellent performance in growth and survival
21	Singring Nursery	Sikkim	Forest & Environment Deptt. Govt of Sikkim	Seedlings growth of / saplings Type of JGT used:- Jute Sleeves 9"x6"	2001	excellent performance in growth and survival
22	Lembuchhera	Tripura	ICAR	Soil Conservation & agromulching Type of JAT used:- Open weave JAT- 6.5 x 4.5 - 500 g/m2 Non-woven JAT - 500 g/m2 Area covered:- 1000 m2	2004	Soil loss significantly reduced
23	Atma,Malda	Malda	Agriculture Deptt	Weed management and Agromulching	2009	Highly encouraging result

Appendix-IV

TABLE OF CONVERSION BETWEEN U. S. SIEVE NUMBER AND ACTUAL SIEVE OPENING SIZE*

The following table will help in correlating opening sizes of JGT expressed in mm and mm (micron)corresponding to U.S. Sieve Numbers.

Conversion between US Sieve Number and Actual Sieve Opening Size, i.e., Actual Diameter of Soil Particles or Actual Size of Geotextile Openings

US sieve designation	Sieve opening size	
Sieve Number	mm	μ (micron)
200	0.075	75
170	0.090	90
140	0.106	106
120	0.125	125
100	0.150	150
80	0.180	180
70	0.212	212
60	0.250	250
50	0.300	300
45	0.355	355
40	0.425	425
35	0.500	500
30	0.600	600
25	0.710	710
20	0.850	850
18	1.000	
16	1.180	
14	1.400	
12	1.700	
10	2.000	
8	2.360	
7	2.800	
6	3.350	
5	4.000	
4	4.750	

* Adapted from the publication of International Geotextile Society on Symbols (1985)

Appendix - V

Percent Slope Corresponding to Degree of Slope

Angles in degrees	Per cent slope	Angles in degrees	Per cent slope	Angles in degrees	Per cent slope
0.5	0.87	15.5	27.73	30.5	58.90
1.0	1.75	16.0	28.67	31.0	60.09
1.5	2.62	16.5	29.62	31.5	61.28
2.0	3.49	17.0	30.57	32.0	62.49
2.5	4.37	17.5	31.53	32.5	63.71
3.0	5.24	18.0	32.49	33.0	64.94
3.5	6.12	18.5	33.40	33.5	66.19
4.0	6.99	19.0	34.41	34.0	67.45
4.5	7.87	19.5	35.41	34.5	68.73
5.0	8.75	20.0	36.40	35.0	70.02
5.5	9.63	20.5	37.39	35.0	71.33
6.0	10.51	21.0	38.39	36.0	72.65
6.5	11.39	21.5	39.39	36.5	74.00
7.0	12.28	22.0	40.40	37.0	75.36
7.5	13.17	22.5	41.42	37.5	76.73
8.0	14.05	23.0	42.45	38.0	78.13
8.5	14.95	23.5	43.48	38.5	79.54
9.0	15.84	24.0	44.52	39.0	80.98
9.5	16.53	24.5	45.57	39.5	82.43
10.0	17.63	25.0	46.63	40.0	83.91
10.5	18.53	25.5	47.70	40.5	85.41
11.0	19.44	26.0	48.77	41.0	86.93
11.5	20.35	26.5	49.86	41.5	88.41
12.0	21.26	27.0	50.95	42.0	90.04
12.5	22.17	27.5	52.06	42.5	91.63
13.0	23.09	28.0	53.17	43.0	93.45
13.5	24.01	28.5	54.30	43.5	94.90
14.0	24.93	29.0	55.43	44.0	96.57
14.5	25.86	29.5	56.58	44.5	98.27
15.0	26.79	30.0	57.74	45.0	100.0

Appendix-VI

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LIST OF MANUFACTURERS OF WOVEN JUTE GEOTEXTILES					
No.	**Name**	**Address**	**Phone**	**Fax**	**Contact person**
1.	Ambica Multifibres Unit:Bally Jute Mills	6, Little Russell St., Kolkata -700 071. E-mail:bally@kankaria group.com	033 2247-9921/ 2286/9720 033 2247-7998	033 2240-3159 033 2247-9621 033 2247-9921	Mr. A.K. Kankaria, Director
2.	Ambica Multifibres Unit: Ambica Jute Mills	6, Little Russell St., Kolkata -700 071. E-mail:bally@kankaria group.com	033 2247-9921/ 2286/9720 033 2247-7998	033 2240-3159 033 2247-9621 033 2247-9921	Mr. A.K. Kankaria, Director
3.	Birla Corporation Ltd. Unit: Birla Jute Mill	9/1 R.N. Mukherjee Rd, 3rd& 4th Floor Kolkata -700 001.	033 2248 9101	033 2248-7988/ 2872	Mr. G R Verma Vice President Mobile- 9839734696
4.	Al Champadany Ind. Ltd. (Anglo India Jute Mills)	18, Netaji Subhas Road Kolkata - 700 001 Email : anglo@vsnl.net	033-2220 5811, 033 2261 0249	033 2236 3754/ 2225 0221	Shri Nirmal Pujara Director
5.	Naffar Chandra Jute Mills	2, Coopers Lane, Kolkata-700 001	033-2248 5558 / 1034	033-2225 0221	Shri D. J. Wadhwa
6.	Gloster Jute Mills Ltd.	21, Strand Road, Calcutta - 700 001. E-mail: projects@glosterjute.com, info@glosterjute.com	033 2230-9601/ 9602/ 9603/ 9604/ 9606	033 2231-6831	Mr. D.C. Baheti, Exe. Director
7.	Hooghly Mills Co. Ltd. Unit: Hukumchand	10, Clive Row, 3rd floor, Kolkata -700 001.	033 2242-9801/ 9842	033 2242-4306/ 6614	Mr. A.K. Bajoria, M.D.
8.	Hasting Jute Mill	15B, Hemanta Bose Sarani, Kolkata -700 001.	033 2210-4821	033 2248-4104	Mr. S. Kajaria, Managing Director, Pankaj Agarwal- 9830970230
9.	Ludlow Jute Mills	Kankaria Estate, 6 Little Russelle St., 4th floor, Kolkata - 700 071. E mail : ajay.todi@ludlowjute.com	033 2283-9081/ 9082/ 9083	033 2283 9078/ 4503	Mr. Ajoy Todi M.D. Mobile- 9830450221

No.	Name	Address	Phone	Fax	Contact person
10.	The Ganges Manufacturing Ltd	33A, J.L. Nehru Road, Chatterjee Intl. Centre, 6th floor, Flat No. A1, Kolkata - 700071	033 2226 0881/ 0883/6283/6953	033 2288 7591	Mr. Abhisek Poddar M.D.
11.	Howrah Mills Co. Ltd.	Howrah House, 135 Foreshore Rd.(Upper), Howrah - 711 102	033 2660-1446/ 2302/ 2748	033 2660-1747/ 5228	Mr. Sanjay Mall, Director
12.	Reliance Jute Ltd.	11/1 Sarat Bose Road Ideal Plaza, South Block 4th floor, Kolkata - 700020 E-mail : mktgho@reliancejute.com	033 2280 7017-19	033 2280 7016	Mr. S Hada Director
13.	Shree Gouri Shankar Jute Mills Ltd.,	67, Park Street, Gr. Floor Kolkata-700 016 e-mail : sgsjml@gl.com	2229-0614 9830971053	2229-1346	Mr. C S Chhajer Managing Director
14	East India Commercial Co.Ltd	G T Road, Eluru-534002,AP E mail: eicc@eiccltd.com	08812 226903	08812 237370	Mr. Brijgopal Lunani-MD Mobile No-09393037371 **MR. Sanker Lunani-09393159900**
15	Cheviot Company Limited	24 Park Street Kolkata-700 016 E mail : mbajaj@chevjute.com	03332919624/ 25/28, 03332926038	03322172488	Mr Monoj Bajaj-GM 9873656362
16	Naihati Jute Mills Co Ltd	7 Hare Street, 4th Floor Kolkata 700001	22489904/18/ 73/74	22484062	Mr. K K Santhalia-VP-9831037979 Pankaj Mandal-GM Mobile 9433042820

LIST OF MANUFACTURERS OF OPEN WEAVE JUTE GEOTEXTILE

No.	Name	Address	Phone	Fax	Contact person
1.	Ambica Multifibres	6, Little Russell St., Kolkata -700 071. E-mail:bally@kankaria group.com	033 2247-9921/ 2286/9720 033 2247-7998	033 2240-3159 033 2247-9621 033 2247-9921	Mr. A.K. Kankaria, Director
2	Birla Corporation Ltd.	9/1 R.N. Mukherjee Rd, 3rd & 4th Floor Kolkata -700 001.	033 2248 9101 9339734696 9831134467	033 2248- 7988/2872	Mr G R Verma - President Mr Adity Sharma
3	Anglo India Jute Mills Co. Ltd.,	18, Netaji Subhas Road Kolkata - 700 001 Email : anglo@vsnl.net	033-2220 5811, 033 2261 0249	033 2236 3754 033 2225 0221	Shri Nirmal Pujara Director
4	Naffar Chandra Jute Mills	2, Coopers Lane, Kolkata-700 001	033-2248 5558/ 1034	033-2225 0221	Shri Nirmal Pujara Director
5	Gloster Jute Mills Ltd.	21, Strand Road, Calcutta - 700 001. E-mail: projects@glosterjute.com, info@glosterjute.com	033 2230-9601/ 9602/ 9603/ 9604/ 9606	033 2231-6831	Mr. D.C. Baheti, Executive Director
6	Hooghly Mills Co. Ltd.	10, Clive Row, 3rd floor, Kolkata -700 001.	033 2242-9801/ 9842	033 2242-4306/ 6614	S K Chanda Ch. Executive Officer
7	Hasting Jute Mill	15B, Hemanta Bose Sarani, Kolkata -700 001.	033 2210-4821	033 2248-4104	Mr. S. Kajaria, Managing Director.
8	Howrah Mills Co. Ltd.	Howrah House, 135 Foreshore Rd.(Upper), Howrah - 711 102	033 2660-1446/ 2302/ 2748	033 2660-1747/ 5258	Mr. Sanjay Mall, Director
9	Ludlow Jute Mills	Kankaria Estate, 6 Little Russelle St., 4th floor, Kolkata - 700 071. Ajay.todi@ludlowjute.com	033 2283-9081/ 9082, 9083 9830450221	033 2283 9078/ 4503	Mr. AjayTodi, Executive Director
10	Brishti Vinimoy Pvt. Ltd. Unit : Premchand Jute Mill	14, N.S. Road 3rd floor (Stand Chat. Building) Kolkata - 700001	033 2210 2913 4005 0721	033 2210 2033	Mr. G L Chirania Director

No.	Name	Address	Phone	Fax	Contact person
11	Reliance Jute Ltd.	11/1 Sarat Bose Road IdealPlaza South Block 4th floor Kolkata - 700020 E-mail : mktgho@reliancejute.com	033 2280 7017-19	033 2280 7016	Mr. S Hada Director
12	Kamarhatty Co. Ltd. 16A, Brabourn Road Kolkata - 700 001 Mill : Graham Road,	2235/3444/45/46 4021-1900 2553-1716/1106	4021 1999	jute@kamarhatty.com	Mr. S. K. Agarwal

LIST OF MANUFACTURERS OF NON WOVEN JUTE GEOTEXTILE

No.	Name	Address	Phone	Fax	Contact person
1.	Gloster Jute Mills Ltd.	21, Strand Road, Calcutta - 700 001. E-mail: info@glosterjute.com	91-33-2230-9601, 9602, 9603, 9604, 9606	91-33-2231-6831	Mr.D.C. Baheti, Executive Director
2.	Birla Corporation Ltd.	9/1 R.N. Mukherjee Rd, 3rd & 4th Floor Kolkata -700 001. E-mail : bjm_birlapur@hotmail.com	91-33-2248 9101	91-33-2248-7988/ 2872	Mr. D C Patni Executive Director
3.	Baranagar Jute Mills	21A, Shakespeare Sarani, 3rd Floor, Kolkata -700 017. Email: sbagro@cal2.vsnl.net.in	91-33-2281-6318, 2287 7512, 2290 8985	91-33-2290-6831	Mr. G. Sarda, Director
4	Auckland International Ltd	6 A Littie Russel St. 7th floor Kolkata -700071 Email: jkk@kankinaragroup.com	91 33 2287 2607 OP Sarma, Mill Manager-9748781490, 9038825737 B D Sengupta (Felt) 9831134943	91 33 2287 3159	Mr. H.S. Baid Director (Marketing) 9831000453

No.	Name	Address	Phone	Fax	Contact person
5	Ghosh & Ghosh Agro Products Pvt. Ltd.	13 A Pandityia Place Kolkata 700029 E Mail: gngagro@gmail.com	9674798553		Mr. Tapan Kr. Ghosh Director
6	Ludlow Jute Mills	Kankaria Estate, 6 Little Russelle St., 4th floor, Kolkata - 700 071. E Mail: Ludlow_123@dataone.in	033 2283-9081/ 9082/ 9083	033 2283 9078/ 4503	Mr. Ajoy Todi, M.D. 9830450221
7	Kalpco & Co	20, Umesh Dutta lane Near Minerva Theatre Kolkata -700006 E Mail : kalpco@yahoo.com	9831095337	91 33 25305391	Mr. Mohan khettry Proprietor 9831095337
8	Sree Ram Cotspin Pvt Ltd.	Diamond Chambers 4 Chowrangee lane, Block -IV, Flat No 10B Kolkata 700016 Email : sreeramcotspin@yahoo.co.in/ sourgupt@gmail.com	9330815004 / 9831741061	Factory - Munshirhat, Amta, Howrah	Mr. S K Agarwal Director

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