Government of Himachal Pradesh

PUBLIC WORKS DEPARTMENT

State Roads Project

DRAFT

# Specifications for Bio-engineering in Slope Stabilisation and Protection

## *INTRODUCTION*

1. The current general specifications (Specifications for Road and Bridge Works, Third Revision, Indian Roads Congress, New Delhi, 2000) have as section 300, "Earthwork, Erosion Control and Drainage". These give practices that are essentially acceptable on gentle slopes, embankments and in plain areas. In general they are not appropriate to steep slopes in the Himalayas, and in certain cases would make slope conditions worse.

2. More detailed guidelines are given in a specific publication for roads in steep terrain (Hill Road Manual, IRC:SP:48-1998, Indian Roads Congress, New Delhi, 1998). Section 11, "Slope Stability, Erosion Control and Landslide Correction" gives a brief introduction to these complex topics. The information on landslide assessment and stability analysis is technically sound, but not easy to apply in practice; also, it is more in manual format than in a form that can be applied as contractual specifications. In that manual, the parts on resolving problems are incomplete and not well linked to the initial identification of the problems. The use of vegetation is given limited treatment and is mainly restricted to techniques that are unnecessarily complicated.

3. In all general documents on road engineering, a number of "standard practices" should be used with caution in the Himalayan environment. Where these have been developed in areas with gentler slopes or different climates, they are often presented without warnings of potential disadvantages in the extreme environment found in the Himalayas. Practices such as slope benching and interceptor or catch-water drains, brought in from other terrain and climatic areas, can be especially problematic. Links with road safety issues, such as the restriction of sight lines by vegetation, also need to be introduced.

4. It is therefore proposed that the existing IRC specifications should be used for operations under the State Roads Project, augmented by the addition of further, more detailed specifications given in this document. If these draft detailed specifications are used in the SRP contracts on an interim basis, the Project will be able to draw out the experience gained in implementing these works, and a specific project output should be a set of guidelines originating in HP but appropriate to other Himalayan areas of India. It is intended that future work, linked to World Bank projects in different biophysical regions of India, should aim to develop similar guidelines for other conditions.

## *CURRENT RELEVANT SPECIFICATIONS*

### 306. SOIL EROSION AND SEDIMENTATION CONTOL

#### 306.1 Description

This work shall consist of measures as shown on plans or as directed by the Engineer to control soil erosion, sedimentation and water pollution, through use of berms, dykes, sediment basins, fibre mats, mulches, grasses, slope drains and other devices.

#### 306.2 Materials

All materials shall meet commercial grade standards and shall be approved by the Engineer before being used in the work.

### 306.3 Construction Operations

Prior to the start of the relevant construction, the Contractor shall submit to the Engineer for approval his schedules for carrying out temporary and permanent erosion/sedimentation control works as are applicable for the items of clearing and grubbing, roadway and drainage excavation, embankment/subgrade construction, bridges and other structures across water courses, pavement courses and shoulders. He shall also submit for approval his proposed method of erosion/sedimentation control on service road and borrow pits and his plan for disposal of waste materials. Work shall not be started until the erosion/sedimentation control schedules and methods of operation for the applicable construction have been approved by the Engineer.

The surface area of erodible earth material exposed by clearing and grubbing, excavation, borrow and fill operations shall be limited to the extent practicable. The Contractor may be directed to provide immediate permanent or temporary erosion and sedimentation control measures to prevent soil erosion and sedimentation that will adversely affect construction operations, damage adjacent properties, or cause contamination of nearby streams or other water courses, lakes, reservoirs etc. Such work may involve the construction of temporary berms, dikes, sediment basins, slope drains and use of temporary mulches, fabrics, mats, seeding or other control devices or methods as necessary to control erosion and sedimentation. Cut and fill slopes shall be seeded and turfed as required on the plans.

The Contractor shall be required to incorporate all permanent erosion and sedimentation control features into the project at the earliest practicable time as outlined in his accepted schedule to minimise the need for temporary erosion and sedimentation control measures.

Temporary erosion/sedimentation and pollution control measures shall be used to control the phenomenon of erosion, sedimentation and pollution that may develop during normal construction practices, but may neither be foreseen during the design stage nor associated with permanent control features on the Project.

Where erosion or sedimentation is likely to be a problem, clearing and grubbing operations should be so scheduled and performed that grading operations and permanent erosion or sedimentation control features can follow immediately thereafter if the project conditions permit; otherwise temporary erosion or sedimentation control measures may be required between successive construction stages. Under no conditions shall a large surface area of erodible earth material be exposed at one time by clearing and grubbing or excavation without prior approval of the Engineer.

The Engineer may limit the area of excavation, borrow and embankment operations in progress, commensurate with the Contractor's capability and progress in keeping the finished grading, mulching, seeding and other such permanent erosion, sedimentation and pollution control measures, in accordance with the accepted schedule. Should seasonal limitations make such coordination unrealistic, temporary erosion/sedimentation control measures shall be taken immediately to the extent feasible and justified.

In the event temporary erosion, sedimentation and pollution measures become necessary due to the Contractor's negligence, carelessness or failure to install permanent controls as part of the work as scheduled or ordered by the Engineer, these shall be carried out at the Contractor's own expense. Temporary erosion, sedimentation and pollution control work required, which is not attributed to the Contractor's negligence, carelessness or failure to install permanent controls, will be performed as ordered by the Engineer.

Temporary erosion, sedimentation or pollution control may include construction work outside the right-of-way where such work is necessary as a result of road construction such as borrow pit operations, service roads and equipment storage sites.

The temporary erosion, sedimentation and pollution control features installed by the Contractor shall be acceptably maintained by him till these are needed, unless otherwise agreed by the Engineer.

### 306.4 Measurements for Payment

The soil erosion, sedimentation and pollution control works will be measured in terms of units specified in the Bill of Quantities for the respective items.

### 306.5 Rates

The Contract unit rate for different items of soil erosion, sedimentation and pollution control works shall be payment in full for carrying out all required operations, including full compensation for all labour, tools equipment and incidentals to complete the works to the Specifications.

## 307. TURFING WITH SODS

### 307.1 Scope

This work shall consist of furnishing and laying of the live sod of perennial turf-forming grass on embankment slopes, verges (earthen shoulders) or other locations shown on the drawings or as directed by the Engineer. Unless otherwise specified, the work shall be taken up as soon as possible following construction of the embankment, provided the season is favourable for establishment of the sod.

### 307.2 Materials

The sod shall consist of dense, well-rooted growth of permanent and desirable grasses, indigenous to the locality where it is to be used and shall be practically free of weeds or other undesirable matter. At the time the sod is cut, the grass on the sod shall have a length of approximately 50 mm and the sod shall have been freed of debris.

Thickness of the sod shall be as uniform as possible, with some 50 – 80 mm or so of soil covering the grass roots, depending on the nature of the sod, so that practically all the dense root system of the grasses is retained in the sod strip. The sods shall be cut in rectangular strips of uniform width, not less than about 250 mm x 300 mm in size, but not so large that it is inconvenient to handle and transport these without damage. During wet weather the sod shall be allowed to dry sufficiently to prevent tearing during handling and during dry weather shall be watered before lifting to ensure its vitality and prevent the dropping of the soil in handling.

### 307.3 Construction operations

**307.3.1 Preparation of the earth bed:** The area to be sodded shall have been previously constructed to the required slope and cross section. Soil on the area shall be loosened, freed of all stones larger than 50 mm size, sticks, stumps and any undesirable foreign matter, and brought to a reasonably fine granular texture to a depth of not less than 25 mm for receiving the sod.

Where required, topsoil shall be spread over the slopes. Prior to placing the topsoil, the slopes shall be scarified to a depth, which after settlement, will provide the required nominal depth shown on the plans. Spreading shall not be done when the ground is excessively wet.

Following soil preparation and top soiling, where required, fertilizer and ground limestone when specified shall be spread uniformly at the rate indicated on the plans. After spreading, the materials are incorporated in the soil by discing or other means to the depths shown on the plans.

**307.3.1 Placing the sods:** The prepared sod bed shall be moistened to the loosened depth, if not already sufficiently moist, and the sod shall be placed thereon within approximately 24 hours after the same had been cut. Each sod strip shall be laid edge to edge and such that the joints caused by abutting ends are staggered. Every strip, after it is snugly placed against the strips already in position, shall be lightly tamped with suitable wooden or metal tampers, so as to eliminate air pockets and to press it into the underlying soil.

On side slopes steeper than 2 (horizontal) to 1 (vertical), the laying of sods shall be started from the bottom upwards. At points where water may flow over a sodded area, the upper edges of the sod strips shall be turned into the soil below the adjacent area and a layer of earth placed over this followed by its thorough compaction.

**307.3.3 Staking the sods:** Where the side slope is 2 (horizontal) to 1 (vertical) or steeper and the distance along the slope is more than 2m, the sods shall be staked with pegs or nails spaced approximately 500 to 1000 mm along the longitudinal axis of the sod strips. Stakes shall be driven approximately plumb through the sods to be almost flush with them.

**307.3.4 Top dressing:** After the sods have been laid in position, the surface shall be cleaned of loose sod, excess soil and other foreign material. Thereafter, a thin layer of top soil shall be scattered over the surface for top dressing and the area thoroughly moistened by sprinkling with water.

**307.3.5 Watering and maintenance:** The sods shall be watered by the Contractor for a period of at least four weeks after laying. Watering shall be so done as to avoid erosion and prevent damage to sodded areas by the wheels of water tanks.

The Contractor shall erect necessary warning signs and barriers, repair or replace sodded areas failing to show uniform growth of grass or damaged by his operations and shall otherwise maintain the sod at his cost until final acceptance.

### 307.4 Measurements for Payment

Turfing with sods shall be measured as finished work in square metres.

### 307.5 Rate

The Contract unit rate for turfing with sods shall mean payment in full for carrying out all the required operations explained above including compensation for
(i) furnishing all the materials to be incorporated in the Works with all leads and lifts; and
(ii) all labour, tools, equipments and incidentals to complete the work in accordance with these Specifications.

The Contract unit rate for application of topsoil shall be as per Clause 301.9.5.

## 308. SEEDING AND MULCHING

### 308.1 Scope

This shall consist of preparing slopes, placing topsoil, furnishing all seeds, commercial or organic fertilizers and mulching materials, providing jute netting and placing and incorporating the same on embankment slopes or other locations designated by the Engineer or shown in the Contract documents.

### 308.2 Materials

A. Seeds: The seeds shall be of approved quality and type suitable for the soil on which these are to be applied, and shall have acceptable purity and germination to requirements set down by the Engineer.

   Fertilizer shall consist of standard commercial materials and shall conform to the grade specified. Organic manure shall be fully putrefied organic matter such as cow dung.

   Mulching materials shall consist of straw, hay, wood shavings or sawdust, and shall be delivered dry. They shall be reasonably free of weed seed and such foreign materials as may detract from their effectiveness as a mulch or be injurious to the plant growth.

B. Topsoil: Topsoil shall not be obtained from an area known to have noxious weeds growing in it. If treated with herbicides or sterilents, it shall be tested by an appropriate agricultural authority to determine the residual amounts in the soil. Topsoil shall not contain less than 2 per cent and more than 12 per cent organic matter

C. Bituminous emulsion: A suitable grade of bituminous cutback or emulsion used as a tie down for mulch shall be as described in the Contract document or as desired by the Engineer. Emulsified bitumen shall not contain any solvent or diluting agent toxic to plant life.

D. Jute netting: Jute netting shall be undyed jute yarn woven into a uniform open weave with approximately 2.5 cm square openings.

   Geonetting shall be made of uniformly extruded rectangular mesh having mesh openings of 2 cm x 2 cm. The colour may be black or green. It shall weigh not less than 3.8 kg per 1000 sq. m.

### 308.3 Seeding Operations

**308.3.1 Seed bed preparation:** The area to be seeded shall be brought to the required slope and cross section by filling, reshaping eroded areas and refinishing slopes, medians etc. Topsoil shall be evenly spread over the specified areas to the depth shown on the plans, unless otherwise approved by the Engineer. The seed bed preparations shall consist of eliminating all live plants by suitable means using agricultural implements. All stones 150 mm in smallest dimension and larger shall be removed. The soil shall be excavated on the contour to a depth of 100 mm. All clods larger than 25 mm in diameter shall be crushed and packed. Where necessary, water shall then be applied. All topsoil shall be compacted unless otherwise specified or approved by the Engineer. Compaction shall be by slope compactor, cleated tractor or similar equipment approved by the Engineer. Equipment shall be so designed and constructed as to produce a uniform rough textured surface ready for seeding and mulching and which will bond the topsoil to the underlying material. The entire area shall be covered by a minimum of 4 passes or 2 round trips of the roller or approved equipment.

**308.3.2 Fertilizer application:** Fertilizer to the required quantities shall be spread and thoroughly incorporated into the soil surface as a part of the seed bed preparation.

**308.3.3 Planting of seeds:** All seeds shall be planted uniformly at the approved rate. Immediately after sowing the area shall be raked, dragged or otherwise treated so as to cover the seeds to a depth of 6 mm.

The operation of seed sowing shall not be performed when the ground is muddy or when the soil or weather conditions would otherwise prevent proper soil preparation and subsequent operations.

**308.3.4 Soil moisture and watering requirements:** Soil moisture shall exist throughout the zone from 25 mm to at least 125 mm below the surface at the time of planting.

Watering of the seeded areas shall be carried out as determined by the Engineer.

### 308.4 Mulching, Applying Bituminous Emulsion and Jute Netting/Geonetting

Within 24 hours of seeding, mulching material mixed with organic manure shall be placed so as to form a continuous, unbroken cover of approximate uniform thickness of 25mm using an acceptable mechanical blower. Mulching material shall be held in place and made resistant to being blown away by suitable means approved by the Engineer. When called for in the Contract documents, mulch material shall be anchored in place with bituminous emulsion applied at the rate of 2300 litres per hectare. Any mulch disturbed or displaced following application shall be removed, reseeded and remulched as specified. Jute netting/geonetting shall be unrolled and placed parallel to the flow of water immediately after bringing to finished grade, the area specified on the plans for the placing of seed and fertilizer. Where more than one strip is required to cover the given areas, they shall overlap a minimum of 100 mm. Jute netting/geonetting shall be held in place by approved wire staples, pins, spikes or wooden stakes driven vertically into the soil.

### 308.5 Maintenance

The Contractor shall maintain all seeded and mulched areas until final acceptance. Maintenance shall include protection of traffic by approved warning signs or barricades and repairing any areas damaged following the seeding and mulching operations. If mulched areas become damaged the areas shall be reshaped and than seeded and mulched again as originally specified.

### 308.6 Measurements for payment

Seeding and mulching shall be measured as finished work in square metres.

### 308.7 Rate

The Contract unit rate for seeding and mulching shall be payment in full for carrying out all the required operations including full compensation for all materials, labour, tools and incidentals.

## *PROPOSED ADDITIONAL SPECIFICATIONS*

The specifications given below are proposed for trial under the Himachal Pradesh State Roads Project, to supplement the existing specifications in the 300 series (see above). They have been numbered within the same series, but this does not imply approval from the Indian Roads Congress.

### 351. SLOPE PREPARATION FOR BIO-ENGINEERING

#### 351.1 Scope

The Contractor shall prepare slopes for planting operations as required by the Engineer. This shall be done according to the specifications described hereunder, as and when required. The Contractor shall supply all necessary expertise, resources and facilities to ensure that these requirements are met.

In the course of all slope preparation works, it is essential that no damage is done to existing vegetation unless the Engineer's instruction specifically requires certain plants to be removed.

The timing of many bio-engineering operations is of the utmost importance. Activities such as planting and seed sowing must be carried out within the critical few weeks when they will yield the desired results. All other operations must be carried out in a timely manner to permit this to happen. The contractor is responsible to keep works to the strict schedule required and under no circumstances to permit delays.

#### 351.2 Slope trimming

**351.2.1 Preparatory measures:** Slope trimming is the main activity where debris masses and inherently unstable slope sections are removed, and the slope made sufficiently sound for civil and bio-engineering works. The Contractor must first check that all prior construction work has been completed and that the site is clear of equipment. It is the Contractor's responsibility to ensure that there is safe access to the site and that site staff and labourers are issued with appropriate safety equipment.

**351.2.2 Setting out:** The Engineer will issue an instruction for the details of trimming required on each site. If this has not already been issued it is the Contractor's responsibility to request it from the Engineer and agree the details before work is commenced. Possibilities for slope trimming are as follows: minor trimming required only on part of site; keeping rill or gully pattern in plan section; trimming to a new designed plan section; new retaining wall to be backfilled; others, as determined by the individual site.

A trimming survey must first be carried out. Pegs and lines must be placed as necessary to show the workers how much material to trim. Notches must be cut through the mass to be trimmed to give the final cut lines.

**351.2.3 Manual trimming:** When trimming a site, work must be started from the top of the slope segment. The slope is trimmed in steps from the top, using the steps as ledges for the workers to stand on during trimming.

If backfilling is required behind a retaining structure below, the trimmed material must be compacted at intervals as the operation proceeds. This will involve halting the trimming, redistributing and compacting the debris as backfill. Compaction is carried out in level layers approximately 100 – 150 mm thick, laid back into the slope at about 5°. If possible, water should be added while compacting the material.

When the main trim has been completed, the workers should return to the top of the slope and work down again, carrying out the final trim. This should give a clean, smooth surface, good enough for vegetation to be planted on.

The final trim line should then be checked to ensure that it is straight and accurate throughout the site. If protrusions or indentations remain, they must be removed or filled with compacted material. Once the profile has been satisfactorily obtained, all debris must be removed from the site to an approved tipping area and the site left in a tidy condition.

**351.2.4 Machine trimming:** In locations where the slope to be trimmed is within easy reach of the road, a back-hoe excavator may be used for trimming. In this situation the principles described for manual trimming are to be followed using the machine in place of labourers.

### 351.3 Final preparation of cut slopes for grass planting and seeding

The objective of final cut slope preparation is to produce a surface adequately prepared for grass planting or grass seeding. Bio-engineering plants provide a strong surface cover but need a well prepared surface in which to be planted; if vegetation is to be an effective form of slope protection, it must be allowed to establish properly on a slope which does not subject it to undue stress from erosion and mass movement in its initial stages.

The Contractor must ensure that the slope under instruction is trimmed to a straight angle, according to the Engineer's specification. Cut slopes to be planted with grass will normally be instructed as 3 vertical:2 horizontal, but this may be varied at the Engineer's discretion. In any event, a straight profile must be obtained. Concavities must be filled with well compacted material or, in some cases, with dry stone dentition. Convexities must be removed and it is essential that the general profile does not have a shape giving over-steep segments.

All loose material must be removed from the slope and tipped elsewhere in an approved location, as per the requirements of specification 351.5.

### 351.4 Final preparation of fill and debris slopes for bio-engineering

The objective of the final preparation of fill slopes and slopes comprising unconsolidated landslide debris is to produce a surface adequately prepared for shrub or tree planting or grass sowing, or a combination of these. Vegetation is used to provide a strong surface cover but needs a well prepared surface in which to be planted: if it is to be an effective form of slope protection, it must be allowed to establish properly on a slope which does not subject it to undue stress in its initial stages.

The Contractor must ensure that the slope under instruction is trimmed to a straight angle, according to specification 351.2. In any event, a straight profile must be obtained. All masses of loose debris, especially where it has previously been tipped at the head of the slope, must be removed. Concavities must be filled with well compacted material or, in some cases, with dry stone dentition. Convexities must also be removed and it is essential that the general profile does not have a shape giving over-steep segments.

### 351.5 Disposal of spoil

In mountainous areas, the disposal of spoil can lead to many problems of erosion and slope instability. The Contractor must follow the Engineer's instructions in disposing of surplus spoil in approved locations.

Where a landfill site (designated debris disposal area) is created, maximum use must be made of terraces, level ground and spurs. If spoil tipping has to be done on steep slopes, it is essential to select areas formed in resistant bedrock. Tipping should result in no more than the removal of vegetation and shallow soil, with negligible slope incision thereafter. Tin sheet disposal chutes can be used to convey the spoil down a short slope to a safe site below.

During tipping, the Contractor must build many small spoil benches, rather than a few large ones, to avoid slope overloading. A drainage blanket must be installed beneath a spoil bench where there is any indication of a spring or water seepage at or near the spoil site. Spoil benches must be compacted during tipping. While benches cannot be compacted in the formal sense, they can be constructed in definite lifts, normally not more than 0.5 m thick, with the top surface of each lift approximately horizontal. This will allow machines involved in spreading the spoil to track the surface and provide some degree of compaction.

Where spoil benches are constructed on agricultural land, the Contractor must form the tip into a benched profile so that it can eventually be returned to agricultural production. In the meantime, the risers between levels must be protected against erosion by applying vegetation or constructing dry stone walls.

Where the top surface of the bench is large, runoff must be reduced by providing regular shallow interceptor drains. The slope of these drains should be constant as far as is practicable and should not be so steep as to induce erosion.

On completion, the Contractor is to leave spoil benches in their required shape and plant them with grasses, shrubs and trees to encourage maximum stability and resistance to erosion.

Under no circumstances are the following permitted:
(i) tipping of spoil into stream or river channels, as the increased sediment load will lead to scour and siltation downstream;
(ii) tipping of spoil on to slopes where road alignments, housing areas or farmland downslope might be affected;
(iii) use of areas of past or active instability and erosion as tip sites, unless they are at least 50 metres from the road;
(iv) the discharge of runoff over the loose front edge of a tip bench during or after construction;
(v) tipping of spoil in front of road retaining walls, where impeded drainage could soften the wall foundation.

### 351.6 Measurements for payment

Slope trimming and preparation shall be measured as finished work in square metres. Debris removal shall be measured as material disposed in cubic metres.

### 351.7 Rate

The Contract unit rate for slope trimming and preparation, and spoil disposal, shall be payment in full for carrying out all the required operations including full compensation for all materials, labour, tools, equipment and incidentals, and shall include all leads and lifts.

## 352. SITE PLANTING AND SOWING

### 352.1 Scope

The Contractor shall plant or sow grasses, shrubs and trees as required by the Engineer. This shall be done according to the specifications described hereunder, as and when required. The Contractor shall supply all necessary expertise, resources and facilities to ensure that these requirements are met.

It is the Contractor's responsibility to ensure that all planting stock, whether provided from a nursery under the same or a separate contract or through a separate instruction, is of high quality and is vigorous enough to grow on the site to be planted.

All seeds and other planting stock must be of species indigenous to Himachal Pradesh unless otherwise specified. All species must be covered in the current approved lists of species produced from time to time by the Public Works Department. They must be appropriate for the precise site conditions in which they are to be planted and the Contractor must ensure that they apply to the specific altitude and other environmental characteristics of the site in question.

The timing of many bio-engineering operations is of the utmost importance. Activities such as planting and seed sowing must be carried out within the critical few weeks when they will yield the desired results. All other operations must be carried out in a timely manner to permit this to happen. The contractor is responsible to keep works to the strict schedule required and under no circumstances to permit delays.

### 352.2 Materials

**352.2.1 Provision of seed:** The Contractor shall provide or collect seeds of the required species in accordance with the requirements described hereafter, of the species and quantities required, as and when required. He shall supply all necessary expertise, resources and facilities to ensure that these requirements are met in full. It is essential that the seed is of a high quality as it forms the basis to the success of any bio-engineering programme.

The Engineer will give indications as to the expected amounts of seeds required and the time of availability. But it is the Contractor's responsibility to ensure that adequate quantities of seeds are obtained in a timely fashion.

Weights to be specified are for sun-dried seeds separated completely from fruiting bodies and other unwanted parts, and ready for storage and subsequent sowing. There is usually a large discrepancy between this weight and that of the freshly collected, untreated fruits.

Should the Contractor be unable to supply the specified seeds, the advice of the Engineer should be sought. It may be possible to substitute other species. Some commercial seed sources in India are known to supply old or badly treated seeds. For this reason, seed should not be obtained commercially without the Engineer's written authority.

**352.2.2 Grass seed collection:** The species of grass seeds to be collected will be determined by the Engineer. The Contractor will be responsible for determining seed sources, though these may be specified by the Engineer's instructions. Seeds should normally be collected in or very close to the project area.

If the Engineer does not specify the species, then the current approved list of bio-engineering plants, as determined by the Public Works Department should be referred to.

Seeds must be collected from as many individual plants as possible. With grasses, it is difficult to determine the best genetic material from the appearance of form; but it is generally sound practice to select from the largest and most vigorous plants.

The Contractor may under no circumstances damage or remove the roots of grass plants while collecting seed. The Contractor is responsible for safety measures and for making all necessary arrangements with landowners, farmers and the local Forest Office, as applicable, before the collection of seeds.

Seeds may only be collected when fully ripe. Seeds collected early are not viable when sown and will cause a failure of the planting programme. The Contractor will be held liable if the germination rate of seeds is seriously lower than the normally expected percentage (as defined in publications issued by the Ministry of Environment and Forests).

Immediately after collection, seeds must be separated from flower heads by the method normally used by farmers for other grasses. Once separated, the seeds must be sun-dried before storage.

Seeds must be stored in a cool, dry, ventilated building with adequate precautions taken against pests. Containers should be raised above the floor. They should not be kept in the same building as cement, or any chemicals, fuels or lubricants. Grass is best stored in bags made of hessian (jute) sheet. Seeds should be carefully inspected on a weekly basis to ensure that there is no deterioration or mould formation, or pest attack. Seeds can only be stored successfully if they have been properly dried in the sun beforehand.

**352.2.3 Tree and shrub seed collection:** The species of tree and shrub seeds to be collected will be determined by the Engineer. The Contractor will be responsible for determining seed sources, though these may be specified by the Engineer's instructions. Seeds should normally be collected in or very close to the project working area.

If the Engineer does not specify the species, then the current approved list of bio-engineering plants, as determined by the Public Works Department should be referred to.

Seeds must be collected from as many healthy individual plants as possible. In any event, they must be collected from at least ten individual plants. The plants from which the seeds are collected must show vigorous growth and good form. Mis-shapen and stunted plants should not be considered.

The Contractor must under no circumstances damage plants while collecting seed. The Contractor is responsible for making all necessary arrangements with landowners, farmers and the local Forest Office, as applicable, before the collection of seeds.

The collection of seeds from trees can be a dangerous business, placing the collectors at considerable personal risk. Specialist equipment and training is available for this purpose. It is the Contractor's responsibility to ensure safe working conditions for his employees or subcontractors.

Seeds may only be collected when fully ripe. Seeds collected early are not viable when planted and will cause a failure of the planting programme. The Contractor will be held liable if the germination rate of seeds is seriously lower than the normally expected percentage (as defined in publications issued by the Ministry of Environment and Forests).

Immediately after collection, seeds must be separated from fruit by the method normally used by farmers and foresters for this purpose; this depends on the individual species but may be a time-consuming process for certain fruits. Once separated, the seeds must be sun-dried before storage.

Seeds must be stored in a cool, dry, ventilated building with adequate precautions taken against pests. Containers should be raised above the floor. They should not be kept in the same building as cement, or any chemicals, fuels or lubricants. If kept in sealed containers, the seeds should be carefully inspected on a weekly basis to ensure that there is no deterioration or mould formation. Seeds can only be stored successfully if they have been properly dried in the sun beforehand.

**352.2.4 Provision of plant cuttings:** The species of plants to be collected for vegetative propagation will be determined by the Engineer. The Contractor will be responsible for determining plant material sources, though these may be specified by the Engineer's instructions. Plants should normally be collected in or very close to the project working area.

If the Engineer does not specify the species, then the current approved list of bio-engineering plants, as determined by the Public Works Department should be referred to.

**352.2.5 Provision of grass cuttings:** Cuttings of various types must be taken from grass species which are known to propagate easily by vegetative means.

Cuttings must be made from as many healthy individual plants as possible. The plants from which the cuttings are taken must show vigorous growth and good form. Grass clumps showing stunted growth should not be considered as sources.

Apart from the clumps which are dug up to make cuttings, the Contractor must under no circumstances damage other plants. The Contractor is responsible for making all necessary arrangements with landowners, farmers and the local Forest Office, as applicable, before the excavation of plants to make cuttings.

The type of cuttings to be made depends on the species and should be as shown in the table below. If the species used is not listed here, then the latest technical information provided by the Public Works Department should be consulted. If the species is still not covered, then stem and root slip cuttings should be used.

| Common name | Botanical name | Best propagation | Details |
|---|---|---|---|
| Bhabar | *Eulaliopsis binata* | Slip cuttings | Stem: 100 - 150 mm; root: 30 - 60 mm |
| | *Neyraudia reynaudiana* | Stem/slip cuttings | Stem cuttings: 2 nodes plus 50 mm each side<br>Slips: stem: 100 - 150 mm; root: 30 - 60 mm |
| Kans | *Saccharum spontaneum* | Slip cuttings | Stem: 100 - 150 mm; root: 30 - 60 mm |
| | *Themeda* species | Slip cuttings | Stem: 100 - 150 mm; root: 30 - 60 mm |
| | *Cymbopogon microtheca* | Slip cuttings | Stem: 100 - 150 mm; root: 30 - 60 mm |
| Khus | *Vetiveria lawsoni* | Slip cuttings | Stem: 100 - 150 mm; root: 30 - 60 mm |
| Napier | *Pennisetum purpureum* | Stem cuttings | Two nodes plus 50 mm each side |
| | *Arundo clonax* | Stem/slip cuttings | Stem cuttings: 2 nodes plus 50 mm each side<br>Slips: stem: 100 - 150 mm; root: 30 - 60 mm |
| | *Arunduella nepalensis* | Slip cuttings | Stem: 100 - 150 mm; root: 30 - 60 mm |
| Sito | *Neyraudia arundinacea* | Slip cuttings | Stem: 100 - 150 mm; root: 30 - 60 mm |

Where roots are required for the cuttings, grass clumps should carefully dug up. They must not be pulled hard, as this can damage the material. They must be separated carefully by hand, using a sharp knife or razor blade when necessary. There must be no tearing of the plant fabric.

Stem cuttings must be made using sharp secateurs. The top cut should be made at right-angles to the stem and the bottom cut should be made at 45º to the stem: this is to show the orientation of planting.

Once cuttings have been made, they must be wrapped in wet hessian jute immediately. At all times, cuttings are to be kept moist and as cool as possible, and should be wrapped in wet hessian between all operations such as digging out of the ground, splitting out, trimming and planting. Under any circumstances, all cuttings must be planted the same day that they are made.

**352.2.6 Provision of hardwood cuttings:** Hardwood cuttings must only be taken from shrubs and trees of species which are known to propagate easily by vegetative means. The species from which hardwood cuttings are to be made for bio-engineering works normally includes species such as willow (*Salix tetrasperma*), lantana (*Lantana camara*), bihaya (*Ipomoea fistulosa*) and vitex (*Vitex negundo*), or as listed by the Public Works Department.

Cuttings must be made from as many healthy individual plants as possible. The plants from which the cuttings are taken must show vigorous growth and good form. Mis-shapen and stunted plants should not be considered as sources.

Apart from the branches from which cuttings are taken, the Contractor must under no circumstances damage plants while taking cuttings. The Contractor is responsible for making all necessary arrangements with landowners, farmers and the local Forest Office, as applicable, before the making of hardwood cuttings. In no event is more than 60 per cent of the aerial parts of a single plant to be removed in the making of cuttings.

Hardwood cuttings must be made from stems which are between 6 and 18 months old. Materials outside this range are not normally vigorous or strong enough to survive as cuttings. The Contractor may be held liable if the success rate of cuttings is seriously lower than the normally expected percentage (as defined in publications issued by the Ministry of Environment and Forests).

Hardwood cuttings must be made using sharp secateurs or a sharp saw. The top cut should be made at right-angles to the stem and the bottom cut should be made at 45º to the stem: this is to show the orientation of planting. Under no circumstances must there be any damage to the bark of the cutting.

Hardwood cuttings are normally 20 to 40 mm in diameter and of the following lengths: 300 to 500 mm for use in palisades, vegetated stone-pitched walls and for pegging jute netting; 450 to 600 mm for use in brush layers; and a minimum of 1000 mm for use in fascines. For use in live check dams, all cuttings are to be 2000 mm in length; the cuttings for cross pieces should be 20 to 50 mm in diameter and the truncheon cuttings for the vertical elements should be 30 to 80 mm in diameter: truncheon cuttings are made only from the species known to be propagated by farmers using this method. These sizes should not be exceeded unless specified by the Engineer.

A number of species can be propagated using large truncheon cuttings. Hardwood cuttings for these species should be in the range of 1500 to 2500 mm in length and 30 to 80 mm in diameter unless otherwise specified.

Once cuttings have been made, they must be wrapped in wet hessian jute immediately. At all times, cuttings are to be kept moist and as cool as possible, and should be wrapped in wet hessian between all operations such as taking from the parent plant, trimming and planting. Under any circumstances, all cuttings must be planted the same day that they are made.

### 352.3 Sowing of grasses

Existing specification 308 shall apply.

### 352.4 Direct seed sowing of shrubs and trees

**352.4.1 Scope:** The direct sowing of shrubs and trees is intended to create a strengthened slope surface which is resistant to erosion, and to contribute to the anchorage of unstable surface layers. The technique is particularly effective where very stony materials preclude the use of other planting techniques or where the site will be badly affected by disturbance during the planting of polypot seedlings, or where the site is still unstable and does not warrant the costs involved in planting but would benefit from relatively cheap seeding. The Contractor is required to carry out the sowing of shrub and tree seeds according to the Engineer's specific instructions.

**352.4.2 Preparation:** It is assumed that the site will already have been prepared for seed sowing, under a separate instruction; but it is nevertheless the responsibility of the Contractor to ensure that the condition of the site is good enough for the successful establishment of shrubs and trees.

The Contractor is required to supervise all field operations very closely. The sowing of any seeds is a delicate business and should be approached in the same way as for agricultural crops. The Contractor should employ experienced agricultural labourers for this work.

**352.4.3 Construction technique:** Sowing should start at the top of the slope and the labourers should work downwards. Care must be taken not to disturb areas already seeded.

To sow the seeds, a small hole should be made in the slope. The tool used to do this depends on the size of the seed. For some seeds, a piece of gabion wire is adequate; for others, a piece of mild steel with a flattened end is required. The hole should be in the best soil available but if there is little real soil, then a crevice between two stones is acceptable. Two seeds should be placed in each hole and a covering of soil or whatever fines are available should be placed over them. This covering should never exceed 10 mm and should preferably be about 5 mm; it should never be less than this. Seeds should be placed at 50 to 100 mm centres, as ground conditions dictate.

In some cases the seed can be broadcast starting at the top of the site and working down slope as evenly as possible so that the whole site is lightly covered. This will be instructed by the Engineer where erosion is still active and only minimum expenditure is warranted, or where the site is naturally rough, providing plenty of niches in which the seed can catch. Quantities of seed depend on the type of seed involved but are generally half that of the quantities used in a nursery.

### 352.5 Planting of grass slips and cuttings

**352.5.1 Scope:** The planting of grass slips and cuttings is intended to create a strengthened slope surface which is resistant to erosion. The Contractor is required to carry out the planting of grass seedlings or rooted cuttings, according to the Engineer's specific instructions. The configuration of planting will be determined according to individual site conditions. It will be either random, contoured, diagonal or downslope.

**352.5.2 Preparation:** It is assumed that the site will already have been prepared for planting, under a separate instruction; but it is nevertheless the responsibility of the Contractor to ensure that the condition of the site is good enough for the successful establishment of grasses, and accords with specification 351.

**352.5.3 Construction technique:** Using appropriate tools (such as tape measures and spirit levels), planting lines must be marked out with string as required. Unless specified differently by the Engineer, the row spacing to be marked out is as shown in the table below.

| Planting configuration | Slope angle | Row spacing |
|---|---|---|
| Random | Slope less than 30 degrees | 1000 mm centres |
| | Slope 30 to 45 degrees | 500 mm centres |
| | Slope more than 45 degrees | 250 mm centres |
| Contour lines | Slope less than 30 degrees | 1000 mm centres |
| | Slope 30 to 45 degrees | 500 mm centres |
| | Slope more than 45 degrees | 250 mm centres |
| Diagonal lines | All slopes | 500 mm centres |
| Downslope lines | All slopes | 500 mm centres |

The Contractor is required to supervise all field operations very closely. The planting of grass slips is a delicate business and should be approached in the same way as the transplanting of millet seedlings. The Contractor should employ experienced agricultural labourers for this work.

The plants supplied should be prepared for planting as given below. The Contractor is to transport them from the nursery wrapped in hessian jute. At all times, plants are to be kept moist and as cool as possible, and should be wrapped in wet hessian between all operations such as extraction from the nursery, final preparation and planting. Under any circumstances, all plants supplied must be planted the same day that they are lifted from the nursery.

Grass slips or cuttings should be carefully separated from the clumps to give the maximum viable planting material. Any roots in excess of 25 mm should be cut off using a sharp knife or razor blade. Shoots and stems should be lopped off 100 mm above ground level.

Planting should be started at the top of the slope and under no circumstances should new plants be walked on or otherwise disturbed. Using a small bar (usually made of mild steel and with a flattened end), a hole should be made that is just big enough for the roots. The slip or cutting is inserted; care must be taken that the roots are not tangled or bent back to the surface. Soil is then replaced around the roots and firmed with the fingers. The spacing of plants within rows should be 100 mm unless otherwise specified.

**352.5.4 Aftercare:** If the soil is dry and there is no rain within 16 to 24 hours of planting, the site should be watered carefully with a fine spray. The Contractor will be required to water for the first two weeks after planting in the event of inadequate rainfall.

**352.5.5 Alternatives:** In certain circumstances it may not be possible to provide grass plants from a nursery. In this case the Engineer will specify the species and expected source of grass plants. It is important to minimise disruption to neighbouring land, in the event that species are collected from areas surrounding the road. It is the Contractor's responsibility to collect the stock required from a wide area and not to give rise to any soil erosion through the excessive removal of plants in one locality.

### 352.6 Planting of shrubs and trees raised in polythene pots

**352.6.1 Scope:** The planting of trees and shrubs is intended to replace or restore something of the natural vegetation on the slope to be treated. The Contractor is required to carry out the planting of seedlings to the Engineer's specific instructions.

**352.6.2 Preparation:** It is assumed that the site will already have been prepared for planting, under a separate instruction; but it is nevertheless the responsibility of the Contractor to ensure that the condition of the site is good enough for the successful establishment of delicate young plants.

The Contractor is required to supervise all field operations very closely. The planting of trees and shrubs is a delicate business and should be approached in the same way as the planting of horticultural seedlings. The Contractor should employ experienced agricultural or forestry labourers for this work.

The plants supplied by the Contractor will normally be from a nursery as arranged by separate instructions, and will be ready for planting. They should be at least 300 mm in height above the soil surface and hardened off in the normal way. The Contractor is to transport the plants to site with all due care. The plants will normally be supplied in polythene pots, which should not be removed until the moment of planting. Plants are to be lifted by the pots, and never by the stem or leaves. At all times they are to be kept as cool as possible. The Contractor is responsible for ensuring that the soil around the roots does not dry out. Under any circumstances, all plants supplied must be planted within three days of removal from the nursery.

Planting should be started at the top of the slope and under no circumstances should new plants be walked on or otherwise disturbed.

**352.6.3 Construction technique:** The spacing of plants will be determined according to individual site conditions. However, it will normally be at one metre centres unless otherwise specified.

A planting pit wide and deep enough for the main root to be buried in without bending it and wide enough for all the roots and surrounding soil ball should be made at the time of planting. Some compost if available should be mixed with the soil from the pit prior to backfilling around the roots. The polythene pot must be removed from the seedling by cutting it away with a razor blade. The plant should then be carefully placed into the hole, the compost and soil packed in, and all surrounding soil firmed up, taking care not to cause any damage to the plant or its roots. The surface over and around the pit should then be mulched using any appropriate, locally available material, such as manure, compost, dead leaves or cut herbage.

**352.6.4 Alternatives:** The Engineer may specify bigger seedlings for specific areas, such as those to be used intensively for amenity purposes. These will normally have been growing in a nursery for at least a year (at least two years for nurseries above 1200 metres altitude) and should have well developed roots as well as aerial parts. They will be provided either as bare root stock with a substantial root ball, or in pots of a minimum of 100 x 180 mm laid flat dimensions. When these larger seedlings are planted, the pits will be of 300 mm diameter and 300 mm depth. In addition, well-rotted compost will be mixed with the soil backfill in a ratio of at least one part compost to ten parts soil.

### 352.7 Planting of hardwood cuttings

**352.7.1 Scope:** Certain trees and shrubs can be planted on site by means of hardwood cuttings. Where these are specified, the Contractor is required to carry out the planting of cuttings as required in the Engineer's instructions.

**352.7.2 Preparation:** It is assumed that the site will already have been prepared for planting, under a separate instruction; but it is nevertheless the responsibility of the Contractor to ensure that the condition of the site is good enough for the successful establishment of delicate young plants.

The Contractor is required to supervise all field operations very closely. The planting of tree and shrub cuttings is a delicate business and should be approached in the same way as the planting of horticultural cuttings (*e.g.* those of tea). The Contractor should employ experienced agricultural or forestry labourers for this work.

The cuttings are normally to be made as per specification 352.2.6 or will be supplied to the Contractor by separate instructions, and will be ready for planting. The Contractor is to collect the cuttings from the nursery and transport them from the nursery wrapped in hessian jute. At all times, cuttings are to be kept moist and as cool as possible, and should be wrapped in wet hessian between all operations such as cutting from the parent plant, trimming and planting. Under any circumstances, all plants supplied must be planted the same day that they are lifted from the nursery.

**352.7.3 Construction technique:** The spacing of hardwood cuttings will be determined according to individual site conditions. However, it will normally be at 500 mm centres unless otherwise specified.

Planting should be started at the top of the slope and under no circumstances should new plants be walked on or otherwise disturbed. Using a small bar (usually made of mild steel and with a flattened end), a hole should be made that is just big enough for the cutting. The cutting is inserted and the soil is replaced around it and firmed with the fingers. The cutting should be inserted to a depth such that two-thirds to three-quarters of it is buried.

Where rooted cuttings have been supplied from a nursery, they must be planted in such a way that the roots are not damaged or badly bunched in the planting hole; the hole must be big enough to take the roots so that they are properly spaced out all around the plant.

**352.7.4 Aftercare:** If the soil is dry and there is no rain within 16 to 24 hours of planting, the site should be watered carefully with a fine spray. The Contractor will be required to water for the first two weeks after planting in the event of inadequate rainfall.

**352.7.5 Alternatives:** The Engineer may specify bigger cuttings for specific areas, using large truncheon cuttings. In this category fall plants such as *Brassaiopsis hainla*, *Garuga pinnata*, *Ficus lacor*, *Erythrina* species and *Gliricidia sepium*. Cuttings of these species should planted at 1000 mm centres. A large crowbar should be used to make the planting hole, but otherwise the technique is as described above for smaller cuttings. Under no circumstances should these cuttings be hammered into the ground.

### 352.8 Brush layering, palisades and fascines

**352.8.1 Scope:** In certain situations, the Contractor will be required to construct vegetation structures using hardwood cuttings. Where these are specified, the Contractor is required to carry out the necessary preparation and planting works as required in the Engineer's instructions.

Brush layering is a technique whereby woody (or hardwood) cuttings are laid in shallow trenches aligned across the slope, usually following the contour. These form a strong barrier, preventing erosion and the development of rills, and trap material moving down the slope. In the long term, a small terrace will develop. The main engineering functions are to catch debris, and to armour and reinforce the slope. In certain locations, brush layers can be angled to provide a drainage function.

Palisades are similar to brush layers, except that the cuttings are inserted directly into the soil upright, rather than being laid into shallow trenches. Palisades are quicker to install and easier in rocky sites, but there is usually a far more limited growth success rate than for brush layers.

The word "fascine" means a bundle of sticks. In this technique, bundles of live branches are laid in shallow trenches. After burial in the trenches, they put out roots and shoots, forming a strong line of vegetation. It is sometimes called live contour wattling. The main engineering functions are to catch debris, and to armour and reinforce the slope. In certain locations, fascines can be angled to provide drainage. Where time is at a premium, brush layers may be more appropriate as these are quicker to establish than fascines.

It is assumed that the site will already have been prepared for planting, under a separate instruction; but it is nevertheless the responsibility of the Contractor to ensure that the condition of the site is good enough for the successful establishment of delicate young plants.

**352.8.2 Materials:** The cuttings supplied to the Contractor may be from a nursery as arranged by separate instructions, and will be ready for planting. They should be at least 400 mm long for brush layering, 600 mm long for palisades and 1000 mm in length for fascines. The Contractor is to collect the cuttings from the nursery and transport them from the nursery wrapped in hessian jute. At all times, cuttings are to be kept moist and as cool as possible, and should be wrapped in wet hessian between all operations such as cutting from the parent plant, trimming and planting. Under any circumstances, all plants supplied must be planted the same day that they are lifted from the nursery.

If the instruction to the Contractor includes the provision of cuttings, then the Engineer will specify the species and expected sources, and the Contractor must then obtain the cuttings required. This will be done in the manner described in specification 352.2.6 except that the size of cuttings will be of a minimum length of 600 mm for brush layering on landslide debris, 450 mm for brush layering on road embankments, 600 mm for palisades and 1000 mm for fascines, and minimum diameters of 30 mm for brush layering, 40 mm for palisades and 50 mm for fascines.

Cuttings of the following species, if specified, should be a minimum of 2000 mm in length: *Brassaiopsis hainla*, *Garuga pinnata*, *Ficus lacor*, *Erythrina* species and *Gliricidia sepium*.

**352.8.3 Construction operations:** The Contractor is required to supervise all field operations very closely. The planting of tree and shrub cuttings is a delicate business and should be approached in the same way as the planting of horticultural cuttings (*e.g.* those of tea). The Contractor should employ experienced agricultural or forestry labourers for this work.

Planting should always be started at the top of the slope and under no circumstances should new plants be walked on or otherwise disturbed.

**352.8.4 Brush layering:** Brush layering should be constructed as given here, unless specified differently.

(i) Starting at the bottom of the area to be treated, and using appropriate measuring equipment, exact lines should be marked out. From 1 metre above the bottom of the slope, a precise contour line should be marked out every 1 metre up the slope.

(ii) Starting at the bottom, terraces approximately 450 mm wide on landslide debris or 350 mm on road embankments should be excavated along the lines.

(iii) Cuttings should then be placed into each trench at 50 mm centres, the correct way up and angled so that they are at right-angles to the maximum slope angle. All cuttings should be inserted to a depth such that two-thirds to three-quarters of their length is buried

(iv) The trench should then be partially backfilled and another line of cuttings placed along the trench at 50 mm centres and 100 mm behind the first line, and with the individual cuttings offset to coincide with the gaps between the cuttings in the first line. This results in cuttings at 25 mm centres in each brush layer (*i.e.* 40 cuttings per running metre). The trench is then completely backfilled and gently compacted. Any loose or excess material is cleared down the slope before the next line is planted.

(v) In some cases it will be specified that cuttings should be placed in a criss-cross fashion. Where this is to be done, one layer of cuttings is laid in the trench at 30º to one side of the line of maximum fall of slope. A second layer of cuttings is laid on top of this, at 30º to the other side of the line of maximum fall of slope. Backfilling and compaction are then completed.

**352.8.5 Palisades:** Palisades should be constructed as given here, unless specified differently.

(i) Starting at the top of the area to be treated, and using appropriate measuring equipment, exact lines should be marked out. From 1 metre below the top of the slope, a precise contour line should be marked out every 1 metre down the slope.

(ii) Starting at one end and using a small bar (usually made of mild steel and with a flattened end), a hole should be made that is just big enough for the first cutting. The cutting is inserted and the soil is replaced around it and firmed with the fingers. The cutting must be the correct way up and angled so that it is vertical. The cutting should be inserted to a depth such that two-thirds to three-quarters of it is buried.

(iii) This process should be repeated along the entire line, with a series of cuttings placed at 50 mm centres.

(iv) If a double line is specified, then a second line of cuttings must be placed in the same way, 100 mm behind the first and with the individual cuttings offset to coincide with the gaps between the cuttings in the first line.

(v) The soil around the single or double line is then completely backfilled into any remaining gaps and gently compacted. Any loose or excess material is cleared down the slope before the next line is planted.

**352.8.6 Fascines:** Fascines are bundles of hardwood cuttings laid horizontally in trenches, and parallel to the line of the trench. The bundles are thereby completely buried. Fascines should be constructed as given here, unless specified differently.

(i) Starting at the bottom of the area to be treated, and using appropriate measuring equipment, exact lines should be marked out. From 1 metre above the bottom of the slope, a precise contour line should be marked out every 1 metre up the slope.

(ii) Starting at the bottom, trenches approximately 200 mm in depth should be excavated along the lines.

(iii) Cuttings should then be laid along each trench, so that they lie horizontally along the trench. There should normally be eight cuttings together, although where material is short a minimum of four cuttings is permissible. They must be overlapped so that no two ends coincide. The cuttings must then be tied using jute or coir (coconut fibre) string at 500 mm intervals to form a bundle. As the fascine is created, it thereby forms a continuous bundle right across the slope.

(iv) The trench should then be backfilled and gently compacted. The top of the fascine should be 50 to 100 mm below the surface. Any loose or excess material is cleared down the slope before the next line is planted.

**352.8.7 Alternatives:** The Engineer may specify that orientations other than along the contour of the slope are used. In this event, the Contractor must alter the laying out of lines accordingly and meet the precise angle required.

**352.8.8 Aftercare:** If the soil is dry and there is no rain within 16 to 24 hours of planting, the site should be watered carefully with a fine spray. The Contractor will be required to water for the first two weeks after planting in the event of inadequate rainfall.

### 352.9 Measurements for payment

Bio-engineering works shall be measured as finished work in the following units.
(i) Seed collection, if instructed separately, per kilogram of treated and dried seed.
(ii) Provision of hardwood cuttings, if instructed separately, per number of cuttings.
(iii) Grass seeding, per square metre.
(iv) Planting of grass slips and cuttings, per square metre.
(v) Planting of polypot seedlings of trees and shrubs, per number of seedlings.
(vi) Planting of hardwood cuttings, per square metre.
(vii) Construction of brush layers, palisades and fascines, per running metre constructed.

### 352.10 Rate

The Contract unit rate for all bio-engineering works shall be payment in full for carrying out all the required operations including full compensation for all materials, labour, tools, equipment and incidentals, and shall include all leads and lifts.

## 353. SITE AFTERCARE AND MAINTENANCE

### 353.1 Scope

The Contractor shall maintain planted bio-engineering sites as required by the Engineer. This shall be done according to the specifications described hereunder, as and when required. The Contractor shall supply all necessary expertise and resources to ensure that these requirements are met.

### 353.2 Site protection

Because of the long time required for plants to become robust, the period of maintenance by the contractor will normally be for twelve months.

The Contractor is to protect a planted site for the period specified. Protection is to include the prevention of damage to all manner of site works and plants by local people and domestic or wild animals. It also includes an active role in tending the plants and improving their growth, as specified below.

### 353.3 Maintenance activities

The Contractor shall carry out weeding as required throughout the site. All annual weeds and other unwanted plants shall be cut just above the ground and the aerial parts will be used to make compost or mulch. Weeds must not be pulled out by the roots since this disturbs the ground surface.

Weeding should be carried out throughout the growing season. It must be undertaken with particular diligence at the end of the monsoon, so that there is the minimum amount of competition during the subsequent dry season.

The Contractor shall carry out mulching as required throughout the site. All plants required under the bio-engineering specifications will be mulched using material prepared as described in Specification 308, or the aerial parts of weeds cut on the site or brought from elsewhere for the purpose. The desired plants should be kept mulched at all times but especial care must be taken in the spring, when the soil moisture deficit is at its greatest.

The Contractor shall replace failed, damaged, diseased and very weak plants, using fresh, healthy plants of the same species, at the correct time of year for planting. This replanting operation will normally be carried out during the monsoon in the year following the first planting works. Vegetation structures will be enriched by the planting of additional cuttings or seedlings, as instructed by the Engineer. Failed seeding areas will be re-seeded at the appropriate time of year.

In replanting and enrichment works, the Engineer may specify the use of different species. This will be done where failures or poor performance of plants may be attributed to poor stock or an incorrect initial choice of species.

All bio-engineering sites must be maintained so that there are at least the following two storeys of vegetation. In certain locations, however, there may be a number of additional vegetation storeys.
(i) A dense ground cover of healthy grass plants, in the configuration specified at the time of planting.
(ii) An open canopy of shrubs or trees with a deeper rooting network.

In general it is necessary to keep the upper canopy thinned in order to maintain the lower ground cover. Most grasses require high light intensities and become degraded if subjected to excessive shade from the overstorey. It is therefore the Contractor's responsibility to thin the canopy as necessary to permit adequate levels of light to penetrate for the optimum growth of the grass understorey.

All thinning and pruning operations are to be undertaken in accordance with the guidelines issued by the Public Works Department. Since these are skilled silvicultural operations, the Contractor must take appropriate professional advice and employ suitably skilled personnel.

All products from thinning and pruning operations are to be disposed of in accordance with the regulations of the Government of Himachal Pradesh. The Contractor should follow the instructions of the Engineer in this regard.

Other maintenance operations are to be undertaken by the Contractor according to the instructions of the Engineer.

# 354. BIO-ENGINEERING NURSERY OPERATIONS

## 354.1 Nursery production of grass

Grass will be propagated in nurseries either by seeding in carefully prepared beds or by vegetative propagation.

Where grass seeding is required in the nursery, finely sieved fertile soil mixed with clean sand to a texture of sandy loam must be placed in beds before the seeds are sown. Seeds will be covered with a sheet of hessian jute until they have germinated, when it will be carefully removed. Watering of fresh seedlings will be by a fine spray and not by the rose of a watering can.

Grasses to be propagated by vegetative methods will be of the species instructed. The Contractor should obtain adequate quantities of the plant material required, but under no circumstances is he to cause serious depletion of grass stocks in any steep or erosion-prone area.

Vegetative propagation will normally be by rhizome cuttings. With this method, the grass is treated in exactly the same way as a bamboo being propagated by the traditional farmer's technique. A clump is carefully dug up and brought to the nursery, being kept cool and damp at all times. Stems are cut above the first or second node above the ground: this usually gives a length of 100 to 200 mm. The clump is separated carefully, with the minimum of damage to the rhizomes and fine roots. Slips should be separated out which keep a length of stem and about 50 mm of the rhizome. Each slip should have some buds on the rhizome, but in some grasses these can be difficult to see. The slips should be planted with the soil surface at the same level as it was originally, in rows at 200 mm centres; slips should be at 200 mm centres within the rows. A sheet of hessian jute should be placed over the tops of the cuttings. When the new shoots are about 50 mm long, it can be removed.

Every two to three months, all grasses should be lifted from the beds, split carefully and replanted. It is normal that, once split out, three times the previous bed area is required. This is a standard practice to bulk up the supply of planting stock without having to degrade the natural vegetation cover in the region of the nursery.

## 354.2 Nursery production of trees and shrubs in polypots

Existing specifications and practices of the Ministry of Environment and Forests apply to this aspect of work.

## 354.3 Nursery production of hardwood plants by vegetative methods

Existing specifications and practices of the Ministry of Environment and Forests apply to this aspect of work.

## 354.4 Extraction of plants from the nursery

The Contractor is responsible for extracting plants from nursery beds and preparing them ready for transport. They should be extracted from the beds only on the morning that they are required for planting on site.

Plants must be hardened off, starting at least two weeks before they are to be taken out of the nursery. This process requires a gradual reduction in the amount of watering and shading. The aim is to prepare them for transfer to a much more hostile location.

The night before the plants are to be lifted, they should be thoroughly watered. This is to make the soil softer and ease the business of extracting the roots.

Plants growing in soil beds should be carefully lifted from the soil. There must be no pulling of stems or roots, but they must be dug out and extracted with no strain on any part of the plant.

Plants from soil beds must be wrapped in wet hessian jute. Hardwood plants should have a ball of soil around the roots. Grass clumps can have most of the soil shaken or washed off.

Polypot seedlings should be lifted and stacked neatly in metal or wooden trays. They must always be lifted by the pot and never by the stem or leaves.

All plants are to be kept moist, in a cool, shady place, until they are loaded for transport to site. In the vehicle, they must not be stacked high. For transport on rough roads, they must be packed in carefully so that they do not fall over or roll around. The vehicle must be shaded.

## 361. WIRE BOLSTER CYLINDERS

### 361.1 Description and use

Wire bolster cylinders are, in cross-section, a wire mesh tube of 300 mm diameter (occasionally 600 mm diameter) filled with stone, laid in shallow trenches across the slope. They prevent surface erosion and the formation of gullies, and provide shallow support to unconsolidated materials. They can be used on most long, exposed slopes with finished grades between 35 and 50º where there is a danger of surface erosion. Contour bolsters are used on well drained materials; slanted (or herringbone pattern) bolsters are used on poorly drained material where there is a risk of creep or slumping, to enhance drainage at the same time as controlling erosion. Wire bolster cylinders stabilise the surface while a vegetation cover becomes established, and thereafter contribute to its reinforcement.

The Contractor shall provide and install wire bolster cylinders as required by the Engineer. This shall be done according to the specifications described hereunder, as and when required. The Contractor shall supply all necessary expertise, resources and facilities to ensure that these requirements are met.

### 361.2 Manual fabrication of bolster panels

Bolster panels will be either 5 x 1 metres or 5 x 2 metres in size, according to the type of bolster to be used. They will be woven with an hexagonal mesh in the same way as normal gabion crate panels. For the panel frame, 10 swg galvanised wire should be used; for the mesh, 12 swg is adequate. Wire should preferably have a high grade zinc coating. Failing this, a medium grade zinc coating is acceptable.

Weaving should start from one of the long sides. A total of 83 coils of wire should be spaced evenly along the 5 metre length. This gives a mesh width of about 60 mm. Each weave should have three twists, as for normal hexagonal gabion crate mesh. If done reasonably tightly, this gives a length of about 80 mm to each mesh link. In any event, the mesh length should not exceed 90 mm. The mesh should be turned on to the larger frame wire at least one and a half turns and made fully secure.

### 361.3 Construction technique for contour bolsters

A contour bolster treatment gives a series of stone-filled wire tubes of 300 mm diameter, laid in trenches cut across the slope. The tops of all the tubes should be flush with the surface of the slope in which they are placed. The purpose is to check erosion of the slope surface by preventing the development of rills and gullies

The site to be treated should be given final preparation immediately before bolster installation. All small protrusions and depressions must be obliterated by cutting, or by infilling and compaction.

Starting at the base of the area to be treated, and using appropriate measuring equipment, exact lines should be marked out. From 2 metres above the base of the slope, a precise contour line should be marked out every 2 metres up the slope.

Starting at the bottom, trenches with circular base should be dug along the lines, adequate to take the final 300 mm diameter tubes.

Bolster panels should then be laid along the trenches and shaped to fit neatly into the base of the trenches, as well as into any curves formed as a result of the slope contours; each panel should be securely joined to the next panel, to form a continuous bolster tube.

The panels should be packed with stones, closed over and the edges wired together. All stones must be bigger than the mesh size. The same care should be taken as when filling a conventional gabion crate basket, and stones must be carefully placed to give good structural integrity.

The ends of the bolsters should be closed over and wired together. The trenches around all the bolsters should then be filled and compacted with material left from the excavations.

Once all of the lines are in place, all surplus debris should be cleaned off the slope. Mild steel bars of at least 10 mm diameter should then be driven into the slope through the lower sides of the contour bolsters. These should be at least every 2 metres along the lines. Bars should be 2 metres in length on slopes composed of soft materials, but at the Engineer's discretion, on slopes comprising hard rocky materials, bars of 1 metre length will be adequate. All bars must be driven home until the tops protrude no more than 25 mm above the slope surface.

### 361.4 Construction technique for slanting (angled) bolsters

In certain situations the Engineer may instruct a bolster network on a herringbone pattern to form a shallow drainage system. This takes the form of an arrangement of wire tubes of 300 mm or 600 mm in diameter depending on the amount seepage water expected on the site, laid in trenches cut into the slope. A main bolster runs straight down the slope (the spine) with others running into it at an angle of 30 to 50 degrees to the fall of the slope (the rib bones or branches) depending on slope angle and terrain morphology. The tops of all the tubes should be flush with the surface of the slope in which they are placed. The purpose is both to stop erosion of the slope surface by preventing the development of rills and gullies, and to drain the surface material in a similar way to a french drain. The diagonal components should be at 2 to 5 metre centres if measured straight down the slope.

The site to be treated should be given final preparation immediately before bolster installation. All small protrusions and depressions must be obliterated by cutting, or by infilling and compaction.

Starting at the base of the area to be treated, and using appropriate measuring equipment, exact lines should be marked out: every 7.1 metres across the slope, a line should run straight up to the top of the slope (these form the main bolster spines). From the base of the line, and every 3 metres above this, other lines of 5 metres length should be marked at 45 degrees to the main line (these will form the ribs).

Starting at the bottom, trenches with circular base should be dug along the lines, adequate to take the final 300 mm diameter tubes, or 600 mm diameter tubes if larger (5 x 2 metre) panels are specified.

If it is specified that an impermeable lining should be used, then 20 gauge black polythene sheeting must be laid along the bottoms of the trenches and the bolsters constructed on top of this.

Bolster panels should then be laid along the trenches and shaped to fit neatly into the base of the trenches, as well as into any curves formed as a result of the slope contours; the panels of the ribs should be securely joined to the panels of the main bolster.

The panels should be gradually closed together and secured, working up from the bottom of the slope, while stones are passed in from above to fill them. The stones should be randomly packed so as to allow free drainage, and all stones must be bigger than the mesh size. The same care should be taken as when filling a conventional gabion crate basket, and stones must be carefully placed to give good structural integrity.

The upper ends of the ribs should be closed over and wired together; they should touch the ends of the next herringbones but should not be secured to each other. The trenches around all the bolsters should then be filled and compacted with material left from the excavations.

Once all of the lines are in place, all surplus debris should be cleaned off the slope. Mild steel bars of at least 10 mm diameter should then be driven into the slope through the sides of the main spine bolsters and the lower sides of the rib bolsters. These should be at least every 2 metres along the lines. Bars should be 2 metres in length on slopes composed of soft materials, but at the Engineer's discretion, on slopes comprising hard rocky materials, bars of 1 metre length will be adequate. All bars must be driven home until the tops protrude no more than 25 mm above the slope surface.

### 361.5 Measurements for payment

Wire bolster cylinders shall be measured as finished work in running metres constructed.

### 361.6 Rate

The Contract unit rate for the construction of wire bolster cylinders shall be payment in full for carrying out all the required operations including full compensation for all materials, labour, tools, equipment and incidentals, and shall include all leads and lifts.

## 362. GABION CRATE RETAINING WALLS

### 362.1 Scope

Gabion crate walls are built using wire cages filled with packed stones and are normally used to retain or protect slopes against mass failure or major erosion (such as along river banks). The gabion crates are usually manufactured with hot dipped galvanised wire. The crates are normally assembled in modular form, with the cages available in lengths up to 3 metres long by 2 metres wide, and are normally 1 metre deep, subdivided into compartments with internal walls or diaphrams to provide strength for the structure. The stone fill for the gabions should be placed in the compartments by hand or machinery starting at the bottom and working up, filling compartment by compartment to form the gabion structure. Fill used for gabions should be hard durable stone and not less than 150 mm in dimension. For non-standard shapes the gabion crates can be made or cut to size.

### 362.2 Design

The design of gabion crate retaining walls shall use the principles described in Specification 9 of IRC:SP:48-1998 (Hill Road Manual).

### 362.3 Materials

Gabions shall consist of steel wire mesh crates. The steel wire shall be mild steel wire complying with IS:280-2006 (Mild steel wire for general engineering purposes). All wires used in the manufacturing of crates and diaphragms, binding and connecting lids and boxes shall be galvanised with an heavy coating of zinc by an electrolytic or hot dip galvanising process. The wire shall be woven into an hexagonal mesh with a minimum of 3 twists. All edges of the crates shall be finished with a selvedge wire at least 3 gauges heavier than the mesh wire. Diaphragms (dividers in multiple-unit crates) shall be manufactured of the same materials as the parent gabion box and shall have selvedge wire throughout their perimeter.

Stones used for filling the gabion crates shall be clean, hard, sound, unweathered and angular rock fragments or boulders. The specific gravity of the stone shall be not less than 2.50 and the stones shall not absorb water more than 5 per cent when tested as per IS:1124-1974 (Method of test for determination of water absorption, apparent specific gravity and porosity of natural building stones). The length of any stone shall not exceed three times the dimension of the mesh of the crate. However smaller size of stones as spalls shall be allowed for filling voids and its volume including voids shall not be more than 20 per cent of the total volume of the stone. Before filling any gabion crates the Contractor shall submit representative samples of the rock he proposes to use in the gabion for approval by the Engineer. Further representative samples shall be submitted for approval each time there is a change in the type and strength of the rock.

Before filling any gabion crates, the Contractor shall submit samples of crates assembled, erected and filled with stones for approval which, when approved, shall be retained for reference and comparison with the crates built as part of the permanent works. The size, type and location of the samples shall be as directed by the Engineer.

### 362.4 Foundations

Gabion crates shall be assembled, erected and filled with stones in the dry on prepared surfaces except as may be otherwise approved. Approval for assembling and erecting gabions in water shall be given only, if in the Engineer's opinion such a method will produce work which is otherwise in accordance with the Specification.

Foundations must bne taken deep enough to rest on sound foundation materials which must be safe from scour, frost and surface water. Rock must be cut in level steps or to a downward slope towards the filling. The rock bed slope should be towards the hill and not away. The necessity of filling foundation pits in front of the toe of the retaining wall back up to original ground level, so as to avoid pooling of water leading to toe erosion, is to be considered. [Existing Specification 9.2.5 of IRC:SP:48-1998]

The bed on which the gabion crates are to be laid shall be even and conform to the levels shown on the Drawing. If necessary cavities between rock protrusions shall be filled with material similar to that specified for gabion filling.

### 362.5 Placement and assembly of crates

Gabion crates shall be placed such that vertical joints are not continuous, but staggered. If more than one unit is required to obtain the necessary width, units of unequal length shall be used and the joints between should be staggered. The crates shall be laid in such a manner that the hinges of the lid will be on the lower side on slopes and on the outer side.

Gabion crates shall be assembled on a hard flat surface. After fabrication, unpacking or unfolding, they shall be stretched out and any kinks shall be removed. Creases shall be in the correct position for forming the boxes or mattress compartments. The side and end panels shall be folded into an upright position to form rectangular boxes or compartments. The top corners shall be joined together with the thick selvedge wires sticking out of the corners of each panel. The tops of all sides and partitions shall be leveled except as may be appropriate to special units. The sides and end panels shall be tied together using binding wire of the same thickness as the crate mesh, starting at the top of the panel by looping the wire through the corner and twisting the wire together. Binding shall continue by looping the wire through each mesh and around both selvedges with three rounds which shall be joined tightly together by twisting and the end shall be pushed inside the unit. The diaphragms shall be secured in their correct positions by binding in the same way. The binding wire shall be fixed using 250 mm long nose fencing pliers or equivalent approved tools.

The crates shall be placed in their final position before filling commences. They shall be stretched to their full dimension and securely pegged to the ground or wired to adjacent gabion before filling. The vertical corners shall be kept square and to full dimension by inserting a steel bar of at least 20 mm diameter at each vertical corner, maintaining it in the correct final position throughout the filling process, and removing it when the crate is full. Before filling commences, the selvedges of the crate shall be bound to the selvedges of adjacent crates with binding wire.

### 362.6 Filling of crates

The filling shall be carried out by placing individual stones into the crates by hand in courses in such a manner that the stones are bedded on each other and bonded as in dry random rubble masonry as per Specification 1405. No loose stones shall be tipped into the crate and the practice of coursing and bonding the outer layer and filling the interior with unlaid stones shall not be permitted. All 1 m deep crates shall be filled in three equal layers. Horizontal bracing wires made with the same binding wire as used for tying shall be installed to keep the face of the gabions even and free from bulges. The bracing wires shall be fixed directly above each layer of the stone in the compartments, the wires being looped round two adjoining meshes in each side of the compartment and joined together to form a double tie which shall be tensioned by winding and lashing together. Bracing wires shall be spaced horizontally along and across the crates at the rate of four braces per square metre of side face (that is, eight cross braces per cubic metre crate). Where the upper faces of crates are not covered with further crates, vertical bracing wires shall be fitted between the top and bottom mesh using two tie wires per square metre of surface.

The ties shall be fixed to the bottom of the units prior to filling and tied down to the lid on completion. Where a double layer of crates boxes is used to form an apron, both upper and lower layers shall have vertical tie wires.

The gabion crate compartments shall be over filled by 50 mm above their tops to allow for subsequent settlement. The lids shall then be tied down with binding wire to the tops of all partition panels. The lids shall be stretched to fit the sides exactly by means of suitable tools, but due care shall be taken to ensure that the gabions are not so full that the lids are overstretched. The corners shall be temporarily secured first.

### 362.7 Measurement

Gabion wire mesh for boxes and mattresses shall be measured as completed work in square metres. The binding wires, selvedge wire and tension wires shall not be measured, but will be included in the measurement of the gabion crates.

Stone filling in crates, including fixing of gabion in position, tying with binding wires and tension wires as specified shall be measured as completed work in cubic metres.

### 362.8 Payment

The Contract unit rate for the provision and construction of gabion crate walls shall be payment in full for carrying out all the required operations including full compensation for all materials, labour, tools, equipment and incidentals, and shall include all leads and lifts.