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GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS

GUIDELINES

ON EROSION CONTROL AND DRAINAGE OF RAILWAY FORMATION

(Guideline No. GE: G-4)

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Lucknow - 226011

PREFACE

Ours is a vast country with variegated climate, rainfall and soil characteristics. Network of Indian Railways passes through different types of terrain - deserts in Rajasthan, heavy rainfall regions in sub Himalayan belts, Deccan plateau and alluvial Gangetic plain. Therefore, problem of erosion and drainage of formation varies from one region to another. Erosion protection measures have to be provided in such a way that they cater to specific site requirements. Keeping this in view, present guidelines have been formulated detailing various measures for adoption in field.

Classification studies of soils over Indian Railways have shown that the soils are generally clayey in character possessing great affinity with water. Such soils lose their shear strength considerably, when they come in contact with water. Therefore, removal of water i.e. drainage from formation and adjacent areas is the most important factor in track maintenance. In this Guideline, an effort has been made to provide a systematic approach for finding out suitable, economical, and efficient drainage system.

It is expected that the guidelines will help in creating awareness about various aspects of erosion control & drainage and enable field staff to adopt suitable measures in tackling erosion and drainage problems relating to formation.

(Nand Kishore)
Executive Director/Geo-technical

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PART A - EROSION CONTROL

1.0 INTRODUCTION

Soil erosion is the process of detachment and transportation of soil particles by erosive agents such as wind, water and gravity. Resultant loss of soil due to erosion from railway formation is a matter of serious concern as the slope stability of embankments supporting permanent ways is governed by the degree of damage suffered by them due to erosion. Unchecked erosion may result in cuts, rills or gullies and slide problems.

It is, therefore, essential to study mechanism of erosion and take adequate measures for controlling it. This guideline throws light on the mechanism of erosion, available erosion control systems, selection of appropriate erosion control systems, material requirement, field execution and maintenance practices.

Erosion in Slopes

2.0 MECHANISM OF EROSION

2.1 AGENTS OF SURFACE EROSION

The prime agents of erosion are wind, water and gravity. These agents combine in a variety of ways to perform the dual role of abrading and simultaneously transporting the soil.

2.2 WIND EROSION (AEOLINE)

In wind erosion, fine cohesionless soil particles are blown away. Wind force disturbs the exposed soil surface leading to gradual depletion of soil particles that cement the larger ones and hold the soil surface together, causing erosion. Wind erosion is quite predominant on following areas having specific site conditions such as:-

a) Exposed slopes of non-cohesive (loose and dry) soil
b) Smooth and bare surfaces without any protective layer
c) Lack of shelter from wind (open areas)

Various parameters affecting wind erosion are speed, direction, turbulence and distance from ground level. There is a threshold wind velocity for different particle sizes, which results in erosive action when exceeded e.g., wind velocity over 12 to 15 km/h at 150 mm above ground level is the threshold value for the grain size of 0.10 to 0.15 mm. Over the years, various studies have tried to correlate the diameter of soil particles to its propensity for erosion. One such classification system for soil erodibility, given by Chepil and Woodruff is as follows:

Relationship between particle diameter and susceptibility to wind erosion

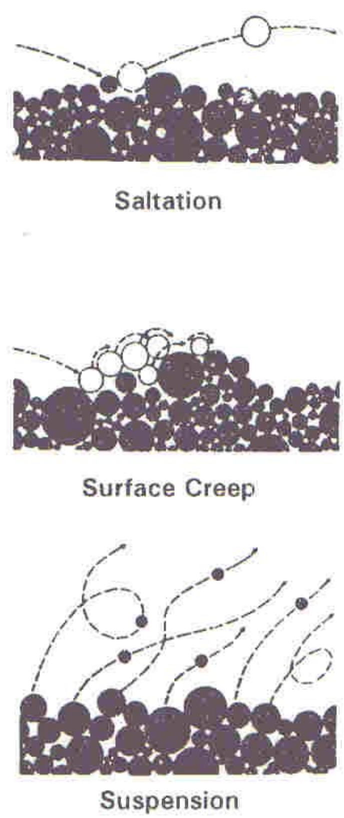
S. No.	Particle Diameter, mm	Wind Susceptibility
1	<0.42	Highly erodible
2	0.42 to 0.84	Difficultly erodible
3	0.84 to 6.4	Usually non-erodible
4	>6.4	Non-erodible

2.2.1 FACTOR INFLUENCING WIND EROSION

Transportation of soil by wind takes place by following three processes-

- Saltation
- Surface Creep
- Suspension

All these processes take place simultaneously. Saltation can be defined as the process of transportation of hard particles over an uneven surface in a turbulent flow of air. This process involves bouncing and jumping motion of soil grains and takes place within few cm of ground. Saltation grains, largely in the range of 0.05 to 0.5 mm, can move individual grains, upto 200 times of their own weight by force of impact. Surface creep involves slow movement of soil surface particles of size 0.05 to 1 mm dia. Suspension is wind transportation of very small particles of size 0.1mm dislodged from surface by salting particles.

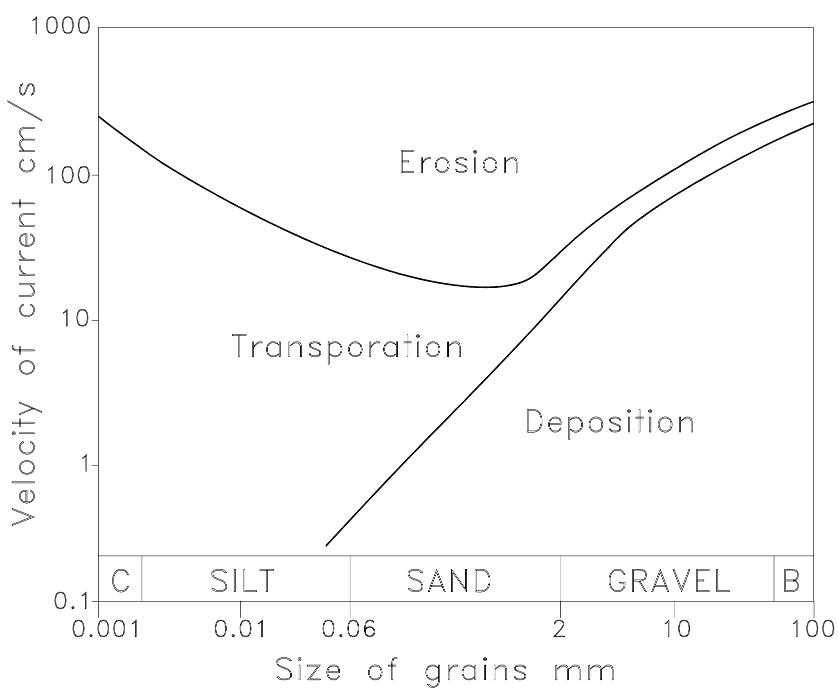


Modes of Soil Transport

2.3 RAIN EROSION

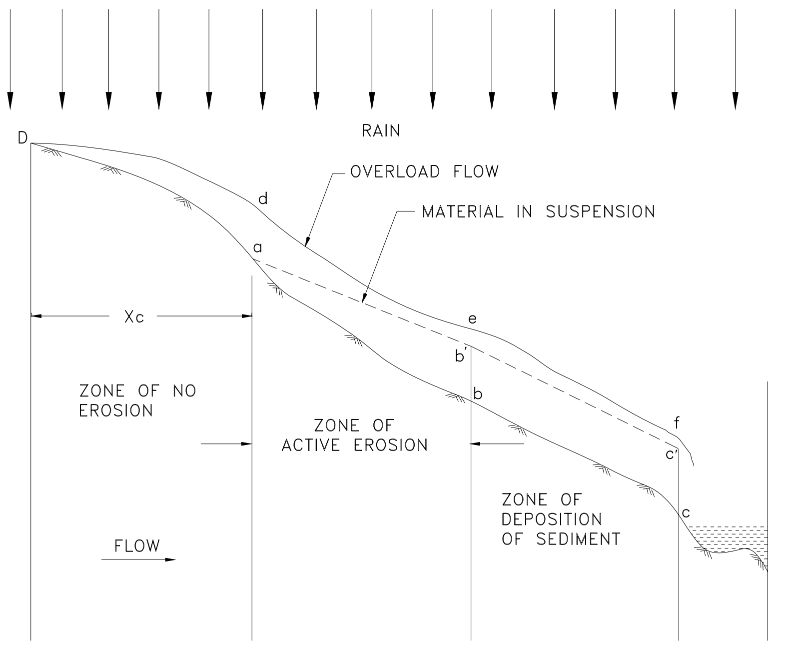
Rain erosion is a phenomenon of transportation of soil particles due to action of rain water. Impact of rain drops on the soil surface loosens the soil particles and results in their movement along with water. When the flow is concentrated, it facilitates carriage of subsequent particles. This results in development of small rivulets initially, then to the gullies and ultimately to erosion ditches which widen and deepen in the process. As a consequence, a chain reaction is set up, which would impair the slope stability adversely, if not arrested at the beginning itself.

Unlike wind, water has relatively high viscosity and density, therefore, has the ability to carry particles at a much lower velocity. In addition, water has the inherent ability to move semi-rounded soil particles by rolling them. This rolling velocity is much lower than lifting/carrying velocity. Typical relationship between particle size, velocity of flow and erosion is as shown in figure below-



Erosion Susceptibility in Relation to Water Velocity

Soil erosion process on a slope due to rain water is depicted in the figure below. For a certain length in the top portion of the slope, there is no erosion. Beyond this initial zone of no erosion, water starts picking up soil particles along the slope and erosion process starts. The concentration of suspended material in the water increases down the slope until it reaches maximum (represented by the line b-b' in the figure). Below this point, erosion from the lower part of the slope length is balanced by deposition of material. If the flow continues to the lowest point of the slope, some of the eroded material is fed into the channel which may be a small rill, large gully or even stream channel.



Process of Soil Erosion on a Slope

2.3.1 FACTORS INFLUENCING RAIN EROSION

i) Erosiveness of rainwater:

It describes the potential of the water flow for detaching the initial particle and initiating the phenomenon. It depends on duration/intensity of rain fall & the kinetic energy of the rain drops.

Rainfall Kinetic Energy related to rain fall intensity and droplet diameter

S. No.	Rainfall	Intensity (mm/hr)	Diameter of droplet (mm)	Kinetic Energy J/sq.m/hr
1	Drizzle	<1	0.9	2
2	Light	1	1.2	10
3	Moderate	4	1.6	50
4	Heavy	15	2.1	350
5	Excessive	40	2.4	1000
6	Cloud burst	100	2.9	3000
7	Cloud burst	100	4.0	4000
8	Cloud burst	100	6.0	4500

ii) Erodibility of soil

Erodibility of soil is described as the susceptibility of a given soil to erosion under given erosiveness of rainwater. This depends on the clay content of soil, particle size distribution and other factors such as saturation, density, permeability, plasticity, compaction etc.

Soil erodibility :-

- is low in well-graded, coarse gravels.
- is high in uniform silt and fine sands.
- decreases with increasing clay and organic content.
- decrease with low void ratios and high antecedent moisture content.
- increases with increasing sodium absorption ratio and decreasing ionic strength of water.

There is no simple and universally accepted erodibility index for soils. Generally accepted hierarchy of erodibility for different type of soil is as follows:

Most Erodible ⟶ Least Erodible

ML>SM>SC>MH>OL>>CL>CH>GM>SW>GP>GW

iii) Exogenous factors:

Factors like topography, gradient of slope, slope length, presence of berms, vegetation growth potential etc. also affect the process of erosion.

3.0 EROSION CONTROL

3.1 Erosion control systems for the treatment of exposed slopes could be classified into three broad categories:

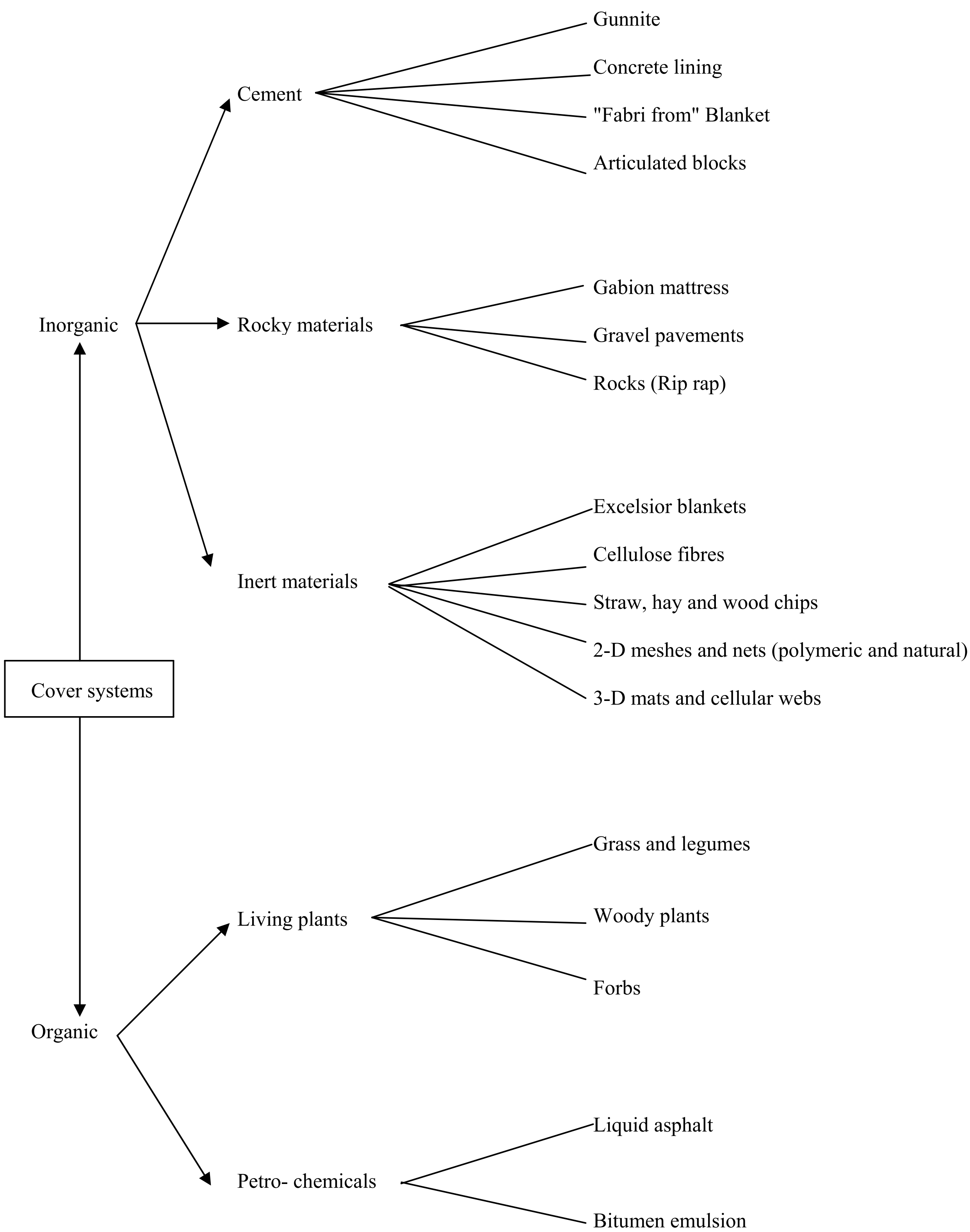
- Agronomic or biological
- Non –agronomic or conventional
- Engineered innovative

Agronomic or biological methods make use of vegetative or other forms of protective cover to check erosion. Protection of bare soil is effected by live plant cover afforded by maturing crops or by mulching derived from crop residue such as straw, wood shavings, sawdust, etc.

Non-agronomic treatments include asphalting, aprons, pitching, soil cement stabilisation, etc. Large scale adoption of these techniques is often restricted on economic considerations, even though some of them may offer long lasting solutions.

Engineered systems of erosion control, largely bio-technical systems include geo-synthetics, geojute, etc. In case, long term soil protection is afforded by vegetative cover alone, biodegradable nets and meshes, usually derived from natural fibre, are used to provide short term protection. In situations, where vegetative cover alone is inadequate or can not be ensured for long periods of time and high velocity overland flow is anticipated, synthetic roots reinforcing mats are advocated.

Another classification system for various erosion control measures as given by Gray is depicted in figure below-



Classification of ground cover for Erosion control

4.0 ROLE OF VEGETATION IN EROSION CONTROL

4.1 PROTECTIVE MECHANISM

Joint action of trees, grass and other plant species for protection of soil from water/wind erosion has been recognised from times immemorial. Vegetation provides adequate canopy interception to the falling raindrops and saves the soil from splash erosion, and acts as speed breaker for running water on slope and collects soil particles. Consequently, more water percolates recharging the soil profile for better vegetation yield. Besides soil protection, vegetation plays a significant role in binding the particles with its fibrous root system. Protective role of vegetation in preventing surfacial erosion can be summarised as follows :

INTERCEPTION : Foliage and plants residue absorb rainfall energy and prevent soil detachment by rain drop splash.

RESTRAINT : Root system physically binds or restrains soil particles while above ground portions filter sediment out of runoff.

RETARDATION : Stems and foliage increase surface roughness and decrease velocity of run off.

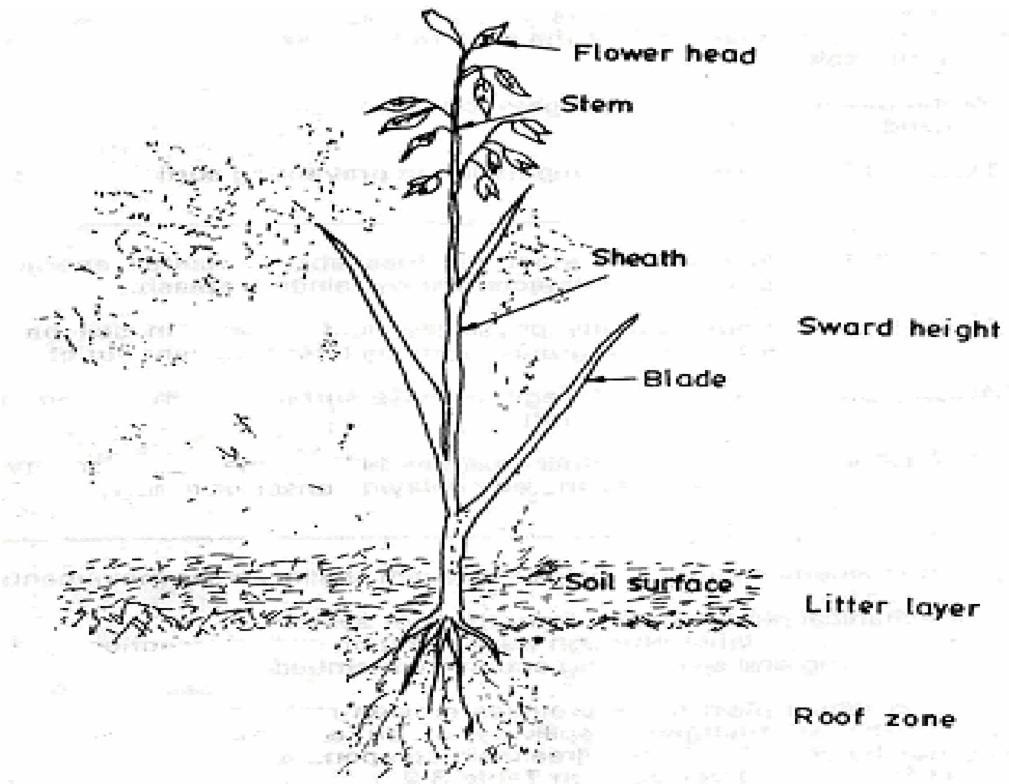
INFILTRATION : Plants and their residue help to maintain porosity and permeability, thereby delaying onset of run off.

A grass plant can be broadly classified having three components. Contribution of these components to erosion resistance is as follows:

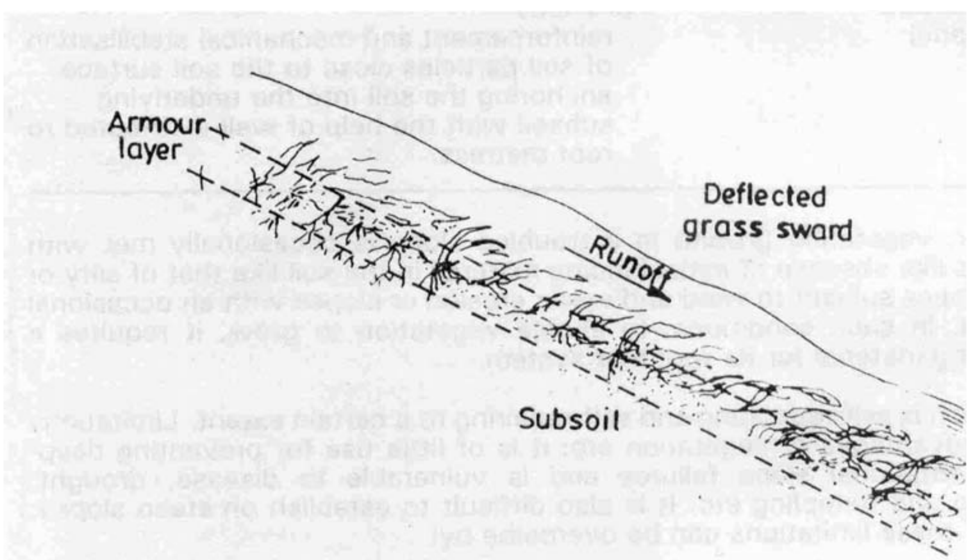
i) Sward Height	Provides
(upper Zone)	- Reduction of erosive velocity at the soil surface by interfering with flow. - Soil protection, particularly when the sward is laid down by drag force of high velocity flow, providing ground cover.
ii) Litter Layer (middle zone of dead vegetation above the soil surface)	- Soil protection for ground cover

iii) Root Structure (lower zone)

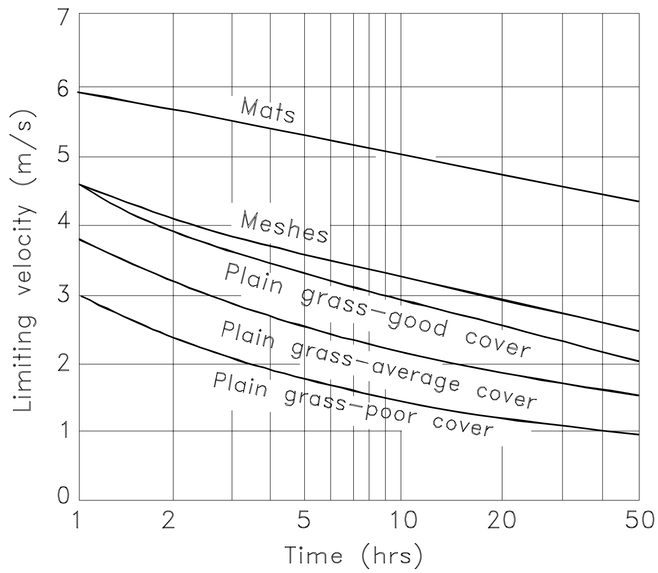
- Reinforcement and mechanical stabilisation of soil particles close to the soil surface
- Anchoring soil into the underlying subsoil with the help of well distributed root mattress



Components of the Grass Plant



Armour Layer provided by Vegetation



Limiting velocities of plain and reinforced grass

4.2 EROSION CONTROL BY VEGETATION

This is the most economical and site suited method on exposed slopes. Its use is advocated solely on site consideration. Vegetation network of root system penetrates 50-75 cm deep into the slope serving as soil anchor and offering added resistance to erosion. Deep rooted species of grass such as *vetiver grass* are suitable for use on soft soil slope. Following types of vegetation are recommended for use on soil slopes irrespective of the type of soil. Altitude is also a significant factor in deciding vegetation.

a) Hilly areas: (high altitude more than 4500 ft above sea level).

Grasses and shrubs:

(i) Eragrostis Curvula Love grass

(ii) Pao Pratensis (above 6000 ft)

(iii) Lemon Grass (over upto 6000 ft)

(iv) Robinia Pscudoaecadia

(v) Eragrostis Superva/Vetiver Grass

(vi) Kudzu Vine (Over upto 8000 ft)

(vii) Ficus Cuvea

(viii) Lolium Perrene or Rai grass

(ix) Kikuyu (Pennisctum Cloudestinum)

(x) Philedus cuttings

(xi) Chrysopogon Mountanus.

(xii) Imperate Cylindria

(xiii) Pennisctum orientale.

(xiv) Jatropha curcas.

b) Plane areas: (low altitudes upto 4500 ft above sea level)

Grasses and shrubs:

(i) Doob Grass

(ii) Cynodon plectostycum

(iii) Goat foot creepers

(iv) Erithcrina Indica

(v) Iponea Gornea (Bacharum Booti)

(vi) Chlosis Gyna

(vii) Sachharum Munja

(viii) Psosopis species

(ix) Saccharum spontaneum (Tall pernicious Deep rooted Pernial)

(x) Gasuarina

(xi) Lantana Species

(xii) Agave Americana

If the grass & shrubs mentioned at a) & b) above are unknown in the area, nearby botanical gardens can be checked for its local name.

4.3 VEGETATIVE TURFING WITHOUT SPECIAL TECHNIQUE

This is the most economical method of providing vegetation on embankment slopes. Naturally, this method should be adopted wherever practicable. The method consists of preparing a slope area into seed beds by grading it to the extent possible and then broadcasting seeds or planting root slips of the promising types of locally available plants.

One variation of this technique is that instead of treating the whole slope in poor soils, plantation could be encouraged by putting in seedling in isolated pockets of specially enriched soil. There are limits to the successful application of this method. The method is apt to fail in following situations.

i) On very erodible slopes where seeding or sprigging is liable to be washed down before they have had time to take root.

ii) When work is to be done immediately preceding or during very heavy downpour.

iii) In places where no artificial supply of water is available for promoting growth of vegetation or where adequate supply of moisture to the slopes by light rain or drizzle is not available beyond monsoon season.

4.4 TRANSPLANTATION OF READY-MADE TURFS OF GRASS

It is also possible to provide vegetative turfing by sodding which involves the bodily transplantation of blocks of turfs of grass (with some 2-8 cm or so of soil covering with grass roots) from the original site to slopes to be treated. If found necessary, pegs or nails could be used to hold down the grass sods in the initial stage.

4.5 EROSION CONTROL BY VETIVER GRASS

Vetiver grass is easily available all over India and can be utilized for economical erosion control (Please see the figure on page 16 & 17 for details). Vegetation by vetiver grass is the most suitable in all climatic conditions - least to heavy rainfall as well as low to high temperature. Vetiver grass can easily grow in all types of soil such as clayey, sandy, gravely or least erodible to heavily erodible soils. Moreover, it does not require any maintenance. The stabilization and protection of slope by vetiver grass is effective, efficient and low cost vis-a-vis other traditional erosion control system. Vetiver grass roots penetrate vertically below the plant to at least 3 m, have 1/6th strength of mild steel and improve soil shear strength at a depth of 0.5 m by as much as about 40 %.

4.5.1 ESTABLISHING VETIVER GRASS

The vetiver grass is found throughout India from North to South and East to West. If vetiver grass is unknown in the area, nearby botanical gardens can be checked for its local name. The vetiver grass is established in a hedge system. First of all, the planting material is obtained usually from a vetiver nursery. Vetiver nurseries are easy to establish. Inlets to small dams or water holding tanks make the best nursery sites because water en route to the tank or dam irrigates the vetiver grass which in turns remove silt from water. Large gullies protected with vetiver grass also make good informal nurseries. For best, result, the vetiver root divisions, or slips, should be planted in a double or triple line to from parallel hedges across the streambed. Distance between consecutive hedge rows is about 30 to 50 cm.

To remove a clump of vetiver grass from the nursery, it is dug out with the help of spade or fork. The root system is too massive and strong for the vetiver to be pulled out by hand. Hand full of the grass along with roots is torn out from the clump. The resulting piece, called the slip, is planted in field. Before transporting the slips from the nursery to the field, tops are cut off approximately 0.15 m to 0.25 m above the base and the roots 0.10 m to 0.15 m below the base. This will improve the slips' chances of survival after planting by reducing the transpiration level and thereby preventing them from drying out.

For fast growth of the slips, di-amonium phosphate (DAP) can be utilized as fertilizer. Vetiver grass can be planted in single hedge or more than one hedge as per requirement. The slips should be planted at the beginning of the wet season to ensure that they get full benefit of the rains. Planting vetiver slips is similar to planting rice seedlings. A hole is made in the furrow ploughed to mark the contour. The slip is pushed into the hole in such a fashion that the roots are not bent upward. Then the slip is firmed in the soil. The next slip is planted 10 cm to 15 cm from the slip already planted along the same contour furrow and process is repeated upto required length. Once the hedge has been established at the slope, only care needed is annual trimming, if required.

For vetiver system to work effectively, the plant must form a hedge otherwise the system will not work as a barrier against soil loss. Planting the slips too far apart would render the system ineffective as very long time will be required to form a hedge. Also, the hedgerows should be spaced apart at the proper vertical interval. Vertical interval is the vertical distance from one hedge row to the next one down the slope. The actual distance measured along the ground is called surface run and it depends on the steepness of the slope. Generally, vertical interval of 1.0 m to 2.0 m from one hedgerow to the next one down the slope is adequate.

4.5.2 LOCAL NAMES OF VETIVER GRASS IN INDIA

S.N.	Languge	Names
1.	Hindi	Bala, Balah, Bena
2	Urdu	Khas
3	Panjabi	Panni
4	Bengali	Khas-Khas
5	Marathi	Vala, Khas-khas
6	Gujarati	Valo
7	Telugu	Avurugaddiveru,Kuruveen,Lamajjakamuveru,Vetttiveru, Vidavaliveru
8	Kannada	vettiveeru, Laamanche,Kaadu,Karidappasajjehallu
9	Tamil	Ilamichamver, Vettiver, vilhalver,Viranan
10	Mysore	Ramaccham,Ramachahamver, Vettiveru
11	Saanthali	Sirom
12	Sadani	Birni
13	Oudh	Tin
14	Ganrar	Khas, Onei, Panni

4.5.3 ADVANTAGES OF VETIVER GRASS

Due to following characteristics, the vetiver is ideal for erosion control:

(i) It is cheap and easy to establish as a hedge.

(ii) It can be easily maintained by the user at little cost.

(iii) It can be easily removed when no longer required.

(iv) It is capable of growing in a wide range of climates – from 300 mm rainfall to over 6000 mm & from 15˚C temperature to more than 55˚C. Moreover, it can withstand long and sustained drought for more than six month.

(v) It is totally free of pests and disease, and does not serve as an intermediate host for pests or diseases of other plants.

(vi) Its strong fibrous root system penetrates and binds the soil up to depth of 3 m and can withstand the effects of tunnelling and cracking.

(vii) It is perennial and requires minimal maintenance.

(viii) It can grow in all types of soil such as clayey, sandy shales, gravels etc.

Vetiveria zizanioides — Planting slip — Two year old, two meter root system-Mpa75 equivalent to 1/6 of the mild steel

Tissue cultivation vetiver grass

Cross section through a two year old hedgerow — 3 years old, extreme drought conditions

Longitudinal section through hedgerow — Newly planted vetiver hedgerow — Vetiver nursery

6 year old vetiver,

Planting vetiver on slope

Vetiver in florescence. In many cases vetiver never flowers, but when it does, it produces rather beautiful sterile seeded flowers

4.6 LIMITATIONS OF VEGETATION

The limitations of vegetation are: -

- Vegetation growth in a troubled slope is occasionally met with problems like absence of initial binding material in the soil such as in case of silty or sandy slope. In such conditions, a reinforcing material is required for its root system to enable vegetation to grow.
- Vegetation is of little use in preventing deep-seated, rotational slope failures.
- It is vulnerable to disease, drought and trampling etc. It is also difficult to establish it on steep slopes.
- Selecting the right type of vegetation in a given situation may not be a easy task.
- Planting and maintaining the vegetation properly is also a specialized job.

5.0 REINFORCED VEGETATION

Reinforced vegetation by using geotextile & other materials for enhancement of slope stability is a proven method that is being practised very widely. Normally, the vegetation growth on a slope depends upon several factors like retention of soil moisture, slope angle, constituent soil particle size, velocity of surface runoff, type of soil cover etc. For various slopes, available material and site situation may not provide adequate conditions for the desired dense and sustained vegetation growth. Also, in case of steep and high slopes like those of a cliff face, vegetation growth may not always be sufficient due to inadequate or washed out soil cover and absence of root reinforcing system. In all such slopes, geotextiles provide an unique root reinforcement to induce vegetation, by holding and conserving soil cover, reducing velocity of flow and conserving soil particles. Any material used for improving the soil behaviour, thereby preventing soil erosion is termed as geo-textiles. Synthetics, jute and coir are used as geotextiles. In fact, the concept of geo-textile is not very new. Accordingly, to historical findings, wood, bamboo, straw, reed, wood, and animal hide were used as geo-textiles in ancient times too. In industrial age synthetic material like polyester, polyamide, polypropylene and polyethylene took their place as geo-textiles for engineering applications due to their long life. These geo-textiles, however, have their own disadvantages. Their production causes air and water pollution while their non-biodegradability is responsible for increasing soil pollution.

In an age of growing environment awareness, the use of eco-friendly biodegradable material as geo-textile started gaining momentum and natural geo-textiles like jute and coir fibre came into picture. In natural geo-textiles, lignin content in a fibre determines the resistance to microbial attack. Coir geo-textile has a lignin content of about 46 per cent compared to 17 percent in jute.

5.1 EROSION CONTROL WITH NATURAL GEOTEXTILES

Natural geotextiles are made up of natural fibres obtained from animals (e.g. wool and silk) or plant (vegetable fibres). The vegetable fibres can be grouped into three classes namely bast fibres, leaf fibres and seed/fruit fibres. Bast fibres are extracted from stems of plants e.g. jute, flax, hemp and ramie. Leaf fibres are obtained from leaves of plants e.g. sisal, abace and henequen. Seed fibres are extracted from seeds/fruits of plants e.g. cotton and coir. The bast fibres are much softer than leaf fibres and hence enjoy a more diversified end-use.

Natural geotextiles such as jute and coir etc. can be used where vegetation by the methods described above poses difficulty due to site conditions. Natural fibre (jute/coir netting) geotextiles function as a series of small check dams in reducing the velocity of the water falling down the slope and check erosion. Natural geotextiles have a number of inherent advantages:

i) reduce the velocity of flow and thus the erosive effects of runoff.

ii) give protection against rain splash.

iii) mitigate the extremes of temperature.

iv) maintain humidity in the soil.

v) biodegradable, adding useful mulch to the soil.

5.1.1 JUTE GEOTEXTILES

India is very large producer of jute, therefore, cost of jute geotextiles is quite low as compared to synthetic geotextiles. Jute geotextiles are organic in nature, highly biodegradable and decompose generally in 18 to 24 month. Decomposed jute products are non-toxic which fertilizes plant life. Compared to synthetic geotextiles, jute geotextiles are heavier, thicker and percentage elongation at break is comparatively much smaller. The extreme flexibility of jute fabric allows it to bend, fold and versatile in easy spreading. In the event of a tear occurring, the damage remains localise and does not spread progressively. For extending life of jute, it is treated with Phenol solution which acts as a rot resistant. Also, reduction in tensile strength of phenol treated jute with time is much less than as compared to untreated jute. It is highly water absorbent and it can absorb water 5 times its weight. For detailed guidelines on application of jute geotextiles in erosion control, IS code 14986:20001 may be referred to.

5.1.2 COMPOSITION OF JUTE

The main constituents of jute by weight are the following:

Constituents		Percentage by weight
Alpha cellulose	:	60%
Hemi cellulose	:	20%
Lignin	:	17%
Minerals, fatty & waxy substance		
Nitrogenous matter etc.	:	3%

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

5.1.3 PROPERTIES OF JUTE:

Physical

- Jute is a coarse bast fibre and consists of numerous individual filaments which form a meshy structure.
- Fibre has varying length & fineness.
- Jute is a strong but not rigid fibre.
- The fibre is stiff and rugged.
- The fibre is a very good insulator of heat and electricity.
- The fibre is stable to sunlight.
- The fibre has a moderately high density.

Chemical

- The major component of the fibre are lignin, holo-cellulose, Gums and waxes etc.
- The fibre is hygroscopic and can absorb moisture by as much as five times its own dry weight.
- Jute does not degrade on exposure to sun light.
- Not very much sensitive to chemical attack.

Environment

- Jute is an annually renewable crop.
- Jute agriculture absorbs carbon-dioxide and thus reduces green house effect.
- Jute is non-toxic and safe ecologically. No harmful emission and toxic solid waste are generated during jute agriculture and jute processing.
- Jute products are biodegradable leaving a fibrous residue which improves the soil structure and fertility. The same phenomenon is prevalent during jute agriculture when leaves shed from jute plants are composted in the soil naturally.
- There is no scope of acidification of atmosphere and depletion of ozone due to activities concerning jute agriculture and processing.
- During bio-degradation of jute products, no harmful emission of gases or discharge of toxic chemicals take place.
- Jute product can be re-circulated several times and after this, the product can be recycled. This singular phenomenon makes both jute agriculture and processing energy friendly.
- Jute agriculture or processing hardly depletes any natural resource.
- Jute does not draw upon the valuable nitrogenous reserves.
- No chance for any human toxicity and permanent aquatic toxicity. Jute waste can profitably be used to generate bio-gas and electrical energy.
- Saves precious hydro-carbons.

5.1.4 TYPICAL PROPERTIES OF JUTE FIBRE AND JUTE FABRIC

Basic requirements of jute fibres when used in producing good quality geotextiles are high tensile strength and elastic modulus. Typical properties of jute fibres & jute fabrics made of good quality jute fibres are given in table below. Compared to other synthetic geotextiles, the jute fabric is found heavier.

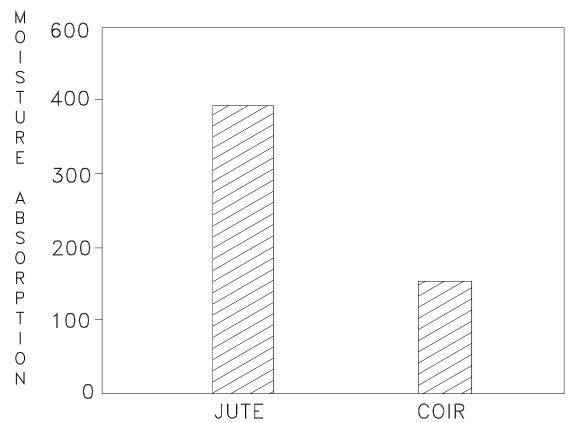
Typical Properties of Jute Fibres

Property	**Range of Value**
Fibre length, mm	180-800
Fibre diameter,mm	0.10-0.20

Specific Gravity	1.0 – 1.04
Bulk Density, Kg/m^3	120-140
Ultimate tensile strength, N/mm^2	250-350
Modulus of elasticity, kN/mm^2	26-32
Elongation at break (%)	2-3
Water absorption(%)	25 - 40

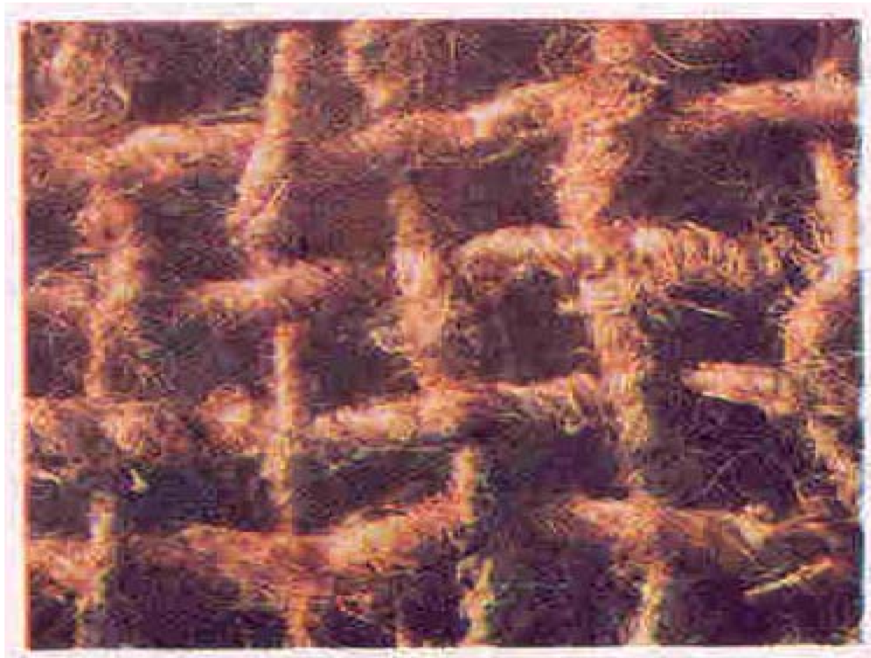
Typical Properties of Jute Fabric

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

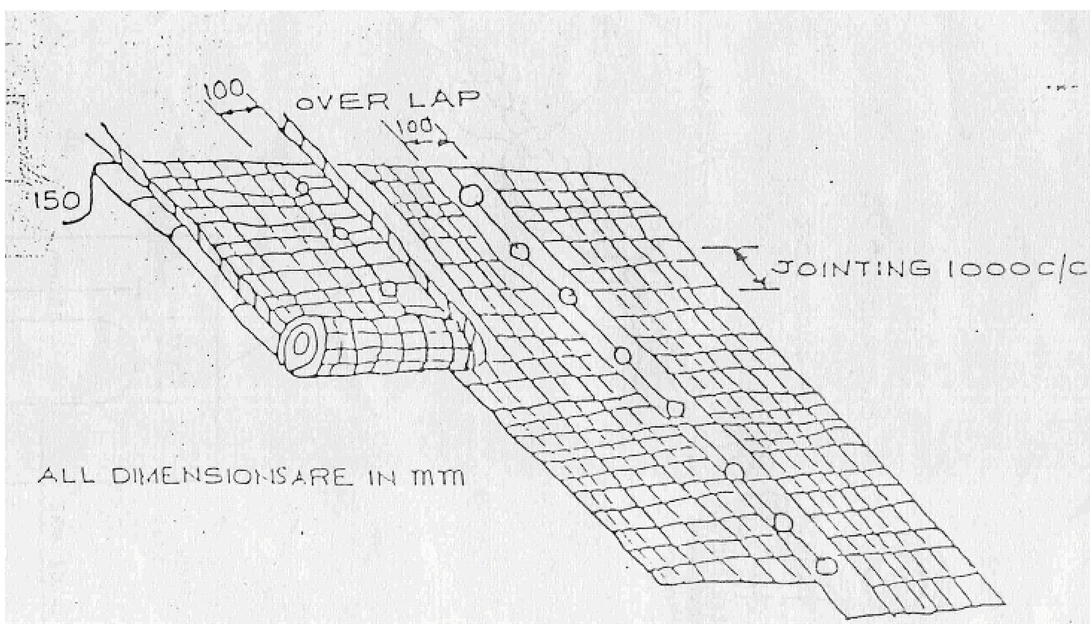


Moisture absorption capacity of various natural fibres

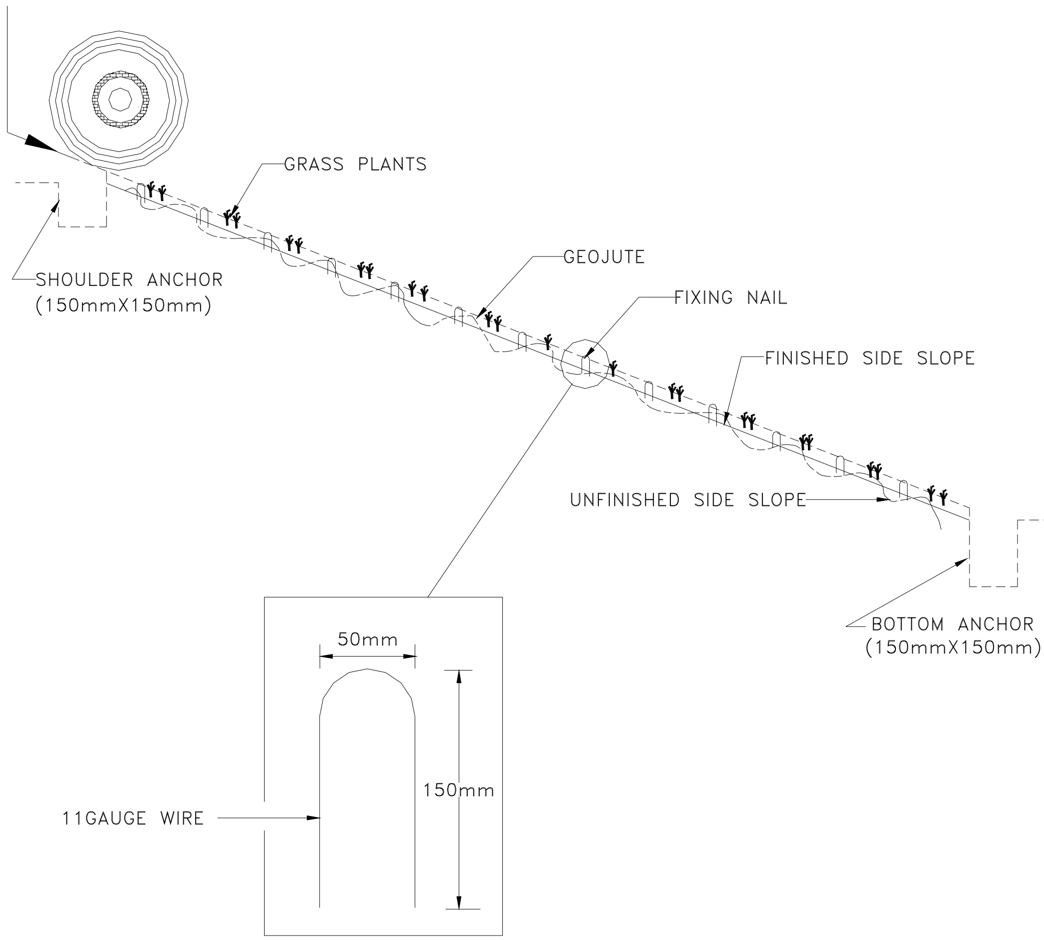
(After Oosthuizen and Kruger, 1994)



Close-up view of conventional jute geotextile (geojute)



Jointing and overlapping of geojute



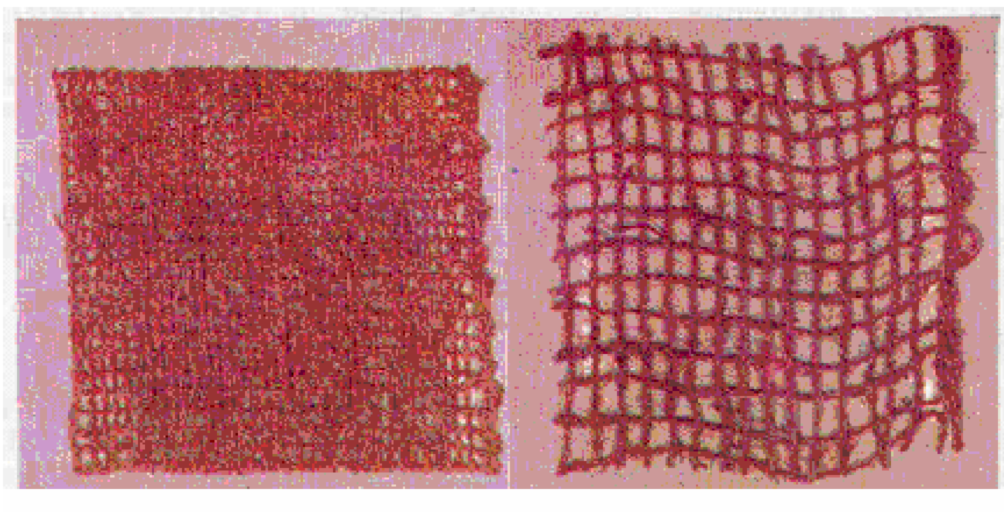
Installation of Geojute

5.2 COIR GEOTEXTILES

Coir is a natural organic product and biodegradable. Coir fibre is obtained from coconut husks. Coir fibre is strong, hard, has high lignin content, with good properties for being spun & woven into matting, decomposes slowly and eventually disintegrates leaving nothing but humus. It is naturally resistant to rot, mounds and moisture. These characteristics make it suited for use in Geotextiles. No chemical treatment is required and there is no synthetic substance to be added during slope applications.

Coir geotextiles degrade slowly as compared to jute geotextiles. They provide good support on slopes for a longer time than jute geotextiles and there is no need for postinstallation work. It is resistant to saline water and provides an ecological niche for a rapid re-establishment of the vegetation cover. Coir resembles natural soil in its capacity to absorb solar radiation. This means that there is no risk of excessive heating as happens sometimes in the case of synthetics. Coir netting breaks up run-off heavy rains and dissipates the energy of flowing water. Coir also promote the growth of new vegetation by absorbing water and preventing the top soil from drying out.

Coir Geo textiles are available in densities from 400 to 1400 g/m^2. The length of rolls is 50 m and width of rolls is 1 m, 2m, 3 m or 4 m. A higher density means a tighter mesh and less open area in the netting.



Coir Geotextile

Typical Coir Fibers

5.3 INSTALLATION TECHNIQUE OF NATURAL GEOTEXTILE

Slope over which geo-jute or coir netting is proposed to be laid is levelled to remove any sharp unevenness such as deep irregular gullies, projected stones etc. that may be present. Thereafter, seeds of selected varieties of deep rooted & quick growing local grass are spread over the slope or cutting. Half the quantity of seeds is spread prior to covering the slope with the geo-jute or coir netting and other half subsequent to laying the netting.

The roll of the geo-jute or coir netting is spread out over the slope. The edges of the netting (geo-jute) are firmly anchored into the ground. This anchoring can be done in a number of ways. Small trenches of 15 to 20 cm depth may be dug and all the edges buried in the trench, which is backfilled with soil and tamped. Alternatively, lengthwise edges are given over lap of 15 cm and anchored by wire staples driven into the ground. In case, the slopes are deficient in nutrients, initial application of a suitable fertiliser is desirable. It is advantageous to take up the work of promoting vegetative growth on denuded slope just before the onset of regular monsoon showers. Normally, the slopes covered with netting should be fenced off to prevent cattle from moving over the area.

6.0 EROSION CONTROL WITH GEOSYNTHETICS

6.1 GEO-MESHES OR GEO-NETS

These are flexible extruded polymer meshes of high-density polyethylene or polypropylene made by special process. In its open mesh formation, it has integrally formed joints or fused joints giving its dimensional stability and stiffness. The geogrid mesh is non-biodegradable, immune to naturally occurring acidic, alkaline or saline environment. Geogrid mesh is generally stabilized against ultraviolet ray degradation for continuous exposure of about 10 years by using finely divided carbon black (defined as retaining 75% of its original strength after 10 years of life). The geogrid is generally black in colour. In case, alternate stabilization material in place of carbon black is used to provide an environment friendly colour, it should provide desired protection using chemical stabilizer of adequate concentration. Geogrids shall be such that they are non-food substitute for rodents.

With geogrid, extreme high density grass growth (4000-5000 kg/ha) is possible, which may not be feasible with normal turfing (1500 kg/ha). Most of ordinary turfing fails to provide erosion control on repetitive change in climate & prolonged drought. In particular, use of polymer geogrid provides long term protection as it is non biodegradable, non-corrosive and inert product. It has a long life and high success rate for vegetation growth year after year. Natural geotextiles used for such application invariably biodegrade within a short period comparatively. With increasingly erratic weather conditions, successful vegetation growth and its maintenance depends on chance rainfall etc, and hence longer life of reinforcing material is definitely essential for vegetation protection.

6.2 REINFORCEMENT MECHANISM

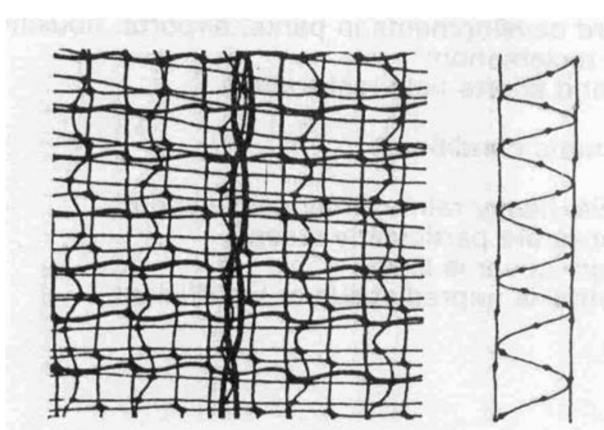
Shallow eroding slopes can be caused by excessive surface runoff, washing soil particles out and depositing them at the based of the slope. Geosynthetics with aperture 25 mm to 55 mm are used extensively to prevent the mass migration of soil particles. Initially, the grid breaks down the flow of water with its profile by providing numerous small check dams and holds the structure of soil in place by reducing the velocity of flow. When sowed with vegetative plants like grass or shrubs, the net reinforced soil cake provides erosion protection to these young plants. Once vegetation is established, the grid acts as a structural matrix for the root mat with intervened roots in net, and creates an extremely strong flexible skin to the slope. With provision of polymer geogrid for root reinforcements, extremely high density of grass growth (4500-5500 kg/ha) can be achieved.

6.3 METHODOLOGY OF PLACEMENT OF GEOGRID

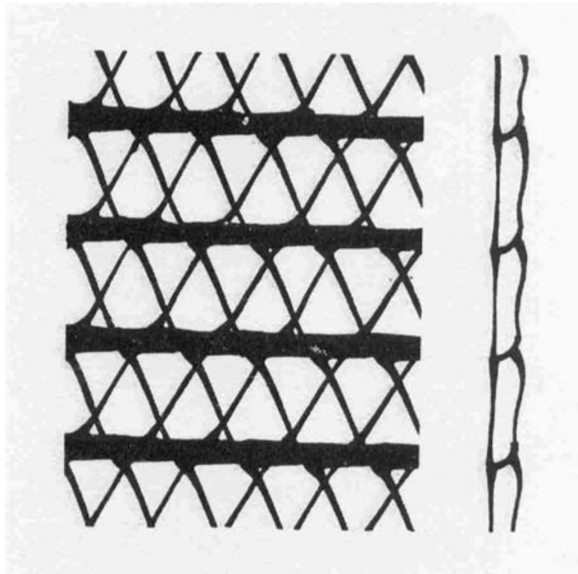
The geogrid mesh is anchored in trenches to provide additional protection against incidental damage/slip or slide. The vegetation may grow automatically with or without sowing. However, to facilitate immediate grass growth, sowing is recommended.

Horizontal creeping variety of grass such as *Doob, Bhabhar, Napier* etc have proved effective in Indian condition. Availability of root moisture is important for initial grass growth and hence sprinkling of water or use of natural rainfall is highly recommended. Application of fertiliser is often resorted to provide free nitrogen for speedy grass growth.

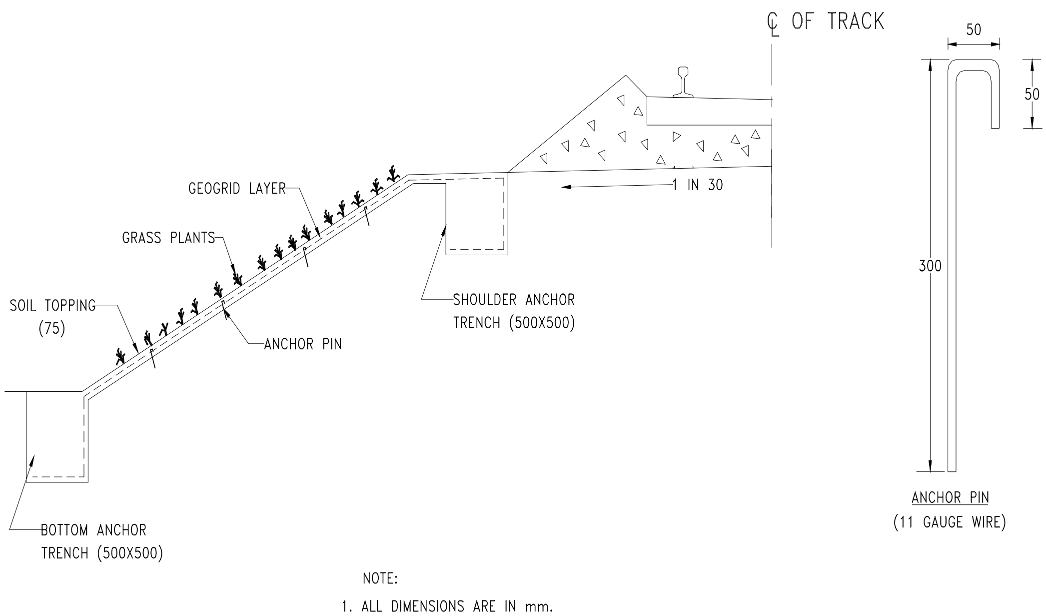
- The installation of geogrid mesh is simple and done with steel or wooden pins/pegs to hold the light weight net in position.
- Prior to laying, the site should be dressed and all pre-existing gullies and cavities are filled up.
- While dressing and preparing side slopes, a hand held vibro-compactor can be used for ensuring compaction of loose fill. Alternatively, a typical mechanical rammer compactor should be used, if the vibro-compactor is not available.
- Key trenches should be cut at the top (on the shoulder) and base of the slope.
- The geogrid mesh is laid on the top trench and soil filled back, this will serve as anchorage.
- The geogrid roll should be laid with surface contact at all points to enable the fullest protection.
- When the roll reaches the bottom trench, the roll is cut to size and anchored.
- Wooden /metallic pins/staples should be pushed into the ground at spacing specified by manufacturer and at overlap points.
- With watering and implantation of grass seed/turf, the roots establish quickly.



Typical Geomat



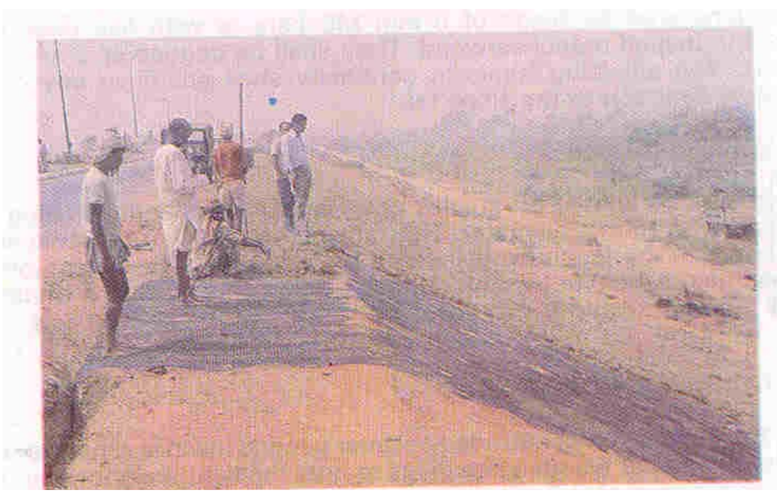
Typical geomat



Installation of Geogrid

Site Preparation

Trench filling



Placing geogrid mesh

7.0 ECONOMICS

Since the stability and performance of slope is primarily dependent on the integrity of exposed surface, erosion control should be given due consideration, while conceiving and designing banks/cuttings through erodible strata. Following aspects which may have important bearing on overall economics of the project, must be borne in mind in design.

- severity of the problem and danger to stability posed by erosion.
- erosion control through other measures e.g. slope easing, catch water drains, etc.
- potential exploitation of local materials like jute/coir mats, bamboo strips, etc.

In severe situations such as drought, etc. when vegetation growth cannot be guaranteed for extended periods, use of polymeric geo-mesh may have to be resorted to, even though costly.

8.0 SLECTION OF EROSION CONTROL SYSTEM

Selection of a particular erosion control system depends on specific site situation, hence no standard yardstick can be laid down to choose a particular system. However, following suggestions may kept in view for general guidance:

Situation	**Height of bank/cutting**	**Rainfall/Velocity of water**	**Erosion Control system**
Bank/cutting made by cohesive soil /fine grain soil (CL,CI,CH, ML,MI, MH)	Less than 6 m	Normal or less than normal (3 m/sec or less)	Vegetation shallow rooted or deep rooted
Bank/cutting made by cohesionless soil (sandy / gravely soil)	Less than 6 m	Normal or less than normal (3 m/sec or less)	Vegetation with 0.25 m to 0.30 m thick clayey soil as a cover for vegetation
Bank/cutting made by black cotton soil	Less than 6 m	Normal or less than normal (3 m/sec or less)	Vegetation with 0.25 m to 0.30 m thick clayey soil as a cover for vegetation

Bank/cutting (all type of soils)	More than 6 m	Normal/heavy (3 m/sec or more)	Reinforced vegetation or reinforced protection
Bank/cutting made by any type of soil and submerged /effect of wave uplift /continuous flooding	Any height	Normal/heavy (3 m/sec or more)	Boulder pitching with or without geotextiles, geo-cell up to flooded height

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(PART – B)

DRAINAGE OF RAILWAY FORMATION

1.0 INTRODUCTION

Drainage is defined as interception, collection and disposal of water away from track. Drainage is the most important factor in track maintenance and for stability of banks/cuttings. When water seeps into the formation, it weakens the bonds between the soil particles, softens the soil and results in creation of ballast pockets. On one hand, ingress of water into bank/cutting adds to weight of soil mass trying to slide, thereby increasing propensity for slope-slide, on the other hand, it reduces shear strength of soil, thereby decreasing factor of safety for stability of slope. Therefore, quick disposal of water from formation top/slopes is very essential.

Drainage system should be effective in preventing the stagnation of water and allow quick disposal of water. At present, drainage is not being given its due importance in field. Provisions relating to drainage have been detailed in various guidelines issued by RDSO from time to time, however, the present Guidelines highlight the salient features of drainage arrangement in embankment as well as cuttings.

2.0 SOURCES OF WATER ENTERING TRACK SUBSTRUCTURE

Water percolates into the sub-grade by following ways-

a) By gravity:

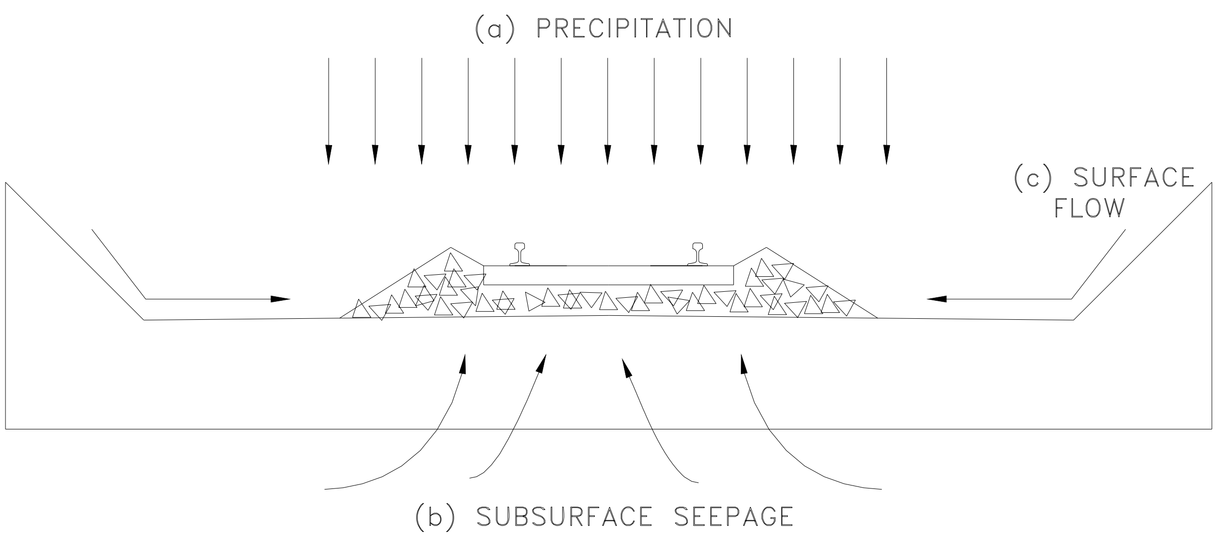
Water due to rains etc. moves in the sub-grade by gravity. This movement of water is resisted by permeability of soil. The effective methods of removal of water from formation are providing proper cross slope on top of formation, side drain, provision of blanket and turfing of side slopes.

b) **By capillary action:**

Water rises into the sub-grade by capillary action from the source of water below. It can be prevented by providing a pervious layer in the bank, which causes a capillary break.

c) **By seepage of water from adjacent area:**

In this case, water enters into the sub-grade by seepage from some source of water nearby. It can be reduced by diverting original source, providing catch water drains, by inverted filter etc.



SOURCES OF WATER ENTERING TRACK SUBSTRUCTURE

3.0 NECESSITY OF EFFECTIVE DRAINAGE

Water is main culprit in damaging banks/cuttings as it reduces shear strength, results in erosion and adds to the weight of slope. Therefore, effective drainage is the most important aspect to safeguard the slope. As already explained above, there are three sources of entering water into the track sub structure viz**.** precipitation, surface flow, and sub-surface seepage. The ingress of water into formation leads to puncturing of ballast, results in mud pumping, erodes soil & ultimately causing failure of slope. In cuttings, non-provision of drainage systems results in boulder falls and landslides etc. In view of this, drainage system should be carefully planned, designed and provided.

4.0 GENERAL CONSIDERATIONS IN DRAINAGE

For effective drainage, following points may be kept in view:

- Top of formation should be finished to a cross slope of 1 in 30 from center of formation to both sides in case of single line as well as double line. In case of multiple lines, the cross slope should be from one end to other toward cess/drains provided in between. (Ref: para 4.2.4 of Guidelines for Earthwork in Railway Projects, July 2003)
- Once the top surface of the formation has been finished to proper slope and level, movement of material vehicle for transportation of ballast, sleepers etc. should be avoided, these movements will cause development of unevenness, ruts on the surface which will accumulate water and weaken the formation. (Ref: para 6.7.1 (i) of Guidelines for Earthwork in Railway Projects, July 2003)
- At locations, where the water table is high and the fill soil is fine grained, it may be desirable to provide a granular layer of about 30 cm thickness at the base, above subsoil across the full width of formation. (Ref: para 6.7.1 (l) of Guidelines for Earthwork in Railway Projects, July 2003)
- Blanket material should conform to specification laid down.
- In case of all new construction, minimum height of embankment should not be less than 1 m. (Ref: para 4.2.9 of Guidelines for Earthwork in Railway Projects, July 2003)
- In case of double line, central drain between two tracks should be avoided. It is not only difficult to construct but also difficult to maintain due to continuous vibrations caused by traffic, problem of proper curing of concrete etc. (Ref: para 6.5.1 of Guidelines for Earthwork in Railway Projects, July 2003)
- In case of double line, if distance between adjacent tracks is large enough, suitable slope should be provided in ground to make rain water flow in natural manner. (Ref: para 6.5.1 of Guidelines for Earthwork in Railway Projects, July 2003)

- In cuttings, properly designed side drains and catch water drains of adequate capacity should be provided. (Ref: para 6.5.2.1 of Guidelines for Earthwork in Railway Projects, July 2003)
- In yard, surface drains should generally be open for ease of cleaning & inspection.
- Overhauling & deep screening of ballast should be carried out at prescribed interval.
- Drains provided should be cleaned and repaired regularly, preferably before monsoon.

5.0 CONVENTIONAL DRAINAGE SYSTEMS

5.1 SURFACE DRAINAGE

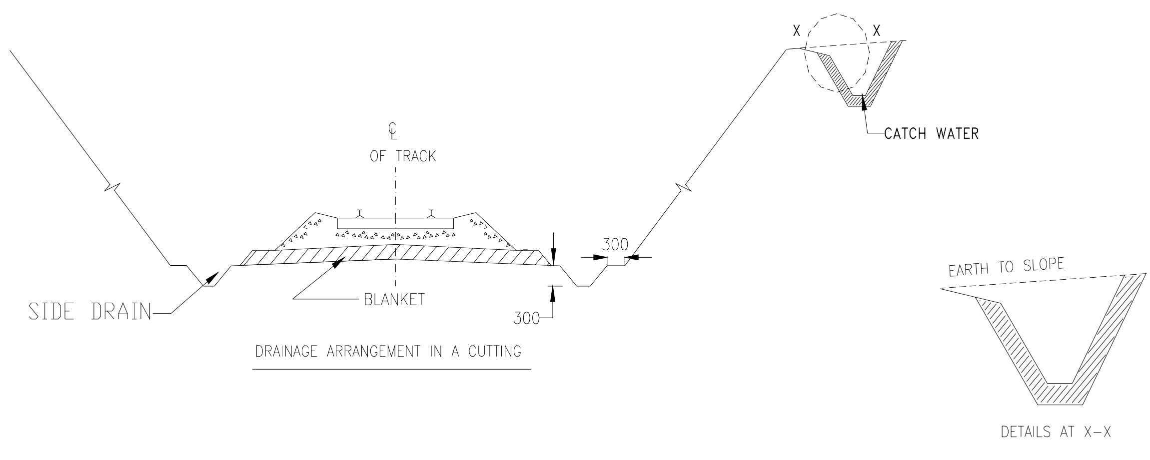
Control of surface drainage is one of the most important factor in embankment design and maintenance. Main purpose of the surface drainage system is to collect water before it reaches the problem areas, diverting the surface water away from formation/slope and reduce infiltration of water. Generally, provision of 1 in 30 cross slope on top of formation towards cess, side and catch water drains, culverts and bridges comes under this category.

5.1.1 SIDE DRAINS

Normally, there is no need of side drains in case of embankment. However, when height of bank is such that the blanket layer goes below normal ground level, side drains may be required along the track at suitable distance so that the track alignment does not become the channel for flow of ground surface water. In case of cuttings, properly designed side drains of required water carrying capacity are to be provided. As blanket material is to be placed like fill/embankment, top of side drains has to remain below the bottom of the blanket material. (Ref: para 6.5.2.1 of Guidelines for Earthwork in Railway Projects, July 2003)

5.1.2 CATCH WATER DRAINS

Surface water flowing from top of hill slope towards the track is controlled by provision of catch water drains. Non-provision of catch water drain will result in erosion of slope and may lead to slope failure. Moreover, side drains will have to be designed for carrying huge quantity of water, which is generally not a practically feasible proposition. Therefore, it is essential to intercept and divert the water coming from the hill slopes, accordingly, catch water drains are provided running almost parallel to the track upto a point where the water can be safely discharged off. In some of the situations, depending on topography of top of cutting, there may be requirement of construction of net of small catch water drains which are subsequently connected to main catch water drain. Catch water drains should be made pucca/lined with impervious flexible material locally available. (Ref: para 6.5.2.2 of Guidelines for Earthwork in Railway Projects, July 2003)



Catch water drains should be located slightly away (as per site conditions) from the top edge of cutting and water flow should be led into the nearby culvert or natural low ground. Alignment plan, longitudinal section and soil survey records of catch water drain should be updated from time to time as per development in the area of influence. Regular inspection, and maintenance, especially to plug the seepage of water before monsoon is necessary. Some additional salient features to be observed while constructing catch water drains are as follows:

- Catch water drains should have adequate slope to ensure development of self-cleansing velocity. (Ref: para 6.5.2.2 (a) of Guidelines for Earthwork in Railway Projects, July 2003)
- Catch water drains should not have any weep hole. (Ref: para 6.5.2.2 (a) of Guidelines for Earthwork in Railway Projects, July 2003)
- The expansion joints, if provided, should be sealed with bituminous concrete. (Ref: para 6.5.2.2 (a) of Guidelines for Earthwork in Railway Projects, July 2003)
- Regular inspection and maintenance work, specially before onset of monsoon, should be carried out to plug seepage of water. (Ref: para 6.5.2.2 (a) of Guidelines for Earthwork in Railway Projects, July 2003)
- Catch water drains should have well designed out fall with protection against tail-end erosion. (Ref: para 6.5.2.2 (a) of Guidelines for Earthwork in Railway Projects, July 2003)

Though capacity and section of the drain will depend on terrain characteristics, catchment area and intensity of annual rainfall etc. but following parameters are important for design of catch water drains: (Ref: para 6.5.2.2 (a) of Guidelines for Earthwork in Railway Projects, July 2003)

- Intensity and duration of rain fall.
- Catchment area- shape, size, rate of infiltration etc.
- Velocity of flow which should satisfy the Manning's formula.
- Minimum gradient of drain should be in range of 1 in 400 to 1 in 700.
- Normally catch water drains should have trapezoidal cross section.
- Catch water drain should not be given gradient more than about , 1 in 50 (but in no case more than 1 in 33) to avoid high water velocity and possibility of washout of lining material
- Rugosity coefficient should be about 0.03.

- Discharge capacity of the catch water drain can be expressed by the Manning's formula given below:

  $$\mathbf{Q = 1 / n\ A\ R^{2/3}\ S^{1/2}}$$

  and

  $$\mathbf{V = 1 / n\ R^{2/3}\ S^{1/2}}$$

  Where:-

  Q = discharge in cum/sec

  V = mean velocity in m/sec

  n = Manning's roughness coefficient

  R = A/P where, R is Hydraulic radius in m,

  A = area of the flow cross- section in square metre

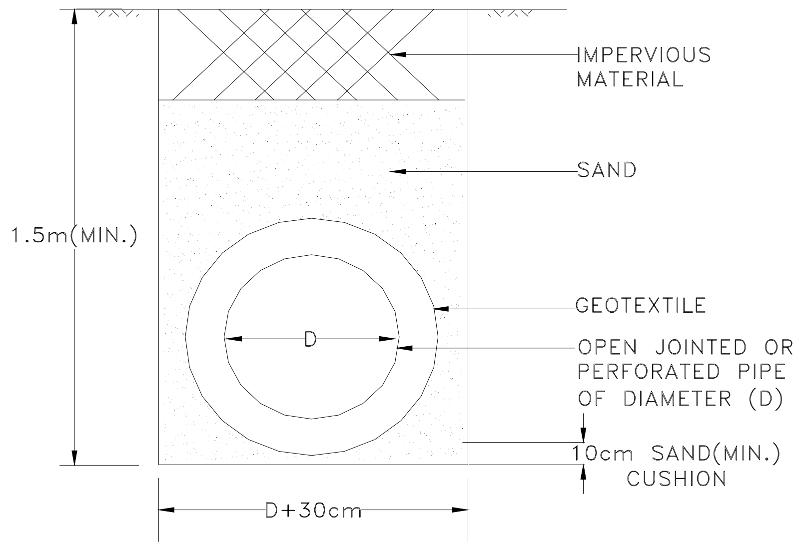
  P = wetted perimeter of cross-section

  S = energy slope of the channel, which is roughly taken as slope of drain bed

After estimation of quantity of water flowing into catch water drain, cross-section /dimensions of the catch water drain can be worked out.

5.2 SUB SURFACE DRAINS

Main objectives of sub surface drains are to lower the level of water table and to intercept or drain out underground water. The subsurface drains in cut slope can carry away the underground water which otherwise would have caused sloughing of the slope. In a cutting, sub-surface drains placed on each side of the formation can lower down the water table under the formation. The sub-surface drains may consist of perforated pipe or open jointed solid pipe in a trench with backfill around it or it may simply be free draining material in the trench without any pipe. The perforated pipes may be of metal/asbestos cement/cement concrete/PVC and un-perforated pipes of vitrified clay/cement concrete/asbestos cement. The subsurface drains can also be provided with geotextile either along the trench or around the pipe or both as shown in figure below.



TYPICAL SUB–SURFACE DRAINS WITH GEOTEXTILE

Outlet of pies should be carefully positioned to avoid possible blockage and protected with grating or screen securely fastened in place. For a length of 500 mm from the outlet end of the trench, pipe may not be provided with granular material but backfilled with excavated soil and thoroughly compacted so as to stop water directly percolating from backfill material around the pipe. The pipe in section should have no perforation.

The top of trench is sealed by providing impervious cap so that only subsurface water may enter the drain. In pipe drain, the internal diameter of pipe should not be less than 150 mm. Holes in the perforated pipes may be in one-half of the circumference only. Size of the holes may be close to D_{85} size of material surrounding the pipe (min. 3 mm and max. 6 mm). D_{85} stands for size of the sieve that allows 85% of the material to pass through it. The backfill may consist of sand-gravel material or crushed stone satisfying the grading in the table given below. The backfill should be free of organic material, clay balls and other deleterious material. The thickness of the backfill material around the pipe should not be less than 150 mm. Considering the minimum diameter of the pipe as 150 mm, the width of the trench shall not be less than 450 mm.

Backfill specification

Type of Grading Material	**Class-I**	**Class-II**	**Class-III**
Sieve size	**Fine silt / clay**	**Course silt to medium sand**	**Gravely sand**
53 mm	-	-	100
45 mm	-	-	97-100
26.5 mm	-	100	-
22.4 mm	-	95-100	50-100
11.2 mm	100	48-100	20-60
5.6 mm	92-100	28-54	4-32
2.8 mm	83-100	20-35	0-10
1.4 mm	59-96	-	0-5
710 µm	35-40	6-18	-
355 µm	14-40	2-9	-
180 µm	3-5	-	-
90 µm	0-5	0-4	0-3

In the table above, grading requirement of backfill material is in terms of percent by weight passing the sieve. Class-I grading filter material is to be used when the soil surrounding the trench is fine silt/clay or their mixture, class–II grading material when soil around the trench is coarse silt/medium sand/sandy soil and class –III grading material is used when the soil surrounding the trench is gravelly sand.

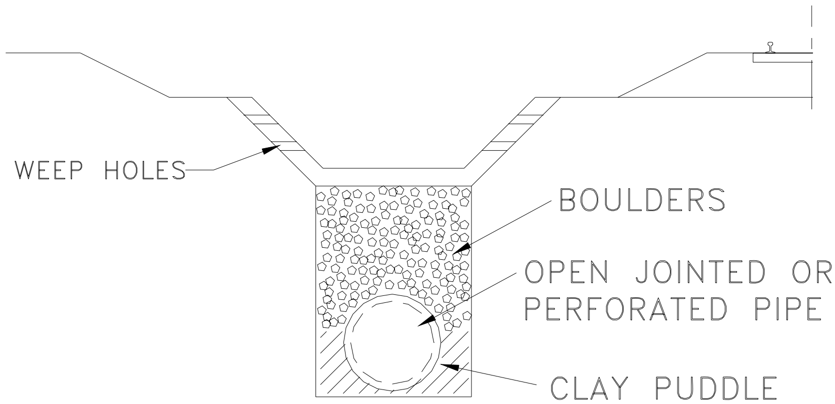
When only free draining material is used in trench, the main drain may be constructed without any pipe. The trench may be filled with material such as gravel or stone aggregate free from organic and deleterious substances. Its grading may be as given in the table below.

Grading of aggregate

Sieve size (mm)	% by weight passing the sieve
13.2	100
11.2	92-100
5.6	27-46
2.8	3-16
1.4	0-6

5.2.1 DEEP BOULDER DRAINS

In cuttings, where the sub-soil water table is high, it is advantageous to lower it well below the formation by providing deep boulder drains. In these cases, trenches 1.8 to 2.0 m deep are excavated on the hillside of the formation. Great care is needed during the excavation, as collapse of side of the trench will seriously affect safety of the adjoining track. After excavation of the trench is completed and a proper grade is provided for flow of seepage water, the trench is filled back with hand-packed boulders. The sides of the trenches should be lined with well-graded filter to avoid choking of the boulder inter-spaces by fines thus frustrating the very purpose of the deep drain. It has, however, been observed that after the initial construction of such boulder drains, periodical renovation should be undertaken at intervals of 8 to 10 years, depending on the soil conditions in the locality. Any negligence in renovating these drains causes rise of the water table again and in turn results in repetition of the earlier formation trouble. Sometimes in poor soils, the bed of the boulder drains settles locally at points and causes the dry weather flow to seep into the hill bench. While maintenance engineer presumes that the drain is functioning effectively in as much as the seepage at the outfall and of the drain, the seepage at the intermediate points may trigger off subsidence of the formation and slope failures.



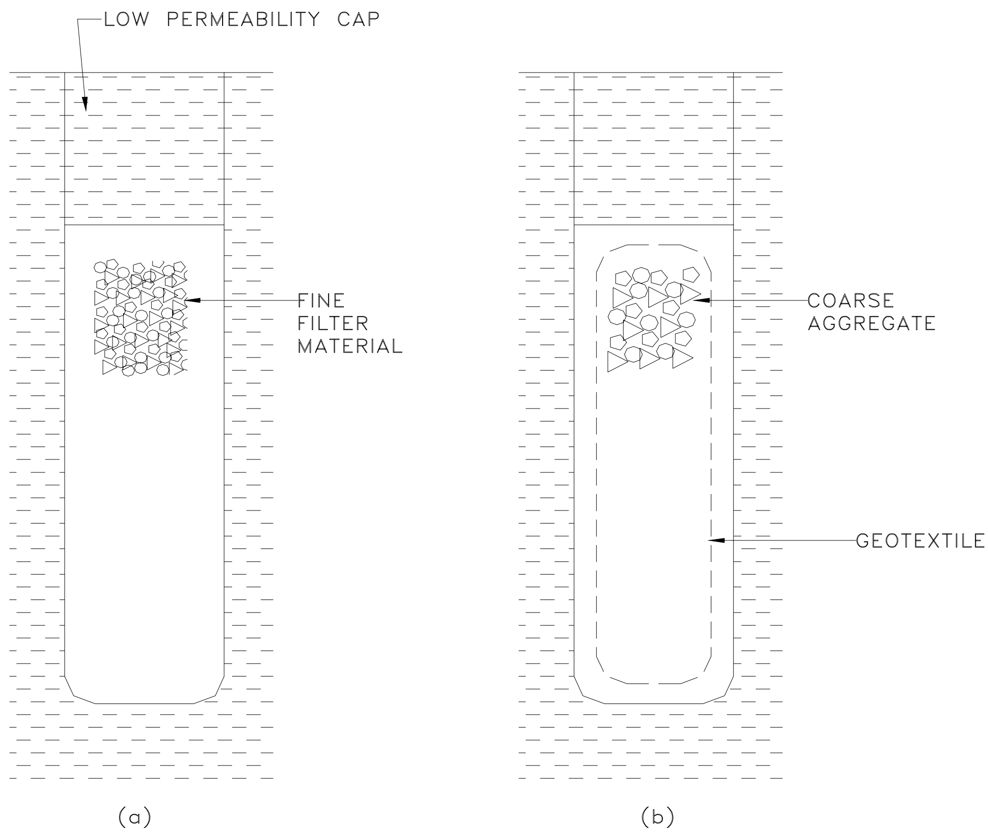
DEEP BOULDER DRAIN

In the usual design of boulder drains, cement concrete open jointed or perforated pipes are kept at the bottom of the drain and they get pushed to the side occasionally due to the swelling pressure developed by the formation soil with the effect that the drain is unable to the function well and in some cases the situation is further worsened. For this purpose, it is necessary to make the drain structurally strong enough to stand the swelling pressure of the formation soil exerted laterally, and to cover it with suitable filter material so as not to allow clay to find its way into the drain and to clog it.

Further, the design of the drain should permit easy cleaning periodically and repairs and replacements when necessary. Also, it should be possible to use standard size components capable of being handled manually.

5.2.2 FRENCH DRAINS

French drains, also called "Blind Drains", are without a drain pipe. These drains are lined with suitable filter material so that they are not chocked. French drains consist of a trench filled with suitable granular material to collect water from the surrounding soil and transmit it longitudinally. The granular material must satisfy the filter criteria. The depth should be adjusted to drain deepest ballast pockets.



FRENCH DRAIN EXAMPLES

5.2.3 HORIZONTAL DRAINS IN CUTTINGS

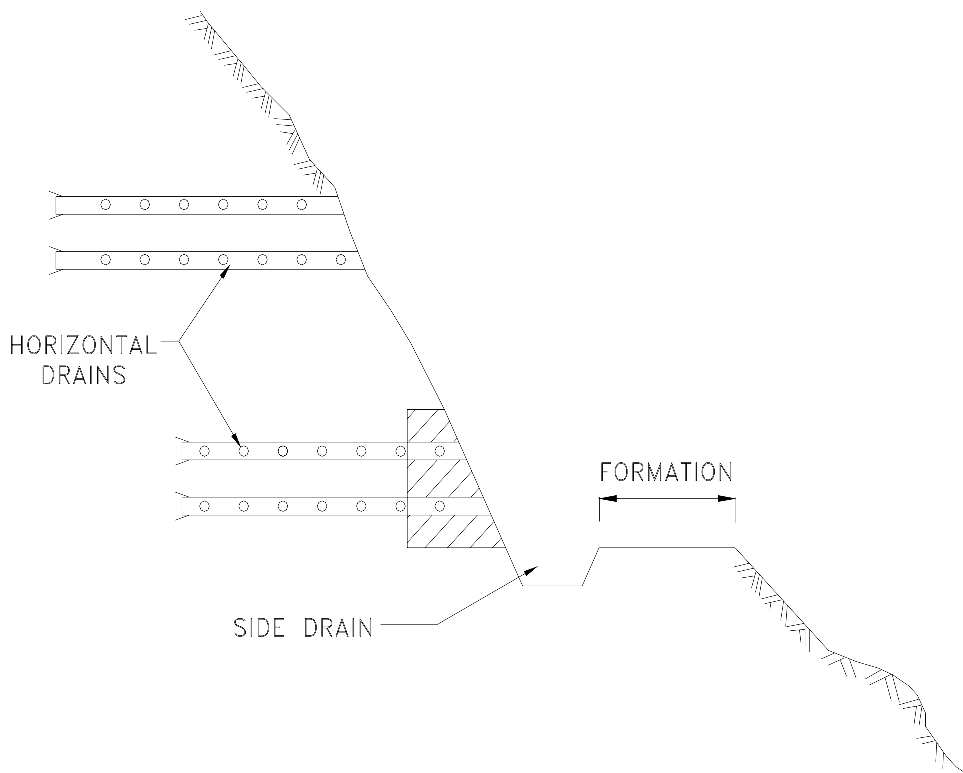
The purpose of these drains is to lower the water table and, hence, the water pressure to a level below that of potential failure surfaces. They are also very effective in reducing water pressures near the base of a suspected tension crack. Horizontal drains may be used in slopes where steady seepage of water is encountered. They provide channels for drainage of sub-surface water either from the sliding mass or from its source in the adjacent area. They bring about an improvement in slope stability in a short period of time.

The drain holes should be designed to extend behind the critical failure zone. The direction of the drain holes may depend to a large degree on the orientation of the critical discontinuities. Drain holes usually are inclined upward from the horizontal (about 5^0) . In weak, soft or weakly cemented rocks, however, the holes may have to be inclined slightly downward to prevent erosion at the drain hole outlet. In this case, a small pipe can be left in the mouth of the drain hole to retard erosion. The effectiveness of drains depends on the size, permeability and orientation of the discontinuities. The optimum drain hole design is to intersect the maximum number of discontinuities for each metre of hole drilled.

The spacing and positioning of these holes depends upon the geometry of the slope and upon the structural discontinuities within the rock mass. In a hard rock slope, water is generally transmitted along joints and horizontal drains can only be effective if they intersect such features. In the case of a soft rock or soil slope, the holes can be regularly spaced but a certain amount of trial and error is necessary in order to determine the optimum spacing. In either case, the installation of piezometers before the drilling of the horizontal holes is strongly recommended since, without an indication of the change in water level, the rock slope engineer will have no idea of the effectiveness of the measures which he has implemented.

Special drilling equipment is required for installation and some periodic maintenance is needed to prevent clogging. They are often 60 m to 100 m in length, thus providing drainage deep into the slope. Drain holes should be thoroughly cleaned of drill cuttings, mud, clay, and other materials; drain holes not properly cleaned may have their effectiveness reduced by 75 %. High-pressure air, water, and in some instances a detergent should be used to clean drain holes. If freezing conditions exist, drain hole outlets should be protected from ice build-up that could cause blockage. Insulating materials, such as straw, sawdust, gravel, or crushed rock, have been used for this purpose.

In highly fractured ground, care should be taken to ensure that caving does not block drain holes. If caving is significant, perforated or porous linings should be installed so that drain holes remain open. A typical sketch and arrangement of horizontal drain is given in figure below-



SLOTTED HORIZONTAL DRAIN

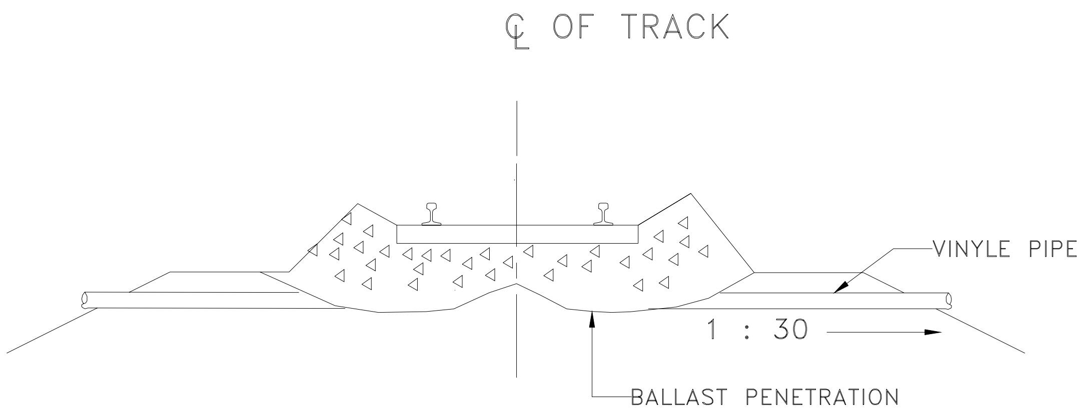
In nutshell-

- Horizontal drains can be used in a wide variety of soil types including weathered and fragmented rocks.
- The absence of damp spots on the rock face does not necessarily mean that unfavourable ground water conditions do not exist. Groundwater may evaporate before it becomes readily apparent on the face, particularly in dry climates.

- The maximum length of effective borings is 250 to 300 m, but at this length the end of the borehole may deviate from the intended position by several metres. This implies that it is difficult to guarantee that it will contact those aquifers in which the groundwater pressure is responsible for impairing the slope stability. Drainage boreholes also have a limited useful life.
- For horizontal drains, perforated or slotted rigid PVC pipes can be used. Perforations or slots are generally made on the upper two thirds of the pipes. A special chuck may have to be attached at the end of each pipe to prevent its slip out from the drill hole.
- Drain holes are drilled at an outward inclination with the horizontal.
- Sub-surface drainage by horizontal drains represents a more effective solution compared to the prohibitive cost of adopting other conventional corrective measures in situations where excess hydrostatic pressure is the main cause of slope failure.
- Adequate geological and geo-technical studies should be conducted to locate the water table, determine the material properties and evaluate the benefits from horizontal drain installation.
- In critical slopes, the horizontal drains may be placed behind retaining structures like breast walls and the discharge allowed to collect by draining across the wall into side drains.

5.2.4 PVC PIPE DRAINS

PVC drains which are commonly known as Poly Vinyl Chloride drains have been used to drain water from ballast pocket in Indian Railways. These drains are inserted from the side of the embankment after making a hole about 1.0 m to 2.5 m below rail level depending upon the ballast pockets. Experience has shown that these drains may get twisted and may become ineffective over a period of time. They may also give rise to twist defects in track and result in rough running.



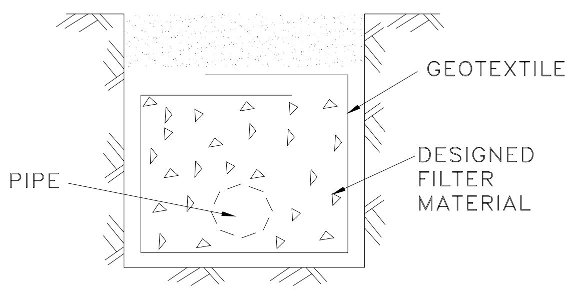
PVC VINYLE PIPE DRAIN

6.0 CONSTRUCTION GUIDELINES FOR TRENCH DRAIN

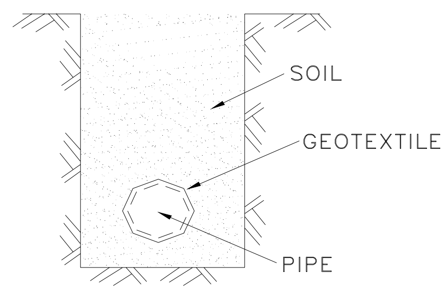
Trench excavation shall be done in accordance with details of the project plans. In all instances, excavation shall be done in such a way so as to prevent large voids from occurring in the sides and bottom of the trench. The graded surfaces shall be smooth and free of debris, depression or obstructions. The geotextiles shall be placed loosely with no wrinkles or folds, and with no void spaces between the geotextiles and the ground surface. Successive sheets of geotextiles shall be overlapped a minimum of 300 mm with the upstream sheet overlapping the downstream sheet.

In trenches equal to or greater than 300 mm in width, after placing the design filter material, the geotextiles shall be folded over the top of the backfill material in a manner to produce a minimum overlap of 300 mm. In trenches less than 300 mm but greater than 100 mm wide, the overlap shall be equal to the width of the trench. Where the trench is less than 100 mm, the geotextiles overlap shall be sewn or otherwise bonded. In case, the geotextiles gets damaged during installation or drainage aggregate placement, a geotextiles patch shall be placed over the damaged area with minimum 300 mm overlap all around or the specified seam overlap, whichever is greater.

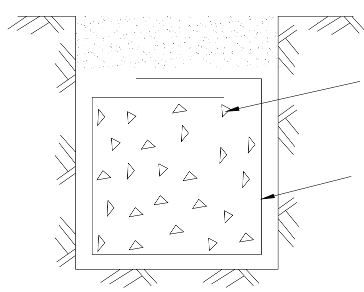
Placement of design filter material should proceed immediately after placement of the geotextile. The geotextile should be covered with a minimum of 300 mm of loosely placed aggregate prior to compaction. If a perforated collector pipe is to be installed in the trench, a bedding layer of drainage aggregate should be placed below the pipe, with the remainder of the aggregate placed to the minimum required construction depth. The aggregate should be compacted to a minimum of 90 percent of standard proctor density. Figures given below illustrate various geotextiles drainage application details.



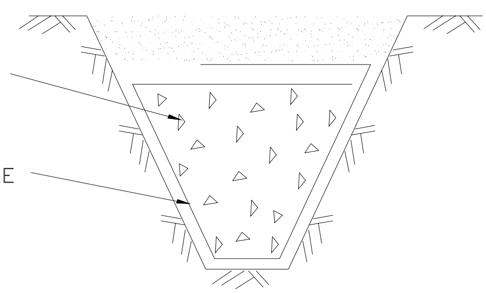
(a) Conventional pipe underdrain with Geotextile around stone



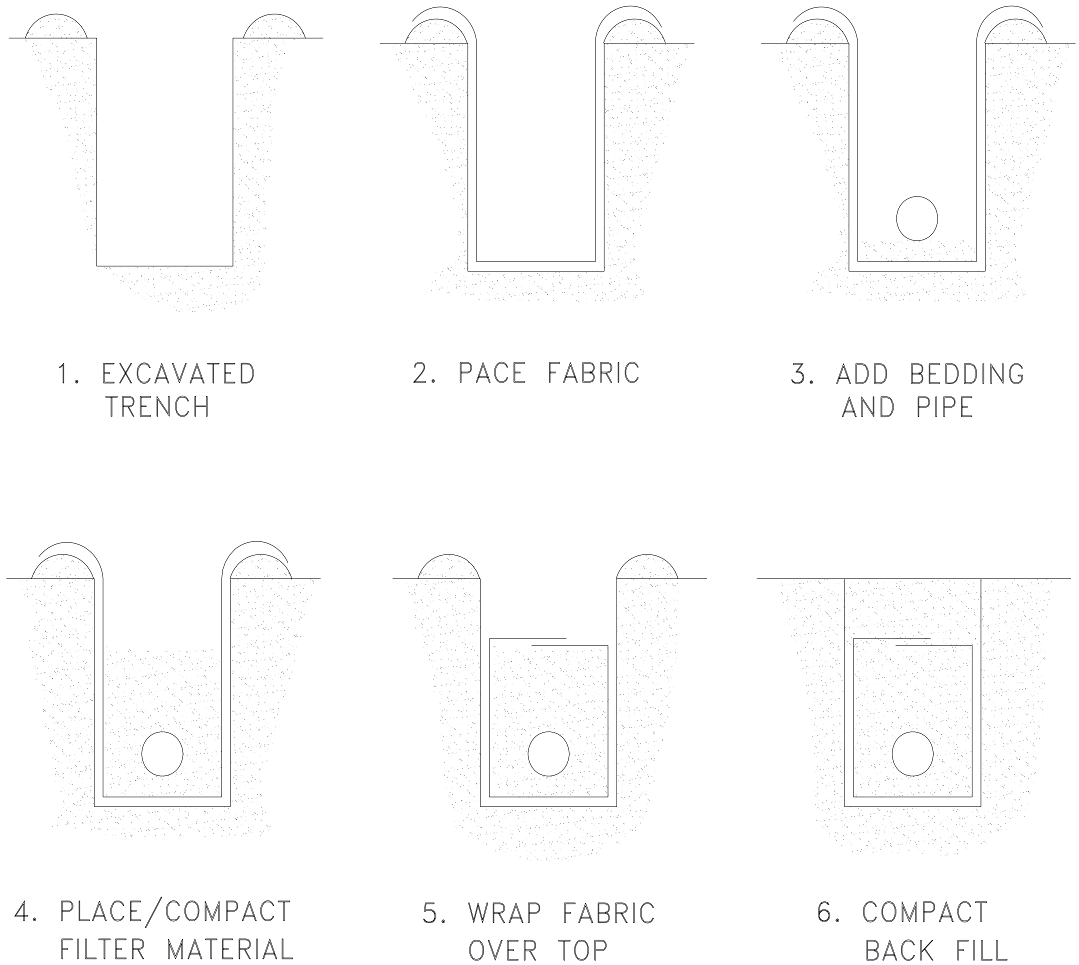
(b) Geotextile Wrapped pipe underdrain with sand backfill



(c) Geotextile Wrapped Stone (no pipe) Rectangular section



(d) Geotextile Wrapped Stone (no pipe) trapezoidal section



7.0 GEOTEXTILE APPLICATION IN SUBSURFACE DRAINAGE

Geotextiles are manufactured from polymers such as polypropylene and polyester. Other polymers that are sometimes used are polyethylene and polyamides but their natural resistance to aggressive environment is generally less than that of polypropylene and polyester. Geotextiles are often are separated in to two sub-categories , namely, woven and non-woven. Woven geotextiles are manufactured by weaving weft threads through warp threads. Warp threads are usually are stronger than the weft threads. Non-woven geotextiles are produced from randomly distributed continuous filaments or staple fibers, which are bonded together chemically, thermally, or mechanically.

7.1 TERMINOLOGY

7.1.1 Geotextile Permittivity

Permittivity ψ, is laboratory measured characteristics of the geotextiles. Once permittivity is known, the flow capacity of the geotextiles can be calculated for any given combination of hydraulic gradient and flow area. Permittivity is derived from Darcy's law as follows :

$$q = k_g . i_g . A$$

$$q = k_g . (\Delta h_g / t) . A$$

$$q = \psi \Delta h_g A$$

where,

k_g = Geotextile coefficient of permeability

i_g = hydraulic gradient , $\Delta h / t$

Δh_g = change in hydraulic head or head loss across the geotextile,

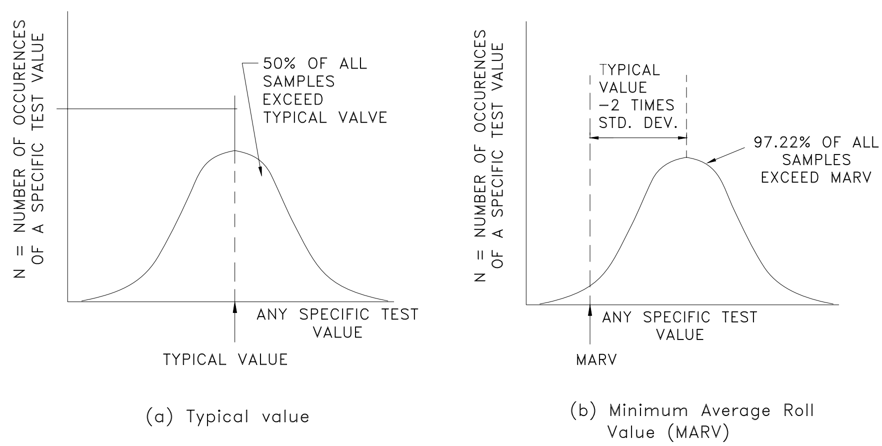
t = Geotextile thickness,

ψ = Geotextile permittivity, kg / t

Two characteristics, which influence geotextiles flow capacity are geotextiles permeability and thickness. Geotextile permittivity expresses these two characteristics in one variable. Permittivity should always be used to specify Geotextile. Permittivity is measured using the index test method ASTM D 4491/IS 14324, "Standard Test Methods for Water Permeability of Geotextiles by Permittivity". This test measures water flow rate through a geotextiles in an isolated conditions. Consequently, it does not provide any information about flow capacity of the soil/geotextiles system. Permeability is the characteristic that defines soil flow capacity and permittivity is the characteristic that defines geotextiles flow capacity. The flow capacity of the geotextiles must be so selected so as to be greater than the flow capacity of the soil. Therefore, geotextiles permittivity must be selected based on the soil permeability.

7.1.2 Typical and Minimum Average Roll Values

The "typical" value refers to the average or mean value. As shown in figure below, 50 per cent of the test results can be expected to exceed this value and 50 per cent can be expected to fall below this value. The "minimum average roll value" (MARV) is the value, which is exceeded by 97.72 per cent of the test data as shown in figure below. The MARV is derived statistically as the average value minus two standard deviations.



Statistical distribution of geotextile properties

A specification based on the MARV means that 97.72 per cent of the product is required to meet or exceed the specified values. In contrast, if a manufacture certifies to higher "typical" values only, lesser percentage of the product would meet the specified values.

The specifications based on the MARV ensures that the specified geotextiles will meet the project requirements. In addition, the MARV gives the design engineer a specific geotextiles property value, which can be verified through laboratory testing. Certifying to the MARV means that, theoretically, 2.28 per cent of the samples from each tested roll may exhibit properties below the certified value. However, the average property value of every roll delivered at the site will be equal or exceed the MARV.

7.1.3 Tensile strength

The single most important property of a geotextiles is its tensile strength (grab strength) . Invariably, all fabric applications rely on this property either as the primary function (as in reinforcement application) or as a secondary function (as in separation, filtration or drainage). The grab tensile test as per ASTM D 4632 is usually conducted to determine the tensile strength of the fabric.

7.1.4 Trapezoidal tear strength

Often during installation, geotextiles are subjected to tearing stresses. This test is carried out to determine resistance of geotextiles against tearing. The test is carried out as per ASTM D 4533 or IS:14293.

7.1.5 Puncture strength

This test is conducted to make an assessment of geotextile resistance to objects, such as, rocks or pieces of wood under quasi-static conditions. Such a test is described under ASTM D 4833 or IS:13162 (Part 4).

7.1.6 Mullen burst strength

The burst strength of fabric is usually determined by Mullen burst test, which is covered under ASTM D 3786. This test is essentially an index test and is widely used for quality control.

7.1.7 Apparent opening size (AOS)

The apparent opening size (AOS) or the equivalent opening size (EOS) is a measure of the largest effective opening in a geotextiles. It can be measured using the procedure described in ASTM D 4751/IS:14294. The test uses known sized glass beads designated by number and determines AOS by sieving the beads of successively smaller size until 5 per cent or less pass through the fabric. It is sometimes given as the equivalent sieve size opening in mm and designated as the 95 per cent opening size or O_{95}. The AOS, EOS and O_{95} are all equivalent terms and refer to the same thing.

7.2 SPECIFICATION OF GEOTEXTILES FOR SUBSURFACE DRAINAGE

The specifications for subsurface drainage are given in table below. The specifications are applicable to placing a geotextiles against the soil to allow long term passage of water into a subsurface drain system retaining the in-situ soil. However, the Engineer may also specify properties different from those listed in table based on engineering design and field experience. The primary function of the geotextiles in surface drainage applications is filtration. Geotextile filtration properties are a function of the in-situ soil gradation, plasticity and hydraulic conditions. For drainage purpose, woven slit film geotextiles (i.e., geotextiles made from yarns of a flat, tape like character) should not be allowed. All numeric values in tables below except AOS represent MARV in the weaker principal direction.

Geotextile drainage property requirement

S.No	**Percent in-situ soil passing 0.075mm sieve**	**Geotextile drainage property requirement**		**Recommended Geotextile***
		Permittivity, per second, ASTM D 4491 (minimum average roll value)	Apparent opening size, mm ASTM D 4751 (maximum average roll value)	Type II from table below (*thick needle punched non woven geo-textile shall be preferred)
1.	<15	0.5	0.43	
2.	15 to 50	0.2	0.25	
3.	50	0.1	0.22	

In surface drainage, installation conditions are generally not very severe and hence geotextile Type-II is recommended. However, the Engineer may specify Type–III geotextile for trench drain applications on one or more of the following conditions :

- The Engineer has found type III geotextiles to have sufficient survivability on field experience.
- Subsurface drain depth is less than 2.0 m, drain aggregate diameter is less than 30 mm and compaction requirement is less than 95% of Proctor density as per IS: 2720; Part-7.

Geotextile strength and drainage property requirements

S. No	**Geotextile installation condition**	**Type of geotextile recommended**	**Strength property requirement(*MARV)**								**Drainage /Filtration property requirement**
			Grab strength in N as per ASTM D 4632		Tear strength in N as per ASTM D 4533		Puncture strength in N as per ASTM D 4833		Burst strength in N as per ASTM D 3786		
			Elongation at failure								
			< 50 %	> 50%	< 50%	>50%	< 50%	> 50%	< 50%	> 50%	Minimum property requirement for permittivity and AOS are based on geotextile application. Refer to table above for subsurface drainage.
1.	Harsh installation condition	Type-I	1400	900	500	350	500	350	3500	1700	
2.	Moderate installation condition	Type-II	1100	700	400	250	400	250	2700	1300	
3.	Less severe installation condition	Type-III	800	500	300	180	300	180	2100	950	

- Woven geotextiles fail at elongations <50 % , while non-woven ge textiles fail at elongation > 50 %

8.0 CONCLUSION:

Water is the main factor responsible for most of the ills affecting track formation. Improvement in the surface or sub-surface drainage shall not only reduce day to day maintenance troubles but also enhance safety and stability of formation. Therefore, well-designed drainage system suited to local conditions should invariably be adopted.

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