RECOMMENDED PRACTICES FOR TREATMENT OF EMBANKMENT AND ROADSIDE SLOPES FOR EROSION CONTROL

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CONTENTS

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RECOMMENDED PRACTICES FOR TREATMENT OF EMBANKMENT AND ROADSIDE SLOPES FOR EROSION CONTROL

1 INTRODUCTION

Indian Roads Congress (IRC) had published the Guidelines 'Recommended Practice for Treatment of Embankment Slopes for Erosion Control' (IRC:56) in the year 1974. During the last 36 years, sufficient amount of work has been carried out in the field of erosion control practices by various agencies and new materials/improved techniques have been evolved. Keeping in view this aspect, the 'Embankment, Ground Improvement and Drainage Committee (H-4)' of the IRC decided to review these Guidelines. The Committee assigned the work of revising the same and preparing a new draft to Shri U.K. Guru Vittal and Mr. Sudhir Mathur from CRRI, New Delhi. The draft prepared by them was discussed by H-4 Committee during its several meetings and the suggestions/modifications proposed were incorporated in the draft. The H-4 Committee in their meeting held on 8.10.2010 approved the revised draft and referred the same to HSS Committee of IRC.

The HSS Committee approved the document with some modifications in its 4th meeting held on 22 October 2010. The Executive Committee of IRC approved the modified document in its meeting held on 27 October 2010 and then the document was placed before the IRC Council in its 19nd meeting held on 11 November 2010 at Nagpur for consideration. The Council approved the document for publication. The composition of H-4 Committee is as given below:

Kumar, Mahesh	...	Convenor
Sharma, Arun Kumar	...	Co-Convenor
Mathur, Sudhir	...	Member Secretary

Members

Chand, Faquir	Rao, Prof. G.V.
Dhodapkar, A.N.	Rao, P.J.
Gajria, Maj. Gen. K.T.	Saha, D.C.
Gupta, Sanjay	Sangal, M.M.
Gupta, Dr. Pradeep	Sen, Samiran
Jain, Naresh Chand	Singh, R.B.

2 MECHANISM OF SURFACE EROSION

The impact of highway location on the environment is a major concern to the highway engineers and the public. The highways, if they are not properly located, designed, constructed or maintained, would be subjected to erosion and may at times contribute sediments to the stream. The control of soil and water is essential for protection of the road structure and the conservation efforts. Therefore, highway design, construction and maintenance procedures must be continuously evaluated to minimise erosion and sedimentation problems. Lack of timely provision of erosion control measures and/or inadequate workmanship accelerates the problems. Erosion can be controlled to a considerable degree by geometric design, particularly through aspects relating to cross - section. In some respects, the control is directly associated with proper provision of drainage and landscape development. Thus, effect of erosion should be considered in the planning and design stage itself. There have been instances where many embankment slopes, irrespective of type of soil used for their construction, have suffered a high degree of damage due to erosion from rain and runoff. Denudation of vegetation from soil slopes or the lack of vegetative cover on embankment slopes is often responsible for formation of rills and rain-cuts, eventually leading to a surficial slide or to an undermining of the edges of the road pavement structure. When vegetation grows on the slopes, there becomes available an effective dense network of root system, penetrating to a depth of about 0.50 to 0.75m into the slope, which serves to anchor down the soil mantle and render it resistant to erosion.

Although some standardisation of methods for minimising soil erosion in highway construction is possible, comprehensive guidelines for control of erosion can be of a general nature because of the wide variation in climate, topography, geology, soils, vegetation, water resources and land use encountered in different parts of the country. Also, erosion process is a natural phenomenon accelerated by man's activity, technical competency in evaluating the severity of erosion problem and the planning and design of preventive and corrective measures is essential in obtaining economical and environmentally satisfactory methods of erosion control. This guideline highlights some of the techniques of establishing a vegetative cover on embankment slopes by different methods such as use of organic mulch, readymade turfs of grass, application of jute or coir nettings, etc. In the recent past, considerable research has been carried out in the field of 'Use of Geosynthetics' for erosion control. There is also an emerging area of bioengineering techniques, which can also be adopted for erosion control by field engineers. These aspects have been kept in view while revising these guidelines. However, this guideline does not provide details about other traditional methods which are in routine use such as the provision of stone pitching, use of concrete blocks, etc. Additionally, this guideline mainly covers the methods used to control/minimise erosion caused by water alone. A general classification of various methods of ground covers for erosion control available to a highway engineer are illustrated in **Fig. 1**. **Fig. 2 to 7** which show different erosion patterns encountered in case of road embankments. Erosion process may sometimes lead to rock fall problems in hill slopes. Brief details about rockfall control techniques applicable to hill slopes are given in **Annex-I**. For further details about rockfall mitigation techniques, HRB Special Report – 15, 'State of the Art: Landslide Correction Techniques' can be referred to.

3 OBJECTIVE OF EROSION CONTROL

The objective of the erosion control practices should be, in order of priority:

- To protect the road infrastructure so that it continues its function of permitting uninterrupted flow of traffic at design speed and safety;
- to protect and preserve the earthwork in fill or road side cut slopes especially in hilly terrain, ditches and drainage structures;

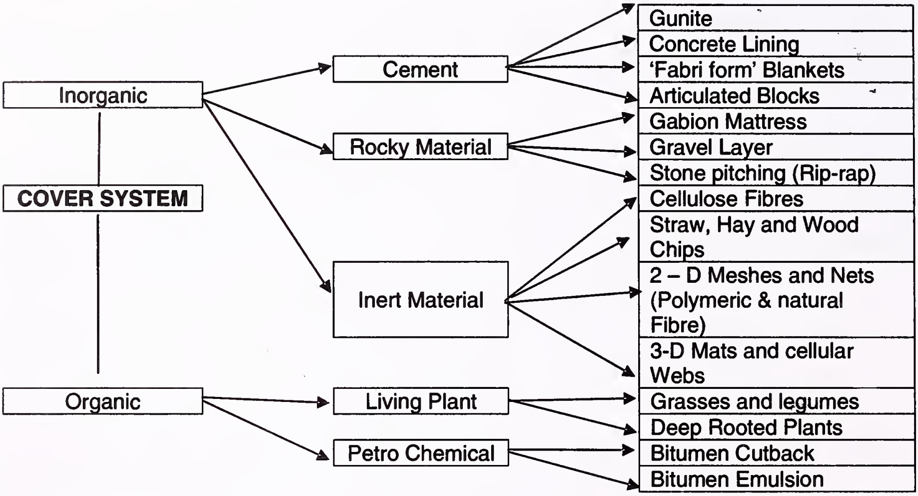

Fig. 1 Classification of Ground Covers for Erosion Control

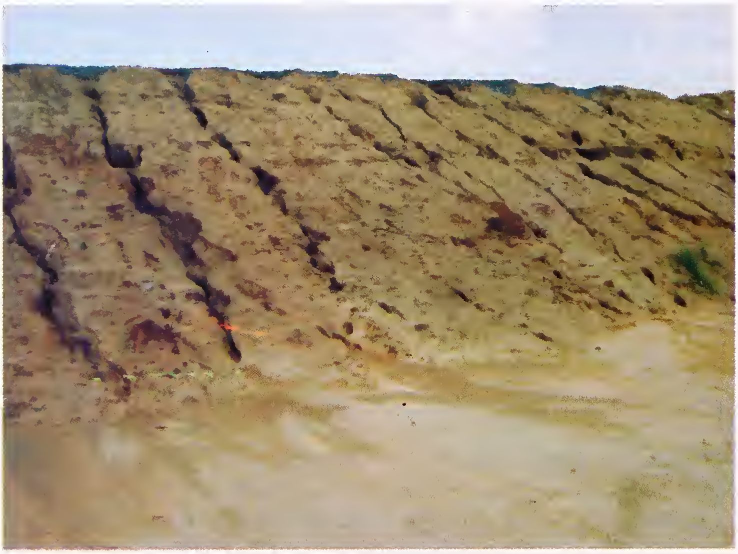

Fig. 2 Erosion Patterns – Rill Erosion of Embankment Side Slope

Fig. 3 Erosion Patterns – Deep Gulley Formation in Embankment Side Slope

Fig. 4 Erosion Patterns – Embankment Toe Cutting by Flood Waters

Fig. 5 Erosion Patterns – Severe Erosion of Approach Embankment by Flood Waters

- to prevent damage to land adjacent to the road structure (in fact quite often, the neglect of control measures on adjacent land creates serious problems of erosion within the road land);
- to reduce the soil loss from the road embankment, which silts up drainage channel, waterways of cross drainage structures and pollute rivers;
- to contribute to the improvement of the aesthetics of the landscape;
- to avoid accidental falling of debris.

4 SOIL LOSS ANALYSIS

Erosion may be considered as detachment of soil particles from the soil surface and the transportation of the detached particles to a new location. Erosion is caused by the combined action of physical and chemical processes by which the soil or rock particles are loosened, detached and transported from one place to another by impact of raindrops, running water, wind, moving ice, etc. Clayey soils are less erodible than fine sands and silts.

In the rain induced erosion process, firstly, raindrops hit the slope surface and impact of the raindrops detaches the particles of soil. Additionally, runoff water flowing on the slope surface also contributes towards detachment of soil particles. The overland water flow (surface runoff) resulting from rainfall transports the detached particles. The rate of detachment is a function of kinetic energy of the falling raindrop. Comparing the kinetic energy dissipated by the impact of raindrop with that of water flowing relatively slowly down the slope, the energy of impact would be found to be much higher than the energy of flowing water. Thus, it may be inferred that erosion can be reduced in the first place by protecting the soil surface from direct impact of rain. The equation to calculate energy of raindrops responsible for erosion is given in **Table 1**.

Table 1 Energy of Falling Raindrop

Raindrop Diameter	0.5 – 6.0 mm
Velocity of fall (Raindrop)	2 – 9 m/sec
Rainfall Intensity	
Gentle Storm	5 mm/hour
Extremely high intensity storm	100 mm/hour
Runoff	
Laminar	Sheet wash erosion
Turbulent (Velocity greater than 200 m/hour)	Gulley erosion
Kinetic energy of a rain storm (Joules/m^2 of the area)	$KE = (11.9 + 8.73 \log_{10} I)\ I\ \Delta t$ KE – Kinetic energy (in Joules/m^2) I – Rainfall intensity (mm/hour) Δt – Time in hours

A method to quantify erodibility of site is to measure the rate of soil loss per unit area of site per unit time. Erodibility of site is the function of the erosivity of rain, the soil properties, the topography, land cover and management. When applied to a single slope, the topographical factors to be considered would be the slope length and its steepness. Thus the soil loss can be estimated using the relationship, known as universal soil loss equation (USLE), in t/km^2/yr as given below;

$$A = R \times K \times L \times S \times C \times P$$

where

A = Computed soil loss (e.g., tons) per acre for a given storm period of time interval

R	=	Precipitation (Erosion potential of rainfall, in mm per unit time period)
K	=	Soil erodibility value
L and S	=	Topographic factors (Slope length factor and slope steepness factor)
C	=	Vegetation crop factor
P	=	Erosion control practice factor

This universal soil loss equation was updated and 'Revised Universal Soil Loss Equation (RUSLE)' was given by Renard et al., in 1997. A principal modification is in R factor which includes rainfall and runoff erosivity factor (runoff erosivity also includes snow melt where runoff is significant).

4.1 River Bank Erosion

For protection of a road embankment running along a river course or for protection of bridge abutments close to river edge, bank protection measures are sometimes required to be adopted. Riprap with properly designed apron is generally used as a liner for streams, rivers and channels subjected to high-velocity flow and for lake, reservoir and channel banks subject to wave action. Geotextiles are an effective and economical alternative to conventional graded filters which are placed under the stone riprap. However, for aesthetic or economic reasons, articulated concrete mattresses, gabions or precast cellular blocks or geotextile bags can also be used to cover the geotextile. The velocity of the current, the height and frequency of waves and the erodibility of the bank need to be considered while designing bank protection. Extensive soil conservation and watershed management play an important role in reducing sediment discharge from watersheds. Special construction measures, other than vegetation growth on slope, include compaction of slope and provision of revetment protection such as using stone or bricks, placement of fascines, etc. These are designed to break up energy of flowing water and prevent migration of particles by reducing the threshold velocity of erosion. For more details regarding river bank protection, IRC:89 "Guidelines for Design & Construction of River Training and Control Works for Road Bridges" may be referred.

4.2 Provision of Kerb Drains and Chutes in Embankments

The problem of erosion of slopes and shoulders is most severe in high embankments having steep longitudinal gradient, when the embankment has been built with erodible soil, without proper longitudinal and cross drains. The erosion problems in such embankments become acute when the side slopes are unprotected. In such a case, water gains velocity and eventually when it leaves the roadway at any random location, it may cause serious erosion of slopes manifesting in the form of deep gulleys extending right upto carriageway. Sometimes such problems may undermine road pavement also. The quantum of runoff water becomes considerable in case of four lane roads with paved shoulders, especially in curved sections of the road, where unidirectional camber is provided. This may result in accumulation of huge quantity of runoff water from both carriageways towards one side of the embankment side slope, thereby increasing the severity of the erosion by many times. Therefore in such instances, a system of proper kerb, channel and median drains coupled with chutes should be provided to drain off the rain water from the road embankments. For more details in this regard, IRC:SP:42 "Guidelines on Road Drainage' and 'IRC:SP:50, "Guidelines on Urban Drainage" may be referred to.

Fig. 6 Erosion of Road Embankment Adjacent to River

5 DIFFERENT METHODS TO PREVENT SOIL EROSION

Road embankments as well as hill side cuttings and stream/ river banks experience a high degree of damage due to erosion from rain. Denudation of vegetation from soil slopes or the lack of vegetation cover on such slopes gradually progresses to form rills and gullies, and if they remain unchecked, it leads to surficial slide. The various options available to Highway engineers to mitigate erosion related problems due to water are explained in the following sections.

5.1 Simple Vegetative Turfing

Erosion is often a problem when there is not enough protective cover on steep slopes or in drainage channels that have been designed to rely on vegetation for long term erosion control. Vegetation is ideal for erosion control because it is relatively inexpensive to establish and maintain and it presents aesthetically appealing look. Vegetative turfing has proved to be, by and large, the most economical and simple means of protecting slope of hills and embankments against erosion. Obviously, this method should be adopted where the soil has enough nutrients and the environmental conditions are conducive to promote vegetation growth. The method consists of preparing the slope area into seedbeds by grading the slope to the extent possible and subsequently broadcasting the seeds or saplings/plant roots of promising types of locally available plants. In case the slope has pockets of enriched and poor soils in relation to promotion of vegetation, putting seeds in isolated pockets of specially enriched soil should encourage plantation. The rest of the slope should be treated with some other techniques described in this guideline.

On the basis of field studies, it has been established that shallow surficial slides constitute a significant proportion of landslides in the areas with moderate rainfall intensity and with a soil cover of medium cohesive type. Most of these surficial landslides occur as a result of loss of vegetation cover on soil slopes due to a cut being made for road construction. Surficial slides extend to only a shallow depth below the slope surface and originate as a result of erosion due to flowing water. If erosion is allowed to proceed unchecked, there is every possibility that the damage may spread laterally or the depth of erosion may increase, eventually resulting in a much larger damaged slope area. Vegetative turfing represents one of the most important corrective measures in such cases. In the case of freshly exposed cutting made for road construction, vegetative turfing is important, even as a preventive measure. In the case of deep seated slides, however, vegetative turfing is only one of the several corrective measures which should be adopted and as such it can prove to be effective only when implemented along with other corrective measures.

The joint action of trees, grass and other plant species for protection of soil from water and wind erosion has been recognised from several documented studies. The above ground biomass of the trees and plants provide adequate canopy interception to the falling rain drops and saves the soil from splash erosion, while the mass of litter and Rhizomes act as speed breakers for the running water on the slope.

Besides soil protection, grass plays a significant role in binding the soil particles with their fibrous root system. The root system of different plant species varies and its mass increases with the age of the plant. The protective mechanism of vegetation in preventing surficial erosion can be summarised as given below:

a) **Interception**: Foliage and plant residues absorb rainfall energy and prevent soil detachment due to raindrop splash

b) **Restraint**: Root systems physically bind or restrain soil particles while above ground part of the vegetation filter sediments from the runoff.

c) **Retardation**: Stems and foliage increase surface roughness and slow down velocity of runoff

d) **Infiltration**: Plants and their residues help to maintain porosity and permeability thereby promoting infiltration and delaying onset of runoff

Deep rooted vegetation helps to prevent shallow mass movement by:

- Reinforcement of the soil by the root system
- Soil water depletion through transpiration and adsorption
- Buttressing and soil arching action from embedded stems

Laboratory and analytical studies carried out concerning the role of vegetation in improving the stability of slopes, have established that, the binding effect of roots impart to the soil, cohesive strength of about 2.0 to 2.5 tonnes/sqm. Assuming an effective depth of penetration of 0.5 m and increase in cohesive strength of 2.0 tonnes/sqm, analysis of slope with normal geometry has shown a significant increase in the factor of safety for a slope height of about 6 m. Thus, by providing a vegetative cover, not only the erosion of the soil is checked, but also the possibility of shallow slope failure is prevented, due to the strengthening of the top 0.5 m depth of the soil slope. Some typical deep-rooted species of grasses and shrubs suited to different topographical areas of our country are given in **Annex-II**. These species can be adopted for turfing of denuded slopes.

However, there are certain limits to the successful application of vegetative turfing method. This method may fail in the following situations:

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

2) When seed broadcasting work is done immediately preceding or during very heavy downpour.

3) 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 the monsoon season.

4) At locations, where vegetation growth is difficult to achieve due to infertile nature of soil.

The density of sowing is of great importance. In general, while sowing a mixture of grass and legume plants, seed rate should be normally 15 gm/m^2. Prior to sowing, the soil surface should be adequately prepared. The sowing procedure is to place the seed within a shallow furrow and cover it with about 10 mm loose soil. In steeper slopes (1 V:2.5 H or less), broad casting is used, the object being to spread the seed on the slopes as evenly as possible. Help from botanists/agronomists may be sought for developing vegetation cover on infertile soil slopes. Sometimes, vegetation growth in a soil slope is often met with problems like absence of initial binding (cohesion) in the soil, especially in case of silty or sandy slopes. Because of lack of cohesion, plant growth is inhibited in the initial stage itself. In such conditions, to enable vegetation to grow, it requires a reinforcing material for its root mat system. In such circumstances, it is advisable to go in for special techniques, such as the ones recommended in the succeeding paragraphs.

5.2 Transplantation of Readymade Turfs of Grass

It is also possible to provide vegetative turfing by 'Sodding' which involves bodily transplantation of blocks of turfs of grass (with 5-8 cm of soil covering the grass roots) from the original site to the barren slopes to be treated. If found necessary, pegs or nails could be used to hold down the grass sods in the initial stage. By this method, vegetation cover on a barren slope can be ensured in a very short time duration. Watering and other care to be taken for successful vegetation cover to develop would be similar to simple vegetative turfing method described in **Section 5.1**.

5.3 Application of Mulch

The term 'mulch' refers to any loose or soft organic material, e.g. straw with cowdung or wood shavings mixed with cowdung or saw dust and dung mixture, etc laid down on the slopes to protect the roots of plants. In the case of embankments which are less than 3 m high, where the severity of the erosion problem is not of a high order, the mulch application would be very helpful for vegetation growth. The approximate thickness of mulch cover should be 2.5 cm. The organic mulch covering the soil slopes can be held in place and made resistant to being washed downhill or being blown away by pegging them down with bamboos, at suitable intervals, in a grid pattern and also laying bamboos horizontally connecting the pegs and thus forming the grid.

5.4 Vetiver Grass (Botanical name: Chrysopogon Zizanioides)

Vetiver is a special type of grass which can be grown in a wide variety of soil such as clayey, sandy, silty, gravely types or in other words from least erodible to highly erodible soils. This type of grass does not require any special maintenance. Vetiver is capable of growing in wide range of climates ranging from 300 mm annual rainfall to over 6000 mm annual rainfall and from -14^0C to more than 50^0C of soil temperature. Moreover, it can withstand long and sustained drought for more than six months.

The stabilisation and protection of slope by vetiver grass is effective, efficient and low cost vis-a-vis other traditional methods of erosion control like stone rip-rap. Vetiver grass penetrates vertically below to considerable depths into the sub-soil, its roots have a significant strength and thereby improve the shear strength of sub-soil at a depth of 0.5 m by as much as 40 percent. For best result, the vetiver root divisions, or slips, should be planted in a double or triple line to form parallel hedges across the erosion prone slope. Distance between consecutive hedge rows can be kept between 30 to 50 cm. The slips should be planted at the beginning of the rainy season to ensure that they get full benefit of the soil moisture. Planting operations of vetiver slips is similar to planting of rice seedlings. The next slip is planted 10 to 15 cm from the already planted slip along the same contour furrow and the process is repeated upto required length to cover the entire area. Once the hedge has been established at the slope, only care needed is annual trimming, if required.

Fig . 7 Erosion of River Bank

Fig. 8 Protection of the River Bank by Vetiver Grass

5.5 Hydroseeding/Hydro-Mulching

Straw or hay can be chopped and driven into a pre-seeded soil bed to provide mulching benefits during seed germination. The straw or hay fragments are sometimes secured to the ground surface by crimping, punching, tacking or netting, but often mulch is not secured firmly to the ground. Hence integrity of these mulches can be severely affected by rain, wind, surface runoff and animal/ human trespassing. As a result, conventional mulches provide few weeks of protection to the bare soil, often making grading and reapplication necessary. To overcome such shortfall, the technique of Hydroseeding (also known as Hydro-mulching) was developed.

Hydroseeding is a process which can be considered as alternative to sodding. It involves seed application in a water based slurry via a high pressure pump and hoses or a spray gun. The basic ingredients used in this process are water, seeds, fertiliser, mulch, tackifier and bio-stimulant. Mulch can be made from recycled paper or shredded wood or a mixture of both – wooden mulch breathes while paper mulch forms a protective cover. Chopped straw cut to a length of 10 to 20 mm can also be used as mulch. Tackifier is required to make this mulch and seed stick to the soil surface to which it is being applied. Mulch protects the slope until the seed germinates and provides organic nutrients as the vegetation grows. These mixed ingredients are stored in a tank and applied using a pressure pump, on barren land surface on which vegetation is to be promoted. Hydroseeding method can also be used by adopting cellulose based fibrous mulches. Cellulose based fibrous mulches are spray applied with the seed in this method. The fibres are dispersed in a solution that, when sprayed on bare soil, causes the fibres to stick to each other and to the soil. Hydroseeding method is specially suited for vertical or near vertical soil slopes (steep slopes) on which 'simple vegetative turfing' or manual application of mulch would not be successful. Hydroseeding job is specialised and expensive but for some inaccessible slopes, it offers the only practical method.

5.6 Promotion of Vegetative Turfing by Using Jute Netting

Many field experiments have been successfully carried out in different parts of the country under varying climatic conditions on manmade embankments and natural slopes using jute netting (also known as open weave jute geotextile) for promotion of vegetation and control of soil erosion. The method involves laying the jute netting firmly on the prepared slope after sowing seeds of suitable vegetation.

Before laying jute netting, the slopes which are being treated are to be initially demarcated, graded and fertilised. The levelling of the area must be carried out so that when netting is laid it may cover the entire area flush to the ground ensuring that the runoff would flow over the nettings. Before laying the netting, a dose of seed broadcasting of locally available suitable type of grasses is done. Thereafter, jute netting of 1.25 cm to 2.5 cm opening size is laid on the prepared slope surface firmly in the direction of water flow. The netting is secured against displacement by an overlapping of 5 cm to 8 cm and stitched or pegged down with 15 cm long steel nails about 1.0 m apart. The top and bottom ends of the fully stretched jute netting are fixed/anchored in trenches of 30 cm depth. Afterwards, another dose of seed broadcasting or dibbling of locally available grasses 15 to 20 cm apart, in rows is carried out.

Fig. 9 Application of Jute Netting on Denuded Hill Slope

Fig. 10 Vegetation Growth after Application of Jute Netting and Sowing

The jute net acts as a series of miniature check dams, thus, absorbing the force of impact and dissipating the kinetic energy of surface runoff, and thereby reducing its erosion potential. The soil particles, seed, grass root slips are held securely in their original locations without being dislodged, due to provision of jute nettings. Jute netting absorbs water upto four times its dry weight and transfers it to soil, thereby, giving full benefit of moisture for growth of vegetation. After the first rainy season, the seeded and sprigged vegetation soon envelops the entire surface thus, protecting the slopes against erosion. Jute netting has been observed to have a life of about 1 to 2 years in the field, which is sufficient for fully promoting the growth of vegetation cover on the denuded slopes. Once vegetation growth has been established within two monsoon seasons, the mission is accomplished for the jute netting. At the end of jute netting's life, the geogrid decomposes and in the process adds nutrients to the soil. For more details and specifications of this technique, IS: 14986 'Guidelines for Application of Jute Geotextile for Rain Water Erosion Control in Road and Railway Embankments and Hill Slopes' may be referred to.

5.7 Use of Coir Netting

Coir netting (also known as 'Coir Bhoovastra') is another type of biodegradable material which can be effectively used in a manner similar to jute nettings. Coir nettings degrade much slower than jute nettings (expected field life of about 2 to 3 years) and thus provide protection to the slopes for a longer time than jute nettings. Coir is also 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 it happens sometimes in the case of synthetic nettings. In a manner similar to jute nettings, coir netting also breaks up runoff from heavy rains and dissipates the energy of flowing water. Coir also promotes the growth of new vegetation by absorbing water and preventing the top soil from drying out. However, compared to Jute nettings, drapability of coir netting is lesser and their water absorption capability is also lower than jute nettings. Coir nettings are available in densities varying from 400 to 1400 gm/m^2 (higher density means a tighter mesh and less open area in the netting). The length of the rolls would be 50 m and width can be between 1 to 4 m. For more details and specifications about use of coir nettings, IS: 15869 'Open weave coir Bhoovastra-Specification' and IS 15872 'Application of Coir Geotextiles (coir woven Bhoovastra) for Rain Water Erosion Control in Roads, Railway Embankments and Hill Slopes-Guidelines' may be referred to.

5.8 Erosion Control Using Two Dimensional (2–D) Synthetic Geogrids/ Netting

With the provision of polymer geogrid mesh for root reinforcement, extremely high density of grass growth can be achieved. Geogrid reinforced slope protection has been shown to provide erosion protection equivalent to 250 mm thick revetment and is treated as an attractive cost-effective alternative solution. Under erratic weather conditions, successful vegetation growth and its maintenance depends on un-seasonal rainfall and hence longer life of reinforcing material would be required for ensuring vegetation growth apart from contribution from the mesh towards reduction in velocity of surface runoff. Most ordinary turfing as well as agro based nettings may fail to provide erosion prevention in areas which experience repetitive change in climate, prolonged drought in particular. Use of polymer geogrid mesh provides a permanent protection as it is not biodegradable. When compared with such similar root reinforcing concepts by using natural fibres, it compares very favourably, because of its longer life and almost unfailing success rate for vegetation growth year after year.

The peak tensile strength or tensile strength at 10 percent strain, whichever is lower, of the polymeric geogrid to be used for erosion control should not be less than 4 kN/m when tested as per ASTM D 5035 (minimum average roll value in machine direction). Geogrid mesh shall be stabilised against ultraviolet ray degradation for continuous exposure of about 10 years (defined as retaining 75 percent of its original strength after 10 years of exposure) using finely divided carbon black (ASTM D 4355 – 500 hour exposure). The installation and seed broadcasting procedures would be similar to jute nettings.

Fig . 11 Use of Synthetic Geogrids to Promote Vegetation on Barren Hill Slope

5.9 Three Dimensional Erosion Control Mat/Rolled Erosion Control Products

Relying upon vegetation growth alone may be sometimes very unpredictable and unreliable as it may be extremely difficult to achieve 100 percent vegetation coverage, leaving exposed areas vulnerable to erosion. Furthermore, vegetation may sometimes dry up or become diseased, reducing its erosion control capability. Reinforced vegetation (or reinforced grass) is a better method that is being practiced for enhancing slope stability and erosion control. The synthetic materials that have been employed in reinforced grass technique have two forms. They can be two dimensional polymeric meshes, a mesh being an extruded net with apertures to allow grass growth. This product was explained in **section 5.8**. Alternatively, they can be three dimensional mats, these being multi-filamented materials having specified thickness. Such materials are also known as Rolled Erosion Control Products (RECPs). 3-D Mats/RECPs can also be made using biodegradable natural fibres such as straw, jute, coir or wood shavings (used individually or in combination) stuffed into polymeric or organic nettings on either side to form a mat or blanket like structure. Obviously when mats are made using natural fibres, they would be biodegradable also, but they don't provide everlasting protection. RECPs are used in combination with seed beds to enhance the establishment of vegetation. When geosynthetic mattings (3-D Mats) are made exclusively from polymeric substances, they consist of UV stabilised synthetic fibres and filaments processed into permanent, high strength, three dimensional (3-D) matrices. Installation procedure involves levelling and preparation of the surface to be treated, rolling out and fastening the geosynthetic mat in intimate contact with the soil surface, then in-filling with fine soil and a prescribed seed mix. Seed can be applied to the surface either before or after the mat is installed and the vegetation will develop unhindered by the matrix. A geosynthetic mat installed in this manner is also called as 'Turf Reinforcement Mat (TRM)'. Polymeric mats are used in situations where these products are required to last a long time. Other way of installation involves direct deployment of the material over a freshly seeded soil surface. This allows the natural sedimentation process to in-fill the mat, allowing a more gradual development of a reinforced vegetation cover.

Steel wire mesh is sometimes included in these mats optionally where these mats are required to possess more strength against erosive forces, like steeper slopes or in heavy rainfall areas. The three dimensional mats shall be anchored to the surface to be protected using staples or pins. The 3-D mat increases the soil's resistance to erosion by providing an environment that enhances the growth of vegetation through the mat. Initially the mat works to shield the soil from washing out before the vegetation has a chance to become established. Then as the vegetation matures, the roots anchor the mat to the soil to provide superior soil reinforcement strength, capable of handling greater volumes of runoff water and higher flow velocities.

The three dimensional mat solutions protect the soil surface by:

- Providing immediate protection of exposed areas from direct effects of wind and rainfall impact
- Protecting seeded topsoil from washing out before vegetation has established
- Creating an environment that enhances the growth of vegetation through the mat
- Reinforcing the root system of plants, further binding the soil surface and increasing shear resistance of the surface
- Reducing the velocity and volume of runoff flow by increasing water percolation into the soil
- The steel wire mesh (optional) helps in the retention of gravel sized particles and also acts as an additional reinforcement.

3-D mats having a wide ranging variety of strength are available. The material used for manufacturing these mats also varies. Hence following general specifications are given for guidance:

3-D Mat Property	**Specified value***	**Test Method**
Minimum Tensile Strength	2 kN/m	ASTM D 5035/1505081
UV Stability (Min percent tensile strength retention)	80 percent	ASTM D355 (500 hour exposure)
Minimum thickness	6.5 mm	ASTM D 6525/150 9863
Mass per unit area (Minimum)	250 gm/ m^2	ASTM D 3776/50 9864

* Minimum Average Roll Values, machine direction only for tensile strength test

Field conditions like harsh areas/high survivability requirements may warrant use of 3-D mats with tensile strength of 35 kN/m or more.

Fig. 12 Application of 3-D Mats on Denuded Road Side Slope

Fig. 13 Vegetation Growth after Application of 3-D Mats on Denuded Road Side Slope

5.10 Preformed Polymer Geocells or Webs

Often, steep slopes are to be constructed in areas where vegetation may be difficult to establish. It may also be not possible to mitigate potential erosive forces that are likely to overcome the strength of the root system. In such cases 'Geocells' can be adopted. Geocells are 3-dimensional honey combed structures. They are usually made by a single continuous extrusion process. They can be expanded or collapsed. When expanded, they present a unique cellular arrangement. These web form containment cells come in a jointed lay-flat condition and opens into a honeycomb like container cellular structure with the web height of 75 mm to 150 mm. In very steep slopes exceeding 1:1 gradient, particularly in waterfront, placement of top soil in these cells enables retention of soil veneer. The geocells prevent the soil from slippages and thereby encourage vegetation growth. Multiple layers of geocells placed one over another can also be adopted. Geocells placed on the slope are secured to adjoining cell at suitable intervals by using a clip arrangement and these expanded cells should be secured to the slope using steel staples (typically 300 mm long and 9.5 mm diameter). This process is extremely essential to maintain integrity of geocells especially in steep slopes. When these cells are filled with soil, they physically confine the soil. The cell walls confine the soil and decrease the velocity of water passing across the surface. The confinement forces are generated by the resistance of the cell walls and by the passive resistance of the soil. Geocell placement in the waterfronts can also be designed as an alternative to revetment protection. Geocells can be used where heavy runoff or channel scouring is anticipated. Geocells filled with concrete can be used to protect bridge aprons, guide bunds and pier areas, abutting waterfront as revetment as an alternative to conventional stone/boulder pitching. Geotextile conforming to IRC: SP:59 can be adopted in such situations as filter media behind geocells. Thereby geocells can replace expensive rip-rap or concrete slope protection. Geocells being relatively new type of materials, field engineers may consult published literature/ product brochures regarding specifications and usage at site.

5.11 Erosion Control by Armour Systems

River/Stream bank erosion often creates concern for road agencies because it generally leads to toe erosion and disturb the stability of slopes. Some degree of erosion is natural. However, erosion can be accelerated or decelerated by certain actions. For example, clearing shoreline vegetation will accelerate the process while

Fig. 14 Application of Geocells on Embankment Side Slope

Fig. 15 Growth of Turfing on Embankment Side Slope after Application of Geocells

controlling runoff to the shore will slow it down. Depending upon the degree of erosion and the slope of the bank, adding vegetation, physical erosion control structures, channelizing runoff or some combination of these methods may be appropriate. Soil banks or slopes exposed to constant concentrated flows, currents, or waves cannot support vegetation and thus need to be protected by hard armour systems.

The erosion control structures for bank protection are as follows:

1) Rip-rap – Comprises of stone of different sizes (conforming to specified gradation) placed against the river bank to deflect the force of the water hitting the banks. Stone pitching refers to placement of approximately single sized rocks along the slope to serve the same purpose.
2) Retaining walls, toe-walls or break walls and sheet piles that are placed in such a way to form a barrier between the shore and the water front.
3) Gabion baskets/revet mattresses that are filled with stones of specified size and provided on slopes
4) Geotextile Bags – Bags made from geotextile material, which are filled with sand/suitable type of soil and are kept on the slopes in place of stone pitching

When a hard armour system is in place, water can seep in and out of the bank or slope, but the force of water is resisted by the armour. As the water seeps, it can gradually carry soil particles along with it. The resulting voids cause armour support to be lost after some time. This process is called 'piping' which can culminate in shifting, rolling, or other instability in the hard armour system. Typical solutions include placing a filter layer between the bank soil and the armour to prevent piping. Traditional filter layers have been graded sand and aggregate which are very costly because they are constructed from select graded materials. Also, the filter layer must be of a controlled thickness. On a steep slope, it can be very difficult to properly construct such aggregate filter layers.

Geotextiles have become ,standard filter layers for hard armour systems because they overcome the drawbacks of graded sand and aggregate filters. These are manufactured with specific hydraulic and soil retention properties to suit the soil that needs protection. Also, they can be installed with ease on slopes, even under water. Specifications and other details about provision of geotextile layer below such armour protection system can be obtained from IRC SP:59, 'Guidelines for Use of Geotextiles in Road Pavements and Associated Works'. Details about river bank erosion control techniques can be obtained from 'IRC:89, Guidelines for Design and Construction of River Training and Control Works for Road Bridges' and from MoRTH Specifications for Road and Bridge Works. Brief details about gabions/revet mattresses are given in **Annex. III**.

6 BIOENGINEERING EROSION CONTROL

Stream bank and embankment side slope erosion can be severe, in cases where shorelines are composed of easily erodible soil and where the road runs along the stream. Traditional methods of controlling stream flow and wave induced erosion have relied on structural practices like rip-rap, retaining walls and sheet piles. In many cases these methods are expensive or may be ineffective. An alternative approach is bioengineering, a method of construction using live plants alone or combined with dead or inorganic materials, to produce living, functioning systems to prevent erosion, control sediment and provide habitat. Bioengineering involves the use of live plants to add structural strength to soil.

Advantages of bioengineering solutions are:

1) Low cost and lower long-term maintenance cost than traditional methods
2) Low maintenance requirement of live plants after they are established
3) Environmental benefits of wildlife habitat, water quality improvement and aesthetics
4) Improved strength over time as root systems develop and increase structural stability
5) Compatibility with environmentally sensitive sites with limited access.

Limitations of bioengineering methods include:

1) Installation season is often restricted to plant dormant seasons, when site access is limited
2) The availability of locally adapted plants may be limited
3) Labour needs are intensive and skilled, experienced labour may not be available
4) Installers may not be familiar with bioengineering principles and designs (untrained)

Plants that root quickly are used in a variety of ways to control erosion. There are several ways in which bioengineering solutions can be implemented for protection against erosion as explained in following sections.

6.1 Contour Wattling

One bioengineering technique that has been successfully used is called 'wattling'. It is a bundle of dormant stem cuttings tied together. When the wattles are planted in a bank along a contour, they sprout a continuous line of roots and shoots (resembling a retaining wall of plants) and quickly stabilises the soil than individual plants. Within a few years, the "sprouts" look like a tree lining/continuous row of shrubs.

This method is used to control surface erosion by breaking long slopes into shorter slopes. Bundles of branches (wattles) are placed in shallow trenches along the slope or stream bank contour (**Fig. 16**). Trenches are excavated by hand in such a way that depth of the trench is equal to half of the diameter of wattle and branches are secured with a twine. After the wattle is staked in place, the trench is backfilled until only the top of the bundle is exposed. Wattles can be used for hill slope restoration, road embankments, wide gullies, or slump areas. Installations start at the bottom of the cut or fill and proceeds upslope.

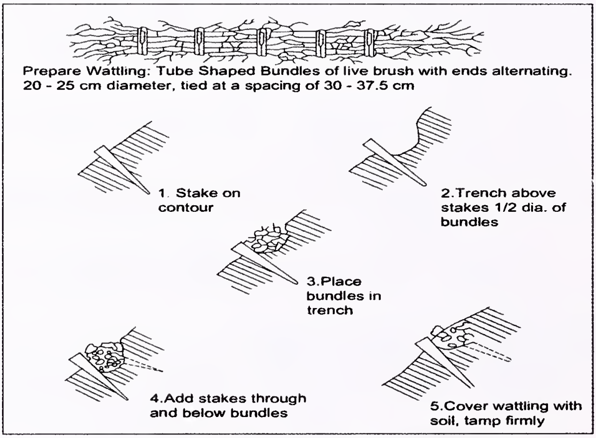

Fig. 16 (a) Contour Wattling Process

Fig. 16(b) Contour Wattling

6.2 Brush Layering

This method is used to restore slopes by constructing a fill-slope consisting of alternating layers of live branches and soil, creating a series of reinforced benches. Large quantities of dormant branches of suitable plant species are often used. While about 75 to 80 percent of the branch is buried, the tips are left exposed **(Fig. 17)**. The layers of branches help reinforce the fill area. Brush layering can be used to place new fill or repair old fill areas, restore shallow slumps, repair narrow gullies and stabilise loose soil slopes. The vertical angle depends on slope angle.

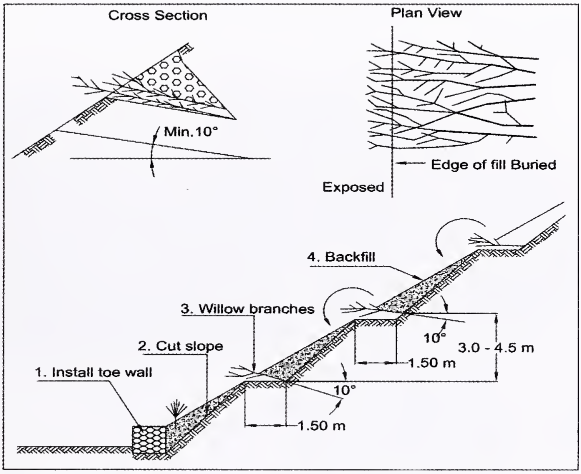

Fig. 17 (a) Brush Layering Process

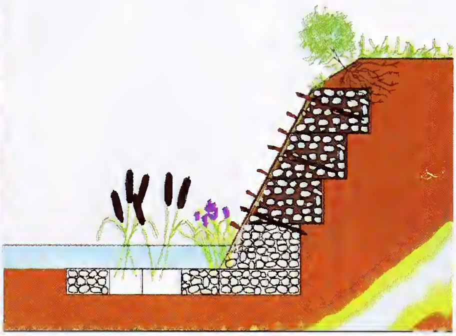

Fig. 17 (b) Brush Layering

6.3 Coir Fascines

Coir fascines are wattles made from the fibrous outer husk of coconuts. Coir is denser than water so it will not float and is very slow to decay. Coir fascines are a readily available manufactured product and are popular for stream bank and wetland restoration where a natural look is desired. Coir fascines are placed with their tops at the water surface. Live plants can be placed into coir fascines to create a natural look. The coconut fibre accumulates sediment and biodegrades as plant roots develop and become a stabilising system **Fig. 18**.

Fig. 18 Coir Fascines – Before and After Application of Coir Fascines

6.4 Pre-Vegetated Mats

Pre-vegetated mats are live plants grown on a movable mat of organic material. Pre-vegetated mats are made of coir or other slowly degradable material and can use many types of plants. They come in many sizes and materials and are moved and installed in one piece. They are generally 1.2 m by 2.4 m in size for easy handling. Vegetated mats are grown in nurseries for upto a year or more to provide a good plant stand. Thin mats can be rolled up and shipped without special packing. Thick mats are handled with heavy equipment because of their weight. Mats are usually used in wetland or lakeshore environments, so wetland plants are the most common.

6.5 Interplanting Rip-Rap

Rip-rap is often used to protect stream banks and lakeshores. Live cuttings can be interplanted in rip-rap to provide additional slope stability. Root growth below the rip-rap will improve soil strength and live vegetation will hide the rocks, presenting a more natural look.

6.6 Staking

Staking is used extensively in bioengineering practice. Stakes can be live or dry. Live staking is often done with willows to stabilise soil or to stake other materials in place. Manufactured timber stakes, 0.6 to 1.0 m long, are used to secure wattles and coir fascines. Timber stakes for upland application need to have a bias, or angle cut, making it easier to install. For wetland or streamside applications, stakes need straight parallel sides to prevent heaving from water pressure.

Live cuttings should be soaked in cold water for at least 24 hours before they are used. This not only provides the cuttings with needed moisture but also improves rooting. Live potted plants are often used. Care of live plants before and during planting is critical for success. Live plants raised indoors need to be acclimatised to the outdoor environment before planting.

6.7 Effectiveness of Bioengineering Techniques

Bioengineering can be effective in many stream bank, lakeshore and hill slope erosion situations, but it will not solve all soil erosion or slope failure problems. The success of a project hinges on many factors including proper design, plant selection, proper installation, weather conditions and outside factors like animal damage. Site evaluation is important to determine whether there is adequate sunlight, soil type and water quality to support vigorous plant growth. Bioengineering solutions may not be successful in submerged areas or in geologically unstable sites. Nor are they ideal for high stress areas with severe wave action, rapid or long-term water level fluctuations or at locations where flow of water is very fast. The following list includes tips that may help ensure a successful bioengineering project.

Bioengineering solutions are not to be attempted in situations where:

a) There is severe soil or water contamination
b) The stream bottom is degrading
c) Locations where human or animal traffic at the site cannot be controlled; or
d) There is too much shade for selected plant species to thrive.

Further, it should be noted that, in case of river bank protection, while using bioengineering techniques, water elevation is the most critical element for successful installation. Records of normal, high and low water elevations for the site must be available at any particular site. The seasonal changes in water elevation and how rapidly these changes occur must also be known. Before implementing bioengineering measures, one must be sure to fence out animals and people, if needed. If the plants are damaged, supplemental planting may be necessary. An awareness of flood or drought conditions that could impact installation must be there. Severe weather will reduce seedling survival. Sometimes a combination of various practices is found to be very effective and has been adopted at many locations. There is a need to provide regular monitoring and maintenance, especially in the first year, to assure adequate plant survival. There is also need to involve the proper design professionals and botanical/agronomy experts to provide information on hydrology, plantings and structural design. A multi-disciplinary approach will assure success.

7 SLOPES IN COHESIONLESS SOILS

In a purely cohesionless soil, it is rather difficult to establish vegetation. Even if it were possible, the sand grains in-between the network of root-system are most susceptible of being ‘piped our or washed out’, since the distant roots can hardly afford resistance to the movement of individual grains at the surface. Once the movement starts, it can become progressively unconfined and is most liable to 'flow'.

The remedial treatment is therefore to provide 25 cm to 30 cm thick clayey soil (but not heavy clays) as a blanket covering the slopes of the embankment, tamp it well on the slopes and subsequently provide the simple vegetative treatment recommended in Section 5.1. Alternatively, root mat systems like 3-D mats or geocells can also be used in case of cohesionless soils.

8 SLOPES IN BLACK COTTON SOILS

Invariably, there does not appear to be any need for special treatment against erosion on black cotton soil slopes, since this type of soil promotes natural growth of grass and other types of vegetation. The main problem seems to be the formation of shrinkage cracks. Therefore, it is recommended that these slopes may be managed with the simple method of providing vegetative turfing if the natural growth of grass happens to be inadequate. Artificial watering can be resorted to if there are economic means of procuring water, in the eventuality of the rainfall proving to be very scanty and in the event of the work having to be carried out beyond the monsoon season. Vetiver planting and any other suitable method can also be taken up on these slopes.

9 SELECTION OF EROSION CONTROL METHOD

The following suggestions may be generally kept in view for adopting suitable method of erosion control for soil slopes:

a) Developing vegetation cover would be the best method to prevent soil erosion. This may be attempted by using 'Simple Turfing Method'. At locations where turfing is to be achieved within a short time period, transplantation of readymade turfs can be tried.

b) Organic mulch application (either manually or by using hydroseeding) can be adopted to aid simple vegetative turfing. By using hydroseeding method, inaccessible and near vertical slopes can be successfully vegetated and hydroseeding method can be used in combination with nettings/ mats to make them even more effective.

c) At locations where simple turfing method cannot ensure vegetation cover, natural fibre based netting can be adopted to support vegetation growth. When the site is located in a drought prone area and it is difficult to sustain green cover throughout the year, synthetic geogrids can be adopted to provide long term protection.

d) Where vegetation cover alone is insufficient and soil surface needs to be protected in the absence of vegetation cover in certain patches, root reinforcing geosynthetic systems (3-D mats or geocells) can be used. Depending upon the duration for which protection needed (short term – 2 to 3 years or for longer term), either natural fibre based or polymer based 3-D mats can be adopted. For slope heights more than 5 m, root reinforcing systems would be better suited.

e) For slopes in the waterfront having velocity of flow in excess of 3 m/sec or having wave uplift effect, having inundation or continuous flooding for many days, slope protection system as indicated in Section 5.11 shall be resorted to. For floodable slope with silty clay type of soil, combination of rip-rap and geogrids may be used upto high flood level and for the remaining slope portion geogrid may be used. Should occasional flooding is envisaged in slope laid with geogrid, appropriate plant species which can survive under short term submergence shall be chosen.

In general, suggestions which may be kept in view while selecting the appropriate methodology for erosion control are given in **Table 2**.

Table 2 Suggestions for Selection of Erosion Control Technique

Situation	Height of Bank/ Cutting	Rainfall/ Velocity of water	Erosion Control System
Bank/cutting made in cohesive soil/ fine grained soil (CL, CI, CH, ML, MI, MH)	Less than 6 m	Low or moderate rainfall (Flow velocity 3 m/sec or less)	Vegetation (shallow rooted or deep rooted)
Bank/cutting made in cohesionless soil (Sandy/gravely soil)	Less than 6 m	Low or moderate rainfall (Flow velocity 3 m/sec or less)	Vegetation grown on 0.25 m to 0.3 m thick clayey soil as a cover over cohesionless fill
Bank /cutting made in all types of soil	More than 6 m	High rainfall (Flow velocity more than 3 m/sec)	Reinforced vegetation or reinforced protection
Bank/cutting made in any type of soil and submerged/ effect of wave uplift/ continuous flooding	Any height	High rainfall (Flow velocity more than 3 m/sec)	Boulder pitching with appropriate type of geosynthetic application

Annex- I
(Clause 2)

Rockfall Protection Measures

Sl. No.	Site Conditions	Measures	Applications	
1)	Falling rocks and boulders	**Trenches** and wall at foot of slope	Protection of road running at the bottom of manmade cuttings.	PASSIVE SYSTEM
		Rock fencing with high energy dissipation capacity	Road and building at the foot of natural building.	
		Rockfall protection barriers made on site.	Interception of falling rocks path in rocky slope.	
		Serating, Benching and Vegetations	Against loose weathered rock, Vegetation is expected, no accumulation of water on benches.	
2)	Controlling Rockfall, guiding falling debris to collect and accumulate at foot of slope.	Simple Drapery System-(**Rock fall netting or mesh),** Protective blankets and Geotextiles	Protection of road cliffs and building, also in combination with trenches or wall.	
3)	Consolidating the slope's surface and preventing possible rock detachment	Surficial strength (**Gunite and Shotcreting**)	Protection of road cut and buildings,	ACTIVE SYSTEM
4)	Global stabilisation of slope	**Soil Nailing**	Management of slope cuts.	
5)	Stabilisation of huge rocks individual or in groups which are prone to seismic shift.	Deep Consolidation with **nails and ties.**	Natural cliffs and slope cuts.	
6)	Water control	**Drainage holes,** dewatering wells and drainage galleries.		

Note: The rock fall protection measures given above are for general guidance only.

Annex- II
(Clause 5.1)

The following types of vegetation are recommended for use on soil slopes in India, irrespective of the types of soil. Altitude is of course a more significant factor.

I. PLAINS: (including altitudes upto 1500 m above sea level)

Grasses and Shrubs

1) HORTICULTURE Grass Cynodon dactylon
2) Cynodon plectostycum
3) Chloris gayana
4) Saccharum spontaneum Tall Pernicious Deep rooted Perennial
5) Sachharum munja
6) Ipomea carnea (Bacharum Booti)
7) Lantana species
8) Agave americana
9) Erythrina indica
10) Prosopis species
11) Casuarina species
12) Goat foot creepers

II. HILLS:

Grasses and Shrubs

1) Eragrostis curvula Love Grass (Kumaon – Central Himalaya)
2) Eragrostis superva (Locally known as Babla in Kumaon – Central Himalayas)
3) Chrysopogon mountanus – Central Himalayas
4) Pennisctum orientale – Central Himalayas
5) Lolium perenne (Rai Grass – H.P. & Kumaon)
6) Poa pratensis (above 1800 m)
7) Imperata cylindrica
8) Robinia pseudoaccadia Cuttings as well as plants
9) Kudzu vine all over upto 2400 m (Pueraria thungbergia)
10) Kikuyu (Pennisetum clandestinum)

11) Jatropha curcas
12) Ficus carica
13) Philendus cuttings
14) Lemon grass (Cymbopogon flexudosus) for use in elevations around 1900 m)

Guidance for Selecting the Species of Vegetation (As per IS 15869)

Name of the Species	**Suited for**
Avicennia officinalis	Shrub suited for marshy place
Rhizophora mucrunata	– do –
Cyperus exaltatus	Grass suited for road embankments/ road side slopes
Acrostichum aureum	Shrub suited for dam sites
Adiantum species	– do –
Cyanodon dactylon	For sandy soils
Cenchurs ciliaris	Can be used for most types of soils
Eragrostis curuvla	For protecting terraces and channels
Dichanthium annulatum	For alluvial soils
Pennisetum pedicellatum	Sandy loam soils
Rochola glabra	Lateritic semi arid soil
Stylosanthis gracilis	Alluvial soils having less moisture
Pueraria hirsuta	Suited to alluvial soils and for hills in humid climate
Pennisetum purpureum	For hill slopes
Pueraria hirsuta	Alluvial soils

Annex- III
(Clause 5.11)

Slope Erosion Protection Using Gabions and Mattresses

With mechanically woven double twisted steel wire mesh products such as Gabions, it is possible to construct flexible structures that effectively sustain the eroding slope and also preserve their natural look, thus providing eco-compatible solutions. The hexagonal shape of the mesh provides a better distribution of the working tensions along the wires that form the mesh. Double twist avoids spreading of the damage caused by the accidental breaking of any wire. The steel wire shall either be heavily zinc coated or zinc plus PVC coated to provide adequate protection against corrosion. Steel wire mesh Gabions and Revet Mattresses should conform to ASTM specification A 975 or ISO 7989 and ISO 22034. Gabion baskets are also made using welding process. While such welded wire mesh gabions do not possess flexibility as compared to woven wire mesh gabions, welded wire mesh gabions can be made to any convenient size and also their protective coating thickness can be easily varied.

The products of Mechanically Woven Double twisted hexagonal steel wire meshes that can be used for protecting the slope from erosion are

a) Gabions
b) Gabion mattresses (revet mattresses)

Gabions

Gabions are rectangular wire mesh baskets filled with rock at the project site to form flexible, permeable, monolithic structures. They are made of hexagonal shaped double twisted steel woven wire mesh, with high mechanical characteristics. The gabion is divided into cells by means of diaphragms positioned at approximately 1 m centres. The steel wire used in the manufacture of the gabion shall be coated with zinc or zinc and polymeric coated for protection from corrosion. In order to reinforce the structure, all mesh panel edges are selvedged with a wire having a greater diameter. With 30 per cent voids, gabion structures offer free drainage providing higher bank stability when used for river bank protection.

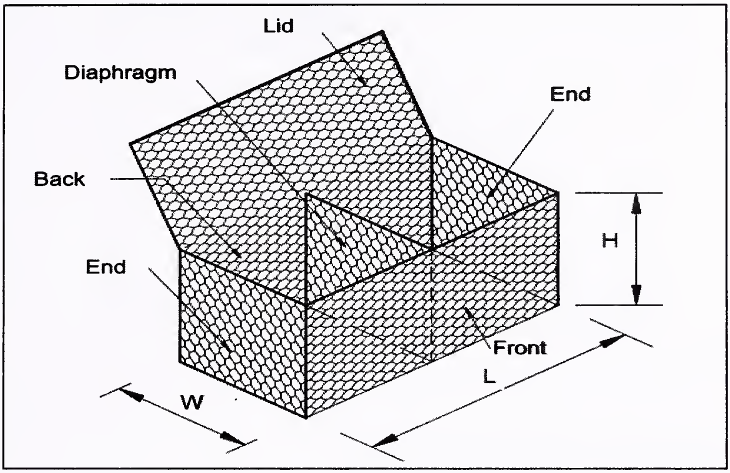

Fig. A- Gabion Box

Gabions are provided on the eroding slopes at suitable locations to prevent the soil from moving down the slope and thus protecting the slope. Gabions can be used for construction of protection structures like toe walls or breast walls. They serve both purposes of protecting the slope from being eroded and provide stability to the slope, if the slope is unstable.

Gabion Mattress

Gabion mattress also known revet mattresses, is a special form of gabion with a large plan area/thickness ratio. It is fabricated from a similar but smaller double-twist hexagonal mesh to that used to manufacture the gabions. Diaphragms are spaced usually at 1.00 m centres, and a continuous panel of mesh forms the base, the side and the end walls of the unit to obtain the open-topped multicellular container. All panel's edges are selvedged with a wire of larger diameter than that used for the mesh, so as to strengthen the structure.

These are used as mattresses on the slope to protect the bank from erosion. Gabion mattresses can be sealed by hot poured sand asphalt mastic, in order to provide an impermeable revetment. These are mainly used for riveting the slopes and thus prevent erosion of the slope.

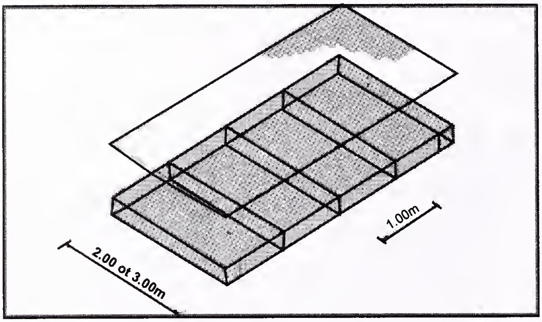

Fig. B - Gabion Mattress Unit

Gabions made from Polymeric Materials

Gabions and revet mattresses can be made using polymeric materials also. Such materials can be easily used in saline waters also. However, such type of gabions may not be able to retain the intended shape as effectively as compared to steel wire gabions.

(The Official amendments to this document would be published by the IRC in its periodical, 'Indian Highways' which shall be considered as effective and as part of the code/guidelines/manual, etc. from the date specified therein)