GOVERNMENT OF HIMACHAL PRADESH
PUBLIC WORKS DEPARTMENT

SPECIFICATIONS FOR BIO-ENGINEERING IN SLOPE STABILIZATION AND PROTECTION

(First Edition)

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FOREWORD

Himachal Pradesh Public Works Department is executing various major road works under externally funded projects with active participation of World Bank. In all these works emphasis has been given to construct environment friendly roads with appropriate application of Bio-engineering which is first of its kind in the country. Bio-engineering is simply part of a wise and sustainable asset management. Bio-engineering techniques offer the best way of blending slopes into the landscape and limiting damage to surrounding agriculture and forest land. Bio-engineering refers to the use of live plants and plant parts to reinforce soil, act as erosion prevention barriers and promote dewatering of water laden soils.

The department of Public works has complied this Bio-engineering specification document by introducing new vegetative structures for slope stabilization and protection. I am sure these specifications for Bio-engineering in their present form will prove to be very useful to all the practicing engineers involved with road network as well as for the forest officers dealing with soil conservation projects.

I appreciate the efforts made by the members of the committee in preparing this document and compliment the officers of PWD, in their efforts and hope that the user agencies shall find the 'Bio-engineering specifications', a useful document in the pursuit of their professional duties.

(Virbhadra Singh)

Narinder Chauhan, IAS
Addl. Chief Secretary

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MESSAGE

It is a matter of great pleasure the HPPWD has made untiring efforts towards finalization of bio-engineering specifications, which document, I believe is the first of its kind in the country. Himachal Pradesh, has a good potential and necessity to adopt bio-engineering techniques in road network. It is possible to construct environment friendly roads with appropriate application of bio-engineering in Himachal Pradesh. Environment friendly roads add to the splendour of driving in the hills and check soil erosion, water and air pollution. It is also useful for improving road safety, reducing overall road maintenance cost and improving the ecological environment. It allows the restoration of original vegetation and ecosystem.

The specifications of bio-engineering given in this handbook of specifications will serve as standard bio-engineering specifications, and would form an integral component of overall road construction and road sector policy of the Government.

I appreciate and wish to place on record the efforts made by H.P. PWD officers in bringing out this document and hope that the user agencies shall find these 'bio-engineering specifications' useful in the pursuit of their professional duties.

(Narinder Chauhan)
Additional Chief Secretary
(Public Works) to the
Government of Himachal Pradesh.

ENGINEER-IN-CHIEF
Himachal Pradesh
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ACKNOWLEDGEMENT

I take this as an opportunity to acknowledge the untiring efforts put in for finalization of bio-engineering specifications by Committee consisting of experienced Senior Engineers, of which Er. K.K. Gupta, Engineer-in-Chief, Quality Control and Design is the Chairman, Er. B.K. Sharma, Superintending Engineer, HPRIDC, State Road Project, Er. B.B. Bhardwaj, Superintending Engineer and Er. D. S. Chauhan, Executive Engineer Quality Control & Design as the members and Shri S. S. Rana, Executive Engineer, Horticulture as Member Secretaty.

Further I gratefully acknowledge the efforts made by Ms. Neha Vyas, Environment Specialist of World Bank for rendering valuable help in preparation of the specifications of bio-engineering in slope stabilization and protection.

I hope the user agencies shall find these bio-engineering specifications very useful document in pursuit of professional activities.

(Er. Naresh Sharma)
Engineer-in-Chief,
HPPWD Nirman Bhawan,
Shimla-2

PREFACE

The Himachal Pradesh, PWD aims to adopt principle of sustainable environment friendly roads with appropriate application of bio-engineering in the road net work. There is a need of incorporating bio-engineering as an integral part of overall road planning, design and construction from inceptions.

The general specifications for earth work, erosion control and drainage in road and bridges works third revision IRC New Delhi 2001, Orange book, Hill Road Manual IRC: 48/1978 IRC New Delhi 1998 Blue Book and Rural Road Manual IRC : SP : 20-2002 and IRC Red Book IRC 2004 have been essentially designed for gentle slopes, embankments and plain areas. The vegetation has been given a limited treatment and is mainly restricted to techniques that are unnecessarily complicated. In general they are not appropriate to steep slopes in the Himalayas and in certain cases would make slopes conditions worse.

It has been considered more convenient to prepare separate volume of bio-engineering specifications. The specifications of bio-engineering given in this book will serve as standard bio-engineering specifications which will apply as an integral part of overall road construction for inception.

Bio-engineering is that part of biological science, which works as one tool towards attaining sustainable asset management, improving safety, reducing overall road maintenance cost and improving the ecological environment. Bio-engineering is an appropriate way of enhancing civil engineering structures to increase slope stability. The vegetative structures are flexible and therefore capable of absorbing movement and recovering from damage. They allow the restoration of something of the original vegetation and ecosystem.

These specifications for bio-engineering works in slope stabilization and protection were firstly prepared in 2007 by Mr. John Howell a Bio-engineering specialist of World Bank for the execution of bio-engineering works first of its kind in the country road net work for pilot sites in the State Road Project, Himachal Pradesh. The Pilot sites were constructed and State Road Project experienced very promising results. The bio-engineering techniques were further executed in field on debris dumping sites and observed very good output.

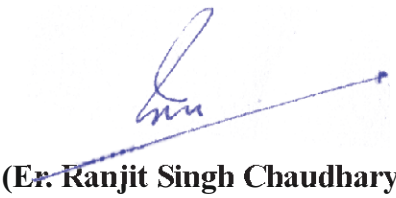
A committee has been constituted for the finalization of draft specifications consisting of six experienced senior engineers, of which Er. K. K. Gupta,, Engineer-in-Chief, Quality Control and Design is the Chairman, Er. Naresh K. Sharma, Chief Engineer-cum-Project Director & Er. B. K. Sharma, Superintending Engineer, HP, RIDC, State Road Project, Er. B. B. Bhardwaj, Superintending Engineer and Er. D. S. Chauhan, Executive Engineer Quality Control and Design as the members and Shri S. S. Rana, Executive Engineer. Horticulture as member secretary. The draft bio-engineering specifications in slope stabilization and protection were placed before the

committee for approval. Shri S. S. Rana, Executive Engineer (Hort.) explained the necessity and requirement of bio-engineering in slope stabilization and protection. The analysis of rate for items 16.1 to 16.9 (Grassing : small, medium and large, brush layer, hedge brush layer, Palisades, Fascines, well rotten cow dung manure, tree guards and live crib wall) in schedule rate HP PWD 2009 and HP PWD data book were incorporated. Now this draft specifications for bio-engineering works with addition of list of species of plants and the required sketches have been finally prepared as required for the execution of bio-engineering works in Himachal Pradesh.

The committee after detailed discussion has agreed and approved the draft specifications for bio-engineering works in slope stabilization and protection.

Comments and suggestions on the specifications especially with regards to the errors, omissions, local conditions and local materials with a view to making the document more comprehensive, will be highly appreciable.

Himachal Pradesh, Public Works Department gratefully acknowledges the efforts made by Mr. John Howell Bio-engineering Specialist and Ms Neha Vyas, Environment Specialist, World Bank for preparing the draft specifications of bio-engineering and keen interest evinced and invaluable help rendered by the members of the bio-engineering specifications committee and made the publication of this document a reality.



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INTRODUCTION

1. The current general specifications (Specifications for Road and Bridge Works, Third Revision, Indian Roads Congress, New Delhi, 2001: Orange Book) have as section 300, "Earthwork, Erosion Control and Drainage". These give practices that are essentially designed for gentle slopes, embankments and 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: Blue Book). 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. Vegetation is given only very brief mention in the Rural Roads Manual (IRC:SP:20-2002, Indian Roads Congress, New Delhi, 2002).

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 finalise a set of guidelines appropriate to the Himalayan areas of India.

5. The clause numbers used in the proposed additional specifications are arbitrary and have been adopted because they are not used already in existing specifications.

CURRENT RELEVANT SPECIFICATIONS

6. The specifications given here are from the IRC Orange Book (Specifications for Road and Bridge Works, Third Revision, Indian Roads Congress, New Delhi, 2000). The IRC Red Book (Specifications for Rural Roads, Indian Roads Congress, New Delhi, 2004) has similar sections, with the Orange Book specification clauses 306 to 308 appearing with minor variations in the Red Book as clauses 308 to 310, and repeated in clause 1610 (under hillslope rather than general protection).

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306. SOIL EROSION AND SEDIMENTATION CONTROL

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.

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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.

307.3.2 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 (IRC Orange Book, Road and Bridge Works, 2001).

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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 25 mm 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 then 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.

OTHER EXISTING RELEVANT SPECIFICATIONS

In addition to the specifications quoted above, the following existing specifications are also partly relevant to slope protection and bio-engineering works.

IRC Orange Book (Road and Bridge Works, 2001)		**IRC Red Book (Rural Roads, 2004)**	
Clause no.	**Subject**	**Clause no.**	**Subject**
704	Protection Works with Geosynthetics [covers protection for embankments]	No equivalent	
2504	Pitching/Revetment on Slopes [covers stone surface pitching of bunds and embankments]	1302	Pitching on Slopes [covers stone and brick surface pitching, and non-live timber stake toe protection]
No equivalent		1307 and 1606	Hillside Drains
No equivalent		1604	Retaining Walls/Breast Walls
No equivalent		1705	Fencing
No equivalent		1914	Cutting of Branches of Trees, Shrubs, and Trimming of Grass and Weeds

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 (IRC Orange Book, Road and Bridge Works, 2001): see above. They have been numbered within the same series, but this does not imply approval from the Indian Roads Congress.

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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 greatest 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.

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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. High quality seeds are those seeds that have been collected from healthy plants and are free from impurities, diseases and insect pests, have been properly processed and stored, and have a high germination percentage.

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.

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 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
Narhal	*Arundo clonax*	Stem/slip cuttings	Stem cuttings: 2 nodes plus 50 mm each side 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 slip cuttings, grass clumps should be dug up carefully. 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. Two or three sections of stem must be part of the cutting, with their associated nodes intact.

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 camera*), bihaya (*Ipomoea fistulosa*) and banaa (*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 to be of the following sizes, which should not be exceeded unless specified by the Engineer.

Purpose	**Diameter**	**Length**
Cuttings for single planting	20 to 40 mm	450 to 600 mm
Truncheon cuttings	50 to 80 mm	2000 mm
Brush layers on road embankment slopes	20 to 40 mm	450 mm
Brush layers on landslide debris and all other sites	20 to 40 mm	600 mm
Palisades, vegetated stone-pitching and vegetated walls	20 to 40 mm	500 to 600 mm
Pegging jute or coir netting	20 to 40 mm	300 to 400 mm
Fascines	20 to 40 mm	Minimum 1000 mm
Live check dams: cross pieces	20 to 50 mm	2000 mm
Live check dams: truncheon cuttings for the vertical elements	30 to 80 mm	2000 mm

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.

352.2.7 Provision of containerised seedlings: Specification 355.4 shall be followed.

352.2.8 List of appropriate species of plants to be used in bio-engineering technique attached-Annexure-1

352.3 Sowing of grasses

Existing specification 308 (IRC Orange Book, Road and Bridge Works, 2001) 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 containerised seedlings, or where the site is still unstable and does not warrant the costs involved in planting but might 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 has already 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 fine particles 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 has already 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**
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
Random	Slope less than 30 degrees	Average 10 plants/sq.m.
	Slope 30 to 45 degrees	Average 20 plants/sq.m.
	Slope more than 45 degrees	Average 40 plants/sq.m.

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.

352.5.6 Sketch attached— Annexure-2

352.6 Planting of rooted shrubs and trees raised in containers

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 has already 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. Other containers are to be removed carefully, as appropriate to their character. 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. Polythene and plastic pots are to be removed from the site.

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 or of 5 litres capacity. When these larger seedlings are planted, the pits will be of 300 mm diameter and 300 mm depth. In addition, well-rotten compost will be mixed with the soil backfill in a ratio of at least one part compost to ten parts soil.

352.6.5 Sketch attached – Annexure - 3

352.7 Planting of single hardwood cuttings (small cuttings and truncheon 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 has already 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 size of cutting should be 450 to 600 mm in length and 20 to 40 mm in diameter. The Contractor is to collect the cuttings from the nursery and transport them 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 cuttings must be planted the same day that they are taken from the mother plant.

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, and soil must be carefully placed around the cutting and its roots so that there are no air voids.

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 be 2000 mm long and 50 to 80 mm in diameter.

Truncheon cuttings should be planted at a spacing of 1000 mm centre to centre unless ordered differently according to the needs of individual site conditions. Planting should be started at the top of the slope and under no circumstances should new cuttings be disturbed.

A large crowbar should be used to make a vertical planting hole 10 to 20 mm bigger in diameter than the truncheon cutting, and at least 1000 mm deep. The bar may need to be hammered into the slope with a large sledge hammer. The cutting is inserted carefully, making sure that the bark is not scratched or torn against stones in the sides of the hole. Soil or whatever fine material is available is then replaced around the cutting and firmed from the top with gentle foot pressure.

Under no circumstances should cuttings be hammered into the ground.

Unless ordered differently, truncheon cuttings should be placed in horizontal lines. The cuttings should be successively offset to occupy the gaps in the adjacent lines.

352.8 Brush layering

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.

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 600 mm long for brush layering on landslide and other debris, and 450 mm long for brush layering on road embankments. The Contractor is to collect the cuttings from the nursery and transport them 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.

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 and the size of cuttings will be of a minimum length of 600 mm for brush layering on landslide and other debris, and 450 mm for brush layering on road embankments, and have diameters of 20 to 40 mm.

Under any circumstances, all cuttings must be planted the same day that they are taken.

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.

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.

352.8.4 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.

352.8.5 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.

352.8.6 Sketch attached – Annexure-4.1 and 4.2

352.9 Palisades

352.9.1 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.

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.

It is assumed that the site has already 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.

352.9.2 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 600 mm long for palisades. The Contractor is to collect the cuttings from the nursery and transport them 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.

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 and the size of cuttings will be of a length of 600 mm for palisades, with diameters of 20 to 40 mm.

Under any circumstances, all cuttings must be planted the same day that they are taken.

352.9.3 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.

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. Alternate cuttings may be set 50 mm behind the first line, to give a staggered row.

(iv) If a double row 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.

352.9.4 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.

352.9.5 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.

352.9.6 Sketch attached – Annexure-5.1, 5.2, 5.3 & 5.4

352.10 Fascines

352.10.1 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.

The word "fascine" means a bundle of sticks. In this technique, bundles of live branches (long hardwood cuttings) 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 has already 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.

352.10.2 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 1000 mm in length for fascines. The Contractor is to collect the cuttings from the nursery and transport them 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.

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 and the size of cuttings will be of a minimum length of 1000 mm for fascines, with diameters of 30 to 50 mm.

Under any circumstances, all cuttings must be planted the same day that they are taken.

352.10.3 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.

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 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 30 to 80 mm below the surface. Any loose or excess material is cleared down the slope before the next line is planted.

352.10.4 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.

352.10.5 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.

352.10.6 Sketch attached — Annexure-6.

352.11 Hedge layering

352.11.1 Scope: In certain situations, the Contractor will be required to construct vegetation structures using small rooted woody plants. Where these are specified, the Contractor is required to carry out the necessary preparation and planting works as required in the Engineer's instructions.

Hedge layering is a technique whereby rooted woody plants (shrubs or small trees) are laid in shallow trenches aligned across the slope, usually following the contour. These grow to 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, hedge layers can be angled to provide a drainage function. They are very similar to brush layers, but use live rooted plants instead of hardwood cuttings.

It is assumed that the site has already 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.

352.11.2 Materials: The plants supplied to the Contractor may be from a nursery as arranged by separate instructions, and will be ready for planting. The stem above ground should be at least 500 mm long. The Contractor is to collect the plants from the nursery and transport them from the nursery, shaded and undamaged. At all times, plants are to be kept moist and as cool as possible. 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 plants, then the Engineer will specify the species and expected sources, and the Contractor must then obtain the plants required. This will be done in the manner described in specification 352.2.7 and 354.2, and the size of plants will have a minimum stem length above ground of 500 mm.

352.11.3 Construction operations: The Contractor is required to supervise all field operations very closely. The planting of tree and shrub plants 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.

Hedge 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) Plants should then be placed into each trench at 100 mm centres, the correct way up and angled so that they are at right-angles to the maximum slope angle. All plants should be inserted to a depth such that all the root and half of the length of their stem is buried, but not their branches and foliage.

(iv) The trench should then be partially backfilled and another line of plants placed along the trench at 100 mm centres and 100 mm behind the first line, and with the individual plants offset to coincide with the gaps between the plants in the first line. This results in plants at 50 mm centres in each hedge layer (*i.e.* 20 plants 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 plants should be placed in a criss-cross fashion. Where this is to be done, one layer of plants is laid in the trench at 30º to one side of the line of maximum fall of slope. A second layer of plants 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.

352.11.4 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.

352.11.5 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.

352.11.6 Sketch attached—Annexure - 4.1 & 4.2

352.12 Live check dams

352.12.1 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.

Live check dams are a structure wherein a series of large hardwood cuttings are set vertically on a line of holes across a gully. Between them, long, flexible hardwood cuttings are interwoven horizontally, with their ends buried in short trenches cut into the gully sides. It is used to control erosion in small gullies.

It is assumed that the site has already 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.

352.12.2 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 2000 mm in length for live check dams. The Contractor is to collect the cuttings from the nursery and transport them 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.

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 and the size of cuttings will be of 2000 mm in length, with diameters of 20 to 50 mm for the cross pieces and 30 to 80 mm for the vertical elements.

Under any circumstances, all cuttings must be planted the same day that they are taken.

352.12.3 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.

Live check dams should be constructed as given here, unless ordered differently. The location and spacing between check dams will normally be specified by the Engineer.

(i) If a particular spacing of check dams is ordered, then the locations shall first be marked out along the gully. If the drawing or the Engineer's order allows discretion in the siting of the live check dams, then the Contractor shall work out the best locations, where they will achieve the greatest effects of controlling the water flow and stabilising the gully floor. The Engineer's approval should be sought once the locations have been chosen and before starting construction work.

(ii) At each check dam location, two lines shall be marked out across the gully. These will form the lines for a series of vertical posts placed at intervals of 100 to 200 mm. A foundation trench is then excavated to a depth 100 mm deeper than the gully bed, and extending 300 mm into the gully sides.

(iii) Holes are made deep and big enough to insert vertical truncheon cuttings of to a depth of 1000 mm. To do this, a large crowbar is used to make a hole 10 to 20 mm bigger in diameter than the truncheon cutting. The cutting is inserted carefully, making sure that the bark is not scratched or torn against stones in the sides of the hole. Soil or whatever fine material is available is then replaced around the cutting and firmed from the top with gentle foot pressure. The holes shall be spaced at a maximum of 200 mm centre to centre in two horizontal lines 200 mm apart across the gully.

(iv) Long hardwood cuttings shall then be woven in and out between the vertical posts, separately for each line. This is started at the bottom and worked up, with the weaving alternating on opposite sides of the vertical posts. The horizontal cuttings should be touching each other, which means that there should be between 25 and 40 cuttings per metre of check dam height.

(v) The horizontal members shall be keyed right into the end of the trench in the wall of the gully, and cut to length as necessary. In the centre, vertical posts and horizontal members are cut to form a central spillway about 500 mm wide and 300 mm in height.

(vi) A backfill of stone and soil is then carefully placed by hand around and between the two live walls of the check dam, and compacted with gentle foot pressure.

352.12.4 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.

352.12.5 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.

352.12.6 Sketch attached — Annexure-7

352.13 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 rooted shrubs and trees raised in containers, if instructed separately, per plant.

(iii) Provision of hardwood cuttings, if instructed separately, per number of cuttings.

(iv) Provision of hedge layering plants, if instructed separately, per number of plants.

(v) Grass seeding, per square metre.

(vi) Planting of grass slips and cuttings, per square metre.

(vii) Planting of containerised seedlings of trees and shrubs, per number of seedlings.

(viii) Planting of single hardwood cuttings, per square metre.

(ix) Construction of brush layers, per running metre constructed.

(x) Construction of palisades, per running metre constructed.

(xi) Construction of fascines, per running metre constructed.

(xii) Construction of hedge layers, per running metre constructed.

(xiii) Construction of live check dams, per running metre constructed.

352.14 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.

352.15- Vegetative Crib Formation.

352.15.1- Scope- In certain situations the contractor will be required to construct a vegetative crib wall using Bamboo, hard wood cuttings and live plants. It is a substitute of retaining structure low in cost and more effective and sustainable performing the eco-friendly engineering functions of stabilization of slopes.

352.15.2- Material-

352.15.3- All material i.e. (Bamboo ballies or ballies of any wood easily available for construction of crib walls) should be used.

352.15.4- In case of areas where bamboo ballies are not easily available the ballies other species of the plants that can be propagated by vegetative means can also be used.

352.15.5-Bamboo used shall be of mature growth free from splits, weevil, root borer holes and other defects. Bamboo shall not be older than about 2 to 3 years, well seasoned having minimum girth of 100 mm. The girth measurement shall be taken at the center of the length of each bamboo. Bamboo shall be semisolid, strong and easily knitted.

352.15.6-The indigenous species of plants/ hard wood cuttings locally available should be used as per the direction of the engineer in charge.

352.16- Construction Operations.

Live crib wall formation i.e. providing and fixing 1 meter high crib wall along the destabilized slopes including fixing of 1.5 meter long pegs, 10 meter horizontal bamboo, rooted

plants, hard wood cuttings, compacting, watering and tying with binding wire etc complete as per direction of Engineer-in charge.

352.16.1- Bamboo cuttings/ wooden pegs 1.5 meter long with pointed base are inserted in to the destabilized slopes with the help of wooden hammer in such a way that the pegs are not broken/ splited from the point of hammering. These pegs should be inserted in the ground at a distance of 1.5 meter from each other.

352.16.2-Three number horizontal bamboos are tied together and further fixed to the pegs. The hollow space created by fixing the layer of horizontal bamboos is filled with good earth and suitably compacted and a layer of wooden pegs are inserted at right angle to the earlier pegs fixed in the ground.

352.16.3-Suitable species of plants as well as cuttings are inserted in to hollow space (8 cuttings & 3 plants per Rmt) and further proper watering of the same is done. The same process is repeated upward side three times. Every time hollow space created is compacted, planted and watered respectively.

352.16.4- In the end a small plot is developed at the top of the crib which is grassed, planted by using bush plant or tree etc. as mentioned by the engineer-in charge.

352.16.5- Depth of inserted pegs in the slopes varies from place to place. Tying of pegs and bullies should be done satisfactorily only then it will become a supporting structure against the destabilized slopes.

352.17-**Measurements for payment**: Crib formation shall be measured as finished works in running meters.

352.18-Rate: The contractor shall be paid in full for carrying out all the required operationsincluding full compensation for all materials, labours, tools, equipments, incidental charges and shall include all leads and lifts

352.19- Sketch attached — Annexure -10.

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353. ROADSIDE LINE PLANTING

353.1 Planting of shade trees and hedges

353.1.1 Scope: The planting of shade trees and hedges is intended to replace something of the natural vegetation lost in road construction or upgrading, to help delineate the edge of the road for safety purposes, and to beautify the area. The Contractor is required to carry out the planting of seedlings to the Engineer's specific instructions.

Plants used will normally have been raised as rooted, containerised seedling stock in nurseries. In the case of individual trees, tree guards may be required.

353.1.2 Preparation: It is assumed that the site has already 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.

353.1.3 Construction technique: The spacing of plants will be determined according to individual site conditions. However, it will normally be at two-metre centres unless otherwise specified for shade trees and 500 mm centres for hedge plants.

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. Other containers are to be removed carefully, as appropriate to their character. 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. Polythene and plastic pots are to be removed from the site.

353.1.4 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 or of 5 litres capacity. 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.

353.2 Tree guards

353.2.1 Scope: The Contractor shall provide tree guards 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 supervision, resources and facilities to ensure that these requirements are met.

Tree guards are to be installed on site at the time of planting.

353.2.2 Materials: For brick-built tree guards, standard house bricks and concrete mortar are required.

In the case of bamboo tree guards, the bamboo strips used should be made from *Bambusa nutans* whilst the uprights are to be made from *Bambusa nutans* or *Bambusa balcooa*. Bamboo tree guards shall be a minimum of 450 mm in diameter by 1300 mm in height, so that they are able to provide sufficient protection from grazing herds of animals and public disturbances for the first 18 months after planting the seedling.

Tree guards of proprietary type made from steel mesh are also acceptable if galvanised with a heavy steel coating. They should also be a minimum of 450 mm in diameter by 1300 mm in height.

353.2.3 Construction techniques: For all types of tree guard, it is necessary that the tree to be protected is planted first. In constructing the guard, it is essential that great care is taken not to damage the plant.

Brick tree guards should be constructed as given here, unless ordered differently. The location and spacing of tree guards will coincide with the spacing of the trees that they are protecting.

(i) The position of the tree guard is marked on the ground by drawing a circumference circle around the seedling to be protected. This shall normally have a radius of 500 mm. This line forms the internal dimension of the tree guard.

(ii) The soil around the outside of the circumference line is dug out to form a firm foundation for the tree guard. A bed of concrete mortar is laid to a depth of 50 mm and a width approximately one-and-a-half times the width of the bricks. The first layer of bricks is bedded into the mortar with an average gap between each brick of one third of the length of the brick. If the guard is being constructed on a slope, the lower side should be built up in layers of bricks until a complete circle can be made.

(iii) Successive layers of bricks are then added. A bead of mortar shall be placed on the end of each brick in the lower course, and the next course added so that each brick bridges the one third gap between bricks in the course below. The sides of the guard should be kept vertical.

(iv) The guard should be built up in courses until the minimum side height is 100 mm. The top course is finished with a complete round of bricks, mortared and pointed so that there are no gaps.

(v) All joints are then pointed neatly, and excess mortar and brick fragments removed from the site.

Bamboo tree guards should be constructed as given here, unless ordered differently. The location and spacing of tree guards will coincide with the spacing of the trees that they are protecting.

(i) The guard is made by cutting five bamboo posts which are a minimum of 50 mm wide by 10 mm thick and at least 1600 mm long. The posts should be cut so that they have a strong spear-like point at the bottom that can be driven into the ground when placing out on site. The bamboo poles used to make the uprights should be a minimum of 3 years old.

(ii) Bamboo strips, a minimum of 5 mm thick and 50 mm wide are cut from poles that are at least 2 years old. The bamboo used must be split so that the outer wall remains intact. Only lengths with the outer wall intact are to be used. The split bamboo should be the length of the whole bamboo pole that it is cut from, or as long as possible. The split bamboo must be woven in and out of the

bamboo uprights and pulled tight, so that it is firm and strong. The end of each of the strips must be woven back into the basket and tied with binding wire to keep it in place. End pieces must not be left sticking out and unbound, because they quickly get broken and the basket starts to unravel from this point. The split bamboo should be woven round the poles so that when they are tightly pressed down there are no gaps in the guard.

(iii) The tree guards should be placed over the seedling immediately after planting. The upright posts must be firmly driven at least 200 mm into the ground so that the guard is able to resist bashing and rubbing from cows, buffalo, goats and people. The woven slats should be pushed down firmly from the bottom upwards so that they touch one another and are free from large gaps.

Proprietary tree guards should be constructed as per the manufacturer's recommendations, which shall be submitted to the Engineer for approval before starting the operation.

352.2.4 Aftercare: Tree guards alone are not adequate protection for small plants. The Contractor must provide a site watchman in addition, for the time specified, to maintain the tree guards and ensure that local people respect them, and generally fulfil all the requirements of clause 354.

353.3 Measurements for payment

Works shall be measured as finished work in the following units.

(i) Provision of rooted shrubs and trees raised in containers, if instructed separately, per plant.

(ii) Planting of containerised seedlings as shade trees, per number of seedlings.

(iii) Planting of containerised seedlings of shrubs as hedging plants, per number of seedlings.

(iv) Tree guards constructed, per guard.

353. 4 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.

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354. SITE AFTERCARE AND MAINTENANCE

354.1 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.

There are three main categories of site aftercare and maintenance, as follows.

(i) Routine maintenance in the three years following the implementation of bio-engineering works.

(ii) Perennial routine maintenance and the protection of sites.

(iii) Periodic maintenance of roadside vegetation.

354.2 Initial routine maintenance activities

The successful establishment of bio-engineering works may require follow-up care of the plants while they are at their most vulnerable young stage on the roadside sites. To fulfil this need, the Engineer may instruct special maintenance activities to be undertaken within the first one to three years after planting.

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 (IRC Orange Book, Road and Bridge Works, 2001), 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 dead, 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. At altitudes above 1800 metres, it may also be carried out during the winter, at the Engineer's discretion. 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.

354.3 Perennial routine maintenance activities

354.3.1 Cutting of branches of trees, shrubs and trimming of grass and weeds: Existing specification 1914 in the IRC Red Book (Rural Roads, 2004) shall apply.

354.3.2 Fencing: Existing specification 1705 in the IRC Red Book (Rural Roads, 2004) shall apply.

354.3.3 Site protection: 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.

The Contractor is required to provide an adequate number of site watchmen/women to fulfil the specified requirements. The function is broader than that of simply watching, and it involves a number of routine maintenance operations.

Watchers must be mature and reliable characters who need little supervision for the adequate fulfilment of their duties. They must be active and physically fit. Old people who are losing their strength should not normally be employed. They must be experienced agricultural workers familiar with caring for plants. They must be prepared to remain on site through all hours of daylight and through all adverse weather conditions. They must eat their meals on site and at no time leave the site untended for any reason whatsoever.

The role of the watcher is primarily to tend the plants. He or she must take the initiative in weeding, mulching, replanting failed plants, pruning and protecting plants against all pests. This is an active role requiring individuals with considerable energy and initiative. The watcher must work constantly to maintain and improve the site and its bio-engineering plants.

The watcher is also required to protect plants on the site from damage by local people, domestic and wild animals. In doing this he or she should use a friendly approach to the people as far as possible. The Contractor must educate the watcher fully in the reasons for the job, so that he or she can explain to others the importance of safeguarding plants on the site. Watchers should be effective communicators with others since they also fulfil an inevitable function as the ambassador between the Public Works Department and local road neighbours.

354.4 Periodic maintenance of bio-engineering sites

354.4.1 Scope: All bio-engineering sites must be maintained so that there are at least the following two storeys of vegetation.

(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 certain locations, however, there may be a number of additional vegetation storeys.

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 prune the plants and thin the canopy as necessary to permit adequate levels of light to penetrate for the optimum growth of the grass understorey.

354.4.2 Operations: All pruning and thinning operations are to be undertaken in accordance with the specifications below and any additional 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.

In every case, pruning should be carried out first of all. The bottom branches, up to half the total height of the shrub or tree, should be cut off. For large, mature trees only, branches can be removed up to two-thirds the total height of the tree.

Branches must be cut cleanly, using sharp tools. They are cut as close to the trunk as possible without causing damage, starting with the branches nearest the ground and moving upwards. Where the branch is more than 50 mm in diameter, a small cut should be made underneath the branch first, before removing it with a cut from above. The bark should never be torn: this can damage the plant badly.

Once pruning is complete, the Contractor must consider whether the site needs to be thinned, and if so, what sort of thinning. This is decided by assessing whether pruning has opened the canopy enough to allow sufficient light for grasses to grow under the trees. If it has, then the operation is complete; if not, then thinning is needed. The written approval of the Engineer must be obtained before starting the thinning of trees.

In thinning a group of trees, there are three options.

(i) Pollarding: a treatment in which the main trunk of a tree is cut off, usually two to three metres above the ground, to allow new, smaller, shoots to grow: this allows new shoots to grow out of the reach of grazing animals, but not all plants will tolerate this.

(ii) Coppicing: where the trunk of a tree is cut off about 300 mm above the ground to allow new shoots to grow from the stump, but not all plants will tolerate this.

(iii) Selection felling: where the trunk of a tree is cut off about 150 mm above the ground, and it is not expected to shoot again.

The ability of a shrub or tree to coppice or pollard depends on the vigour and growth characteristics of the species. Plants commonly lopped for fodder will mostly tolerate it. All those grown from hardwood cuttings will certainly tolerate it. Some plants, such as kunis (*Alnus nitida*) will coppice only under ideal growing conditions but otherwise will die; it is unlikely that conditions in roadside areas will be sufficiently good to allow this. With many species, large and older trees do not coppice as well as young trees. In these cases, selection thinning is a better option than relying on coppicing.

Once the thinning option has been chosen, the Contractor's specialist must walk through the site slowly and decide which trees must be cut. The aim should be to remove 50 to 67 percent of the canopy. When marking the thinnings, the ground vegetation must also be looked at: if there are younger trees and shrubs (regeneration), then it should be possible to remove trees from the main canopy to allow them to develop.

The trees that should remain must be marked with paint, and a slash made on the bark of those which should be removed (once it is certain), according to the following criteria.

(i) Mark for removal all dead, dying, fallen, diseased or seriously damaged trees.

(ii) Next consider for removal trees of unwanted species (note that a mixture of species should be retained if possible).

(iii) Next consider for removal trees of bad shape (crooked, unevenly branched, etc). Note that straight stems are not necessarily required for bio-engineering purposes.

(iv) Next consider for removal trees that are spaced close to each other

(v) Next consider for removal trees with large crowns

(vi) Select the remaining trees to leave a variety of sizes and ages, forming only about 33 to 50 percent of the original canopy. Mark these with paint for keeping.

(vii) Now go back through the trees with the defects described above, and slash for removal the worst ones by category, until enough are due to be removed to fulfil the thinning requirement for the site. Then mark the remainder with paint for keeping.

(viii) All slashed trees can now be removed.

Tree felling must be undertaken using sharp tools, by skilled personnel and following all necessary safety rules. Trees are cut at the height specified (2 to 3 metres for pollarding, 300 mm for coppicing and 150 mm for selective felling) without causing damage to the remaining stump. Where the trunk is more than 100 mm in diameter, a wedge cut of one third of the section of the trunk should first be removed on the side on which the tree is to fall, before felling it with a cut from the back. Each felling should be planned carefully so that it does not damage the branches of the trees being left. Ropes should be used to aid the direction of fall. The bark should never be torn on pollards and coppices: this can damage the plant badly.

354.3 Disposal of saleable products: 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.

354.5 Other maintenance operations

Other maintenance operations may be required on certain site. If instructed, they are to be undertaken by the Contractor according to the instructions of the Engineer.

354.6 Measurements for payment

Works shall be measured as finished work in the following units.

(i) Weeding, mulching and general site care, per hectare of site area.

(ii) Replacement of grass plants, per square metre (except where it is the Contractor's liability).

(iii) Replacement of containerised seedlings, per number of seedlings (except where it is the Contractor's liability).

(iv) Replacement of bio-engineering structures involving hardwood cuttings, per running metre of structure (except where it is the Contractor's liability).

(v) Site watchers, per person.

(vi) Pruning of branches, per hectare of site area.

(vii) Thinning of trees and shrubs, per hectare of site area.

354.7 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.

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355. BIO-ENGINEERING NURSERY OPERATIONS

355.1 Nursery Construction

355.1.1 Scope: The Contractor shall provide nurseries to contribute stocks of grasses, shrubs and trees for planting operations as required by the Engineer. This shall be done according to the specifications described hereunder, as and when required by the Engineer. The Contractor shall supply all necessary expertise, resources and facilities to ensure that these requirements are met.

The establishment and effective operation of plant nurseries is a skilled business requiring experienced and trained staff. These specifications alone do not provide all the information needed to set up and run nurseries. The Contractor should seek the advice of specialist agencies and should refer to the large number of reference books available on the subject.

The purpose of a nursery is to supply good quality, healthy plants of the correct type and species, at the precise time they are required, and at a reasonable cost.

355.1.2 Nursery establishment: In selecting a site for a nursery, the Contractor must fulfil the following requirements.

(i) Nurseries must be as close as possible to all sites to be planted. They must be at the same altitude as, and in an identical climatic area to, the sites to be planted.

(ii) Wherever possible, nurseries must be established on land owned by the Public Works Department if it is available and biophysically suitable. If it is not, other land of the Himachal Pradesh State Government or the Government of India should be used if it is available.

(iii) Nurseries must have a reliable and adequate supply of water which remains constant throughout the later part of the dry season. This is most essential.

(iv) Nurseries should have all weather vehicular access.

(v) Nurseries should have a perimeter of stock proof fencing, effective against all domestic animals.

(vi) Nurseries should have a weather- and pest-proof office cum seed store and proper storage facilities for seed.

(vii) All nurseries should be provided with at least two above-ground compost bays, built of stone, brick or timber. These will be used on an alternate basis to ensure a continual supply of compost.

(viii) Where a nursery is established on a slope exceeding 2^{o}, the ground must be levelled by terracing before beds are constructed.

(ix) A constant staff of qualified and experienced people must be provided.

(x) There must be adequate space in each nursery location for all operations to be performed in the cycle of work. In particular, all plants need to be spaced out periodically as they grow and there must be adequate bed area to accommodate them.

355.1.3 Construction of nursery beds: Nursery beds must be made in a different way according to their purpose. The Contractor must ensure that there are adequate beds available for all the operations to be undertaken in the nursery. There must be paths around all beds to ensure the best possible access for operations such as weeding and watering.

The table below summarises the construction details of the four main bed types, which are described in full in paragraphs 4 to 7.

Bed type	Soil beds for grass seeds, grass slips and tree stool cuttings	Seed beds for tree seedlings	Stand out beds for containerised seedlings
Bed size	1000 mm wide × 250 mm high	1000 mm wide × 170 mm high	1000 mm wide × 150 mm high
Details of construction	50 mm of washed gravel placed above the ground; then 50 mm of 1:1 mix of sieved soil and compost; and topped with 150 mm of 3:1 mix of sieved forest topsoil and washed sand.	50 mm of washed gravel placed above the ground; then 50 mm of unsieved forest soil; 50 mm of 1:3 mix of sieved forest soil and washed sand; and topped with 20 mm of washed, sieved and sterilised sand.	50 mm layer of gravel placed above compacted ground. A flat stone or brick surround.

Soil beds should be constructed to hold grass seeds, grasses being propagated by vegetative means and tree stool cuttings. These can be of any practical length but must be flat and of one metre in width. They should rise to a height of 250 mm above the surrounding ground. They are made up as follows: 50 mm of washed gravel is placed above the ground; then 50 mm of 1:1 mix of sieved soil and compost; and the bed is topped with 150 mm of 3:1 mix of sieved fertile, loamy forest topsoil and washed sand. All sieving should be done with a mesh size of 2 mm or smaller. One square metre of such a bed will contain 100 grass slips spaced at 100 mm centres within rows at 100 mm centres and will produce at least 300 slips for planting out, depending on the particular species, and the soil and climate of the nursery.

Seed beds must be made very carefully for germinating small seeds of shrubs and trees. These can be of any practical length but must be flat and of one metre in width. They should rise to a height of 170 mm above the surrounding ground. They are made up as follows: 50 mm of washed gravel is placed above the ground; then 50 mm of unsieved forest soil; 50 mm of 1:3 mix of sieved forest soil and washed sand; and the bed is topped with 20 mm of washed, sieved and sterilised sand. All sieving should be done with a mesh size of 1 mm or smaller.

Standout beds should be constructed to hold seedlings in containers, usually polythene pots. These can be of any practical length but must be flat and of one metre width. Bed floors should be above surrounding ground level and they should have a 50 mm layer of gravel placed above compacted ground. A layer of permeable synthetic geotextile placed on top of the gravel stops root penetration from the pots but permits free drainage (which is essential). They should have a surround, preferably made from flat stones or bricks. One square metre of standout bed will contain an average of 115 filled polythene pots of 100 × 180 mm flat size when spaced out.

Shades must be constructed over the beds and kept in position over delicate seedlings during hours of intense sunlight, according to need. Shades should be 750 to 1000 mm above the soil or the top of filled pots, and angled so as to be effective for as much of the day as possible (i.e. with the lower side to the south). Bamboo strips laced together with coir (coconut fibre) string are particularly suitable in most cases; but over tree and shrub seed beds, thatched shades with a polythene lining must be used.

355.2 Nursery operation and management

The contractor must operate the nursery according to a high standard. The nursery is to be staffed well tended at all times. It must be maintained in a clean, tidy and efficient manner at all times. Plants must always be healthy and vigorous.

Due to the nature of bio-engineering works, nurseries will normally be operated and managed by small local contractors with a range of agricultural skills. Nurseries may also be operated and managed by direct employees of the Public Works Department through its Horticulture Wing.

Plants must be kept properly weeded at all times.

Watering, as required for good plant growth, must be carried out regularly in the cool of the evening between sunset and dusk. The Contractor must ensure that the soil in all beds is kept moist but not saturated at all times. Beds must be kept moist even when empty, so that the soil is kept in good condition.

The timing of many nursery operations is of the utmost importance. Activities such as seed sowing and the taking of cuttings must be carried out within the critical few weeks when they will yield the desired results. Most other operations, such as spacing out, root pruning and watering, must also be carried out in a timely manner. The contractor is responsible to keep works to the strict schedule required and under no circumstances to permit delays.

355.3 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.

355.4 Nursery production of trees and shrubs in containers

Trees and shrubs will be seeded either in seed beds or directly in pots. Finely sieved fertile soil mixed with clean sand to a texture of sandy loam must be placed in well shaded beds for seeding. Watering of fresh seedlings will be by a fine spray, and not by the rose of a watering can.

All plants must be grown on in pots of an adequate size. These might be polythene pots ('polypots') with dimensions of 100 × 180 mm (4 × 7 inches) or greater when laid flat, made of black, 200 gauge polythene. Other proprietary pots of plastic or a biodegradable material such as coir or jute may also be used. All containers must have adequate drainage holes at the bottom and be filled with fertile forest topsoil mixed with clean sand to a texture of sandy loam.

Roots protruding from the bottom of pots must be pruned with a razor blade on a regular basis which will not exceed weekly and may need to be more frequent. Protruding roots should never be allowed to become more than 25 mm in length.

When containerised seedlings begin to compete with each other for light, they should be re-spaced as required. This would typically mean doubling the bed space occupied by the plants.

To be acceptable for planting on site, trees and shrubs must be healthy, vigorous and showing no signs of damage, wilt, irregular growth, fungal or pest attack, or nutrient disorders. They must be at least 300 mm in height above soil surface level and of good form. The roots must be in good condition and there should be no signs of disturbance to the soil in the polythene pot, even after transport to site.

355.5 Nursery production of hardwood plants by vegetative methods

Trees and shrubs which can be propagated by vegetative methods may be specified by the Engineer. The Contractor should produce these by the appropriate method, as required.

All cuttings and stools must be made as specified in clause 352.2.6 and planted in fertile soil beds of the type specified in clause 355.1.3.

Cuttings must be planted 300 mm apart in holes slightly larger than their diameter. They must be placed at such a depth that only one bud remains above the soil surface (i.e. about 30 mm of the cutting).

When plants compete with each other for light, they should be cut back as necessary.

To be acceptable for planting on site, trees and shrubs produced in this way must be healthy, vigorous and showing no signs of damage, wilt, irregular growth, fungal or pest attack, or nutrient disorders. They must be at least 500 mm in height above soil surface level and of good form.

355.6 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.

Container 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.

355.7 Measurements for payment

Works shall be measured as finished work in the following units.

(i) Establishment of nursery, per square metre of bed area or other unit item.

(ii) Production of grass slip cuttings, per 1000 viable planting slips.

(iii) Production of hardwood cuttings, per 1000 viable cuttings.

(iv) Production of containerised seedlings, per seedling of specification standard.

(v) Operation of nursery, per day (unless included in unit rates above).

355.8 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.

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361. JUTE AND COIR GEONETTING FOR STEEP SLOPES

361.1 Scope

The Contractor shall provide and install jute or coir netting 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.

The Engineer may instruct that jute or coir netting applications be used in conjunction with other techniques, particularly the sowing or planting of grasses. In this event, the netting should be applied before the plants are introduced. When planting, the labourers must take care only to hold or stand on the pegs and not to disturb the netting except when carefully placing grass seed underneath on the soil surface.

Existing specification 308 on seeding and mulching (IRC Orange Book, Road and Bridge Works, 2001) gives details of jute netting works on gentle slopes, to help retain and protect mulched plant seeds. This specification is to be used for slopes in excess of 35 degrees, where mulching is not possible.

361.2 Materials

The Contractor will manufacture or obtain a supply of jute or coir netting to the Engineer's specification.

The detailed specifications for jute or coir netting are as follows.

(i) Material: High quality 100% natural jute or coir fibre from the latest harvest, properly treated and dried.

(ii) Yarn: Hand- or machine-spun 5 to 8 mm.

(iii) Mesh size: 25 to 40 mm square mesh holes.

(iv) Weight: 0.8 to 1.2 kg per square metre.

361.3 Construction technique

The Engineer will normally instruct the placement of jute or coir netting on slopes in excess of 40 degrees. It is therefore a difficult task to place the netting in an effective manner which fulfils the Engineer's purpose. Carelessly placed netting is often useless and can actually be detrimental to the slope surface.

It is assumed that the site has already been prepared for the application of jute or coir netting, 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 optimum effect to be attained. In any event, a smooth profile must be obtained. All loose debris 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.

Starting at one end of the site to be treated, a roll of netting should be pegged 300 mm above the slope to be covered.

The netting should be rolled slowly down the slope. Hardwood cuttings, ideally of banaa (*Vitex negundo*) made according to specification 352.2.6 or pegs (usually made from split bamboo culms) should be hammered through the netting at centres of 500 to 1000 mm; they should protrude about 80 mm. Labourers must stand on these cuttings or pegs and not hang on to the netting.

This process should be repeated until the entire slope surface is covered. The strips are then laced together with lengths of the same jute or coir yarn, to form a continuous net. The lacing must form joins every 250 mm or less.

The tension of the netting must now be reduced so that it hugs the slope surface precisely. This is done by pulling up about 200 mm at the bottom of the netting and hooking it on to the pegs a little higher up. This process is repeated up and across the slope until the netting rests snugly against the surface and is nowhere tight or pulled away from the surface in minor concavities.

The netting should then be pegged at 1000 mm centres with staples of 10 mm reinforcing bar at least 100 mm wide and 300 mm long, firmly hammered into the slope face. Additional staples should be used to hold netting closely against the face of concave slope segments.

Finally, the bottom of the netting is trimmed to give a tidy finish.

361.4 Measurements for payment

The supply of jute or coir netting, if ordered separately, shall be measured as untensioned netting in square metres.

The placement of jute or coir netting on slopes shall be measured as finished work in square metres constructed.

361.5 Rate

The Contract unit rate for the construction of jute or coir netting 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.

361.6 Sketch attached — Annexure – 8

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362. WIRE BOLSTER CYLINDERS

362.1 Scope

Wire bolster cylinders are wire mesh tubes 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.

362.2 Materials

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 strands 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.

Mild steel reinforcing bar, of 10 mm diameter, is to be supplied as nails for the bolsters. This will be in lengths of either one or two metres, depending on the material, as described in this specification.

Black polythene sheeting of 20 gauge thickness will be required where bolsters are used for slope drainage.

362.3 Construction operations

362.3.1 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.

362.3.2 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 of 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 45 degrees to the fall of the slope (the rib bones or branches). 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.

362.4 Measurements for payment

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

362.5 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.

362.6 Sketch attached — Annexure-9.1 & 9.2

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363. GABION CRATE RETAINING WALLS

363.1 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 diaphragms 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. For non-standard shapes the gabion crates can be made or cut to size.

363.2 Design

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

363.3 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 a 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 not less than 150 mm in at least one dimension. 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 stones as spalls shall be allowed for filling voids and their 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.

363.4 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 be 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: Hill Road Manual, Blue Book]

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.

363.5 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 of the structure.

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 levelled 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 the adjacent box 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.

363.6 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 (IRC Orange Book, Road and Bridge Works, 2001). 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 crate 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 over-stretched. The corners shall be temporarily secured first.

363.7 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.

363.8 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.

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Annexure-1

List of appropriate species of plants to be used in bio-engineering techniques during the rainy season

Sr. No.	Scientific Name	Common Name	Altitude	Bio-engineering properties of the species.	Habit of species	Propagation method	Uses
1	2	3	4	5	6	7	8
1	Acacia catechu	Khair	1200m	Grows on eroded slops, coppices well, drought resistent, deciduous	9 to 10m height prefer light & browsing	Seeds	Katha, tanning
2	Acacia nilotica/arabica	Babul/Kiker	1200m	Tolerent to excessively hot & dry site, evergreeen to deciduous	10 to 15m height prefer light	Seeds	Tans & dye
3	Adhatoda vasica	Basuti	1000m	Can tolerate dry stony as well as shady places, coppices well	Gregarious, evergreen, 3m hight	Sterm cuttings	Live hedge, medicine
4	Aegle marmelos corr.	Beal	1200m	Hardy, medicinal religious plant, deciduous, drugs	18 to 25m ht. fruit ripe in one year	Seeds	Mermelade, pickle, juice
5	Agave americana	Ramban	2000m	Grows well in hot and dry areas	Large cactus height 1.5m	Root suckers	Fibre
6	Albizia labbech	Siris	Upto 1200m	Control erosion, drought resistant, coppices well & grows on poor soil	Deciduous, susceptible to browsing	Seeds	wood & todder
7	Arundo clonex	Narket	Upto 1500m	Coppices well poor fodder, large stature tropical grass	Hollow stem, Less woody	cutting	Grass
8	Azadirachta indica	Neem	Upto 1000m	Hardy, coppices well tropical semi deciduous	20 to 25m height, use in slops	Seeds/layering	Medicinal
9	Ampelocalamus patellaris	Banse	1200 to 1300m	Clumping bamboo, growing in wet sites good for filled slops	Clumps grows to 2.5m dia.	Seeds/vegetative	Fodder
10	Bambusa biacooa	Banse	Upto 1600m	Tolerate dry conditions, culms topless due to brittleness,	Large clumping bamboo	Seeds/cutting	Fodder
11	Bambusa nutans edible	Banse	Upto 1500m	Grows well in damper site and gullies, largest grasses	Large clumping bamboo	Seeds/cutting	Fodder
12	Bombax ceiba	Catton tree	Upto 1500m	Coppices well when small, timber used for match factory	used for stuffing pillows	Seeds	Flowers edible
13	Berberis aristata	Kashmal	1200 to 2000m	Grows in dry areas, coppices well thorney shrub	bears edible friuts, drugs	Seeds	Medicinal bee flora
14	Bougainvlilea spp	Bougainvillea	Upto 1500m	Flowering ground cover, coppices well, pollard well	In light flowering in shade	cuttings	Hedge
15	Bauhinia purpurea	Kachnar	Upto 1600m	Drought resistant, coppices well, perform well in degraded sites	Midium size tree, susce to browsing	cuttings	Fodder
16	Buddleia paniculata W.	Buddleia	1500 to 2500m	Drought resistant, coppices well, flowering pink.	Tomentum white/brown	Seeds	Soil conservent
17	Cassia fistula	Amaltas	Below 1000m	Hardy, flowering, deciduous tree, drought resistant	Medium to large tree	Seeds	Medicinal tree
18	Carissa carandus	Karonda	Below 1500m	Hardy bush type, thorney, fruit bearing, ornamental shrub	Bush type plant, evergreen	Seeds	Medicinal tree
19	Callistemon lanceolatus	Bottle brush	Below 1800m	pollard well, flowering tree, bea flora	Medium tree evergreen	Seeds	Omamental
20	Canna indica	Canna	Below 1200m	Good for moist soil, ornamental, perennial	Bulbous plants	Bulbs	Omamental
21	Casurina aquistifolia	Casurina	Below 1000m	Drought resistant, grows in moist soil also evergreen	Require good soil, 20m ht.	Seeds	Tanning & fuel
22	Cassia siamia	Sama cassia	Upto 1500m	Hardy , flowering plant, pollard well	Good soil, requirement, hardy	Seeds	Omanental
23	Calotropis procera	Aak	Upto 1000m	Hardy, growing in hot & dry condition	Shrub, fleshy leaves	Seeds	Medicinal plant
24	Celtris australis	Khirk	Upto 1500m	Coppice well, pollard well, hardy plant, moisture loving	10 to 15m ht. fuel wood	Seeds	Fodder
25	Cestrum nocturnum	Rat ki rani	Upto 1800m	Coppies well, pollard well, flowering shrub	3 to 5m. Ht scented flower	cuttings	Perfumary
26	Citrus aurentifolia	Jamtu	Upto 1800m	Pollard well, thorney plant require less heat for fruiting	Bee flora,5m ht.	Seeds	Fruits
27	Cynodon dectylon	Drub	Upto 1800m	Used only for turfing, medicinal value	Creeping grass	Seeds /stolons	Fodder
28	Daibergia sissoo	Shisham	Upto 1500m	Long tap rooted, producing abundence roots when injure	Deciduous large tree	Root suckers	wood
29	Dendrocalamus hookeri	Kalebanse	Upto 1800m	Frost resistant, large, grows well in cool shady gullies	Ever green	Suckers	wood
30	Dendrocalamus hamitioni	Banse	Upto 1800m	Large clumping, widely cultivated bamboos	Ever green	Suckers	wood
31	Debregeasia hypoleuca	Siharu	Upto 1800m	Coppice well pollard well hardy, shade loving	Ever green	Seeds	Fodder
32	Duranta plumerai	Neelkanta	Upto 1600m	Hardy, coppices well, pollard well	Ever green	Cutting/seeds	Hedges
33	Dodonea viscossa	Mehndru	Upto 1000m	Hardy, coppices well, pollard well	Ever green	Cutting/seeds	Hedges
34	Eulaliopsis binata	Sebal grass	Upto 1500m	Used in direct seeding and all configuration of planted grass lines	Medium sized, clumping grass	Cutting/seeds	Grass
35	Eucalyptus citridora	Lemon scented	Upto 1600m	Absorbs lot of moisture from the soil, ever green	Large tree bee flora	Seeds	wood
36	Elaeagnus umbilata	Ghain	1500 to 2000m	Thorney, fruit bearing, hardy plant	Bush type	Seeds	wood
37	Emblica officinalis	Aonla	Below 1500m	Coppices well pollard moderately survive in degraded area	Small tree , strong light demander	Seeds	Pickle
38	Euphorbia pulcherima	Lal pati	Upto 1800m	Coppices well, pollard well	Winter flowering	Cutting/seeds	Omamental
39	Eunymous japonica	Spindal tree	Upto 2000m	Hardy, coppices well, pollard well	Ever green bush	cuttings	Topiary
40	Ficus benghalensis	Bargad	Below 1000m	Frost resistant, Strong light demander, hardy	Deciduous tree	Layering	Religious plant
41	Ficus carica	Anjir	Upto 1500m	Medicinal frost resistant, strong light demander, hardy	Deciduous tree	Seeds	Fruits
42	Ficus glomeratus	Tibmbal	Upto 1500m	Medicinal frost resistant, strong light demander, hardy	Deciduous tree	Seeds	Fodder
43	Ficus religiosa	Peepal	Below 1200m	Medicinal frost resistant, strong light demander, hardy	Ever green	Seeds	Fodder
44	Ficus pumila	Lvy.	Upto 1500m	Used as rock cover or masionary cover	Ever green	cuttings	Greenary
45	Flacourtia indica	Kangu	Upto 1200m	frost resistant, hardy plant	Ever green	Seeds	Fruits
46	Grevillea robusta	Silver oak	Upto 2000m	Omamental avenue, soft wood tree	Ever green	Seeds	Wood
47	Grewia optiva	Beul	Upto 2000m	Pollard well, hardy tree	Medium ht.	Seeds	Fodder
48	Hibiscus mutabilis	Shrub althea	Upto 2000m	pollard well, coppice well, deciduous	Flowering bush	cuttings	Flower
49	Hydrangea paniculeta	Peegee hyora	1200 to 2000m	pollard well, coppice well, deciduous flowers	Flowering bush	cuttings	Flower
50	Indigofera trifoliata	Kathi	Upto 1200m	pollard well, coppice well, flowering, hardy plant	Flowering bush	Seeds	Fooder
51	Indigofera gerardiana	Kathi	Upto 2400m	pollard well, coppice well, deciduous , eatable flowers	Flowering bush	Seeds	Fooder

List of appropriate species of plants to be used in bio-engineering techniques during the rainy season

Sr. No.	Scientific Name	Common Name	Altitude	Bio-engineering properties of the species.	Habit of species	Propagation method	Uses
1	2	3	4	5	6	7	8
52	Indigofera pulchella	Kathi	Up to 2600m	Pollard well, coppices well, deciduous eatable flowers	Flowering bush	Seeds	Fooder
53	Ipomea batata	Ipomea	Upto 1500m	Used largly for various boi engineering techniques	Small bush	cuttings	Mulch
54	Jasminum humile	Pit malti	Upto 1800m	Coppices well Pollard well, ground covering	Leaves used for sugar treatment	cuttings	Omamental
55	Jatropha spp.	Diesal plant	Upto 1000m	Coppices well Pollard well, fast growing plant	Seeds used for oil extraction	Seeds	Oil
56	Leucaena leucocephala	Lucenia	Upto 1500m	Coppices well, fast growing plant pollard well hardy plant	Pods are used as cattle feed	Seeds	Fodder
57	Mallotus philipponensis	Kamal	Upto 1500m	Oil seed bearing, hardy ,woody,soil conserving plant	Medicinal,fodder plant	Seeds	Oil
58	Mengifera indica	Mango	Below 1500m	Large evergreen fruit bearing plant	Bee flora,timber	Seeds	Fruits
59	Musa paradisiaca	Banana	Below 1500m	Absorbs lot of moisture from the soil, ever green	Bee flora	Suckers	Fruits
60	Murraya koengaii	Kari patta	Upto 1300m	Bushy evergreen, soil binder, hardy plant	Used in condiments	Seeds	Hedges
61	Pennisetum purpurium	Napier grass	Upto 1300m	Used in most of the Bio-engeering technique	Large grass	Cutting/slips	Fodder
62	Phoenix sylvestris	Khajoor	Upto 1300m	Very hardy,fruit bearing, fodder plant	Bees flora	Seeds	Fruits
63	Pongamia pinnata	Pongammia	Upto 1000m	Hardy, leaves not relished by cattle etc	Eevergreen	Seeds	Soap ind
64	Prinsepia utilis	Bhekuli	Upto 1800m	Hardy, thorney bush plant, bee flora	Evergreen medicinal plant	Seeds	Oil
65	Pyrus patia	Kainth	Upto 2000m	Hardy, fruits bearing, wood used for agricultural implements	Bee flora ,root stock	Seeds	Walking sticks
66	Pinus gerardiana	Chilgoja	1800 to 3000m	Hardy chilgoja bearing tree [food article]	Huge evergreen tree	Seeds	Seeds
67	Pinus longifolia	Chile	500 to 2100m	Large coniferous tree, turpentine excreting plant	Huge evergreen tree	Seeds	Timber
68	Pinus wallichiana	Kail	1500 to 2800m	Large coniferous tree turpentine excreting plant	Huge evergreen tree	Seeds	Timber
69	Punica granatum	Daru	Upto 1500m	Fruits and bark of the plant has medicinal value	Medium to small tree	Seeds	Anardana
70	Pistecia integerrima	Kakar singi	Upto 1800m	This plant is of medicinal importance, deciduous in nature	Deciduous to small tree	Seeds	Medicine
71	Quercus incana	Ban	Upto 2800m	Huge fodder plant & wood used in charcol making	Ever green, fuel wood plant	Seeds	Fodder
72	Rosa muschata	Kuzo	Upto 2800m	Resistent to grazing, scented flower, root stock for roses	Thorny ground cover/ creeper bush	Cutting/ seeds	Fodder
73	Rubus ellipticus	Hiunre	Upto 1500m	Fruit bearing hedging plant,[yollow fruit]	Spiny shurb 2 mtr. In ht	Seeds/root cutting	Fruit
74	Rubus nivius	Hiunre	Upto 2500m	Bee flower bearing hedging plant	Spiny shurb 2 mtr. In ht height	Seeds/root cutting	Fruit
75	Saccharum spontaneum	Sarkanda	Below 900m	Very good grass for various bio-engineering activities	Grass up to 3mtr. Height	Slip/seeds	Grass
76	Sapindus mukorossi	Ritha	Below 1800m	Deciduous tree require deep soil	Medicinal tree	Seeds	Soap ind
77	Sizygium cumanii	Jamun	Below 1000m	Prefer moist places and coppices well	Medium to large size tree	Seeds	Fruits
78	Shree robusta	Sal	Up to 1000m	Tpropical medium to large size tree, deep soil require	Good quality timbar	Seeds	Fine wood
79	Tecoma stans	Tecoma	Upto 2000m	Copice well, pollard well, pollard well Hardy plants,	Longer flowering season	Seeds	Flower
80	Terminelia bellerika	Behra	Below 1300m	Hardy require deep soil, deciduous, fodder, adhesive	Medium to large size tree	Seeds	Medicine
81	Terminelia Chebula	Hared	Below 1300m	Hardy require deep soil, patented drugs, fodder, deciduous	Medium to large size tree	Seeds	Medicine
82	Terminelia arjuna	Arjun	Below 900m	Hardy require deep soil, patented drugs, fodder, dye,tan	Huge tree, deciduous	Seeds	Medicine
83	Thysanoleana maxima	Broom grass	Upto 1800m	Good grass for bio-engineering techniques	Grass used for making broom	Seeds	Grass
84	Ttamarandus indica	Imli	Upto 1000m	Handsome evergreen tree used in curries & fermentation.	Tonic, astingent, polish brass	Seeds	Fruits
85	Vitex negundo	Shamalu	Upto 1000m	Prefer moist shady, stoney, hot road cuts	Can be used as hedges	cuttings	Medicinal plant
86	Vetivera zizanioides	Vetivera	Upto 2000m	Grows in almost evry condition of soil & climate	Used in hedges, boundary marking	Slip/seeds	Grass
87	Woodfordia fruiticosa	Dhail	Below 1400m	Coppice well, pollard well, hardy plant.	Grows in rocks	seeds	Fodder

List of appropriate species of Plants to be used in Bio-Engineering during the winter season

Sr. No.	Botanical Name	Common Name	Altitude	Bio-Engineering properties of the species.	Habit of species	Propagation method	Uses
1	2	3	4	5	6	7	8
1	Abies pindrow	Tosh	2800 to 3800m	Huge tree, cold tolerant	Evergreen	Seeds	Wood
2	Aesculus indica colobr	Khanore	1800 to 2800m	Huge tree, elegant foliage nuts used In piles	Diciduous 20 to 25m.ht.	Seeds	Seeds/wood
3	Acacia catechu	Khair	Up to 1200m	Growes on eroded slops, coppices well, drought resistant	10m. Ht fodder, prefer light	Seeds	Katha tanning
4	Ailanthus excelsa	Heaven tree	1000 to 2800m	Growing in tough condition, coppices well, pollard well	Midium to large tree Diciduous	Wood/match boxes	Wood/fodder
5	Alnus nepalenses	Alnus	1000 to 2800m	Sowing directely on site,shade loving tree	Midium to large, Deciduous	Seeds	Wood/fodder
6	Alnus nitida	Kunish	1000 to 2800m	Sowing directely on site,shade loving tree	Midium to large, Deciduous	Seeds	Wood/fodder
7	Butea frondosa	Dhak	Up to 1500m	Drought resistant, pollard well	Deciduous Midium tree	Seeds/root cutting	Dye, edible flower
8	Butea Monosperma	Palash	Up to 1500m	Flame of forest, drought resistant, pollard well	Deciduous Midium tree	Seeds/root cutting	Dye, edible flower
9	Cedrus deodara	Deodara	1600 to 2800m	Shade loving, hardy tree, grows in snow areas well	Eevergreen Tree	Seeds	Timber
10	Cedrella toona	Tooni	Below 1500m	Moisture loving , hardy, unsiertific pollarding is fatal to plant	Diciduous	Seeds	Timber fodder / fuil
11	Dendrocalamus spp.	Bainse.	1200 to 2500m	Hardy,grows well in damper site	Evergreen clumps	Seeds	Fodder
12	Erythrina indica	Flame of forest	Below 1500m	Hardy,fodder,faste growing plant	Diciduous	Seeds/stumps	Sieve trame fuel
13	Eulaliopsis binata	Baghad grass.	Up to 2500m	Uses in most of the bio-engineering techinques	Evergreen	Seeds	Grass
14	ficus benghalensis	Bargad	Below 1000m	Frost tesistant, strong light demander and hardy plant	Diciduous	Layring	Fodder
15	Hippophae rhamnoides	See buck thorn.	Kaza Kinnour	Decoduous, small bush, moisture loving, chume is soil binder	Tea, drink, & other products	Seeds/cutting	Fuel/ c
16	Jatropha hastata	Diesal plant	Bilow 1000m	Deciduous, fast growing pollard well	Bush to small tree	Seeds/cutting	Oil from seeds
17	Juniperous communis	Juniper	Up to 2000m	Good ground cover, pollard well	Evergreen	cuttings	Omamental uses
18	Jugulans regia	Akhrot	Up to 2800m	Moist loving, dye of bark is used in candy and ice creem	Deciduous large tree	Seeds/grafting	Nuts, furniture
19	Jacaranda momosaefolia	Neeli gulmohar	Up to 2000m	Hardy omanental, flowering	Semi diciduous	Seeds	Ommental
20	Lagerstroemia indica	Harshingar	Up to 2000m	Hardy omanental, flowering	Deciduous shrub	Seeds/cutting	Omamental
21	Livistonia chinensis	Chinese fan palm.	Up to 2000m	Hardy, fodder and strong light demander	Evergreen	Seeds	Fodder ornamental
22	Melia azadirach	Drake	Up to 1800m	Pollard well, coppices to some extent	Deciduous, fast growing	Seeds	Medicinal timber
23	Morus papyrifera	Paper mulbery	Up to 1800m	Pollard well, fast growing, shade lover[Broussonetia papyrifera]	Deciduous	cuttings	Green cover
24	Morus alba	Mulberry.	Up to 1500m	Moisture loving used in silk worm rearing	Deciduous	Seeds/cutting	Fodder
25	Myrica nagi	Kaphal	Up to 1500m	Drought resistant, pollard well	Evergreen tree	Seeds	Fruit fodder
26	Opuntia dilenali	Opuntia	Up to1800m	Comes up well on neglected soil, druought resistant	Evergreen tree	Seeds/cutting	Fruit
27	Platinus onentalis.	Chinar	Up to 2000m	Moisture loving, require deep soil for its proper growth	Deciduous large trees	Seeds/cutting	Wood
28	Prunus puddum.	Pazza	Up to 1800m	Bee flora,hardy,wood used for making agriculture implements	Deciduous	Seeds	Omamental
29	Pennisetum purpureum	Elephant grass	Up to 2000m	Used in various bio-engineering techniques	Evergreen /cutting	Slips	Fodder
30	Populus ciliata	Himalyan popular	Up to 2500m	Moisture loving, wood used for packing purposes	Deciduous	Cutting/ seeds	Fodder
31	Populus alba	Popular	Up to 1800m	Moisture loving, wood used for packing purposes	Deciduous	Cutting/ seeds	Fodder
32	Picea smithiana	Rai	Up to 2500m	Shade/snow loving, required deep soil, ever green	Snow tolerant	Seeds	Packing cases
33	Parthenosissus tricuspidata.	Verginea creeper	Up to 1800m	Covering rocks, Massionary works/buildings etc.	Deciduous creeper	cuttings	Tree/building cover
34	Pistacia khinjuk	Kakar.	Up to 1800m	Hardy, fodder, used in cough medicine etc.	Deciduous	Seeds/cutting	Medicianal /timber
35	Rosa floribunda	Rose creeper	Up to 2000m	Hardy bush / ground cover, omamental creeper	Deciduous	Cutting	Scent
36	Ricinus communis	Caster oil	Up to 1500m	Hardy pollard well, non drying oil	Deciduous	Seeds	Medicine
37	Robinia psedoacassia	Robinia	Up to 2800m	Bee flora, good root system for soil conservation	Deciduous, medium in sige	Seeds /sucker	Fuel,fodder
38	Spirea betulifolia	Spirea	Up to 2500m	Hardy, soil conserving, flowering bush	Deciduous bush	Cutting	Omamental
39	Spartium juncium	Spanish broom	Up to 2500m	Hardy, soil conserving, flowering bush	Evergreen	Seeds	Omamental

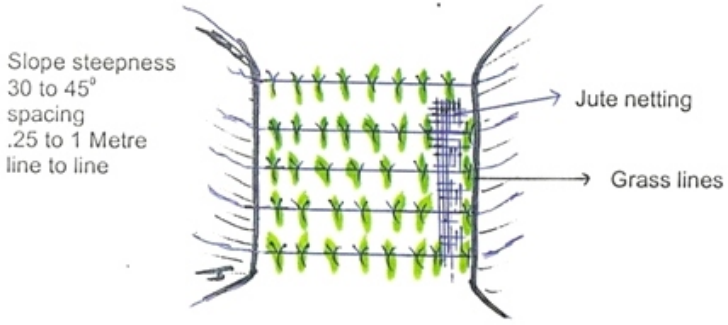
List of appropriate species of Plants to be used in Bio-Engineering during the Winter Season

Sr. No.	Botanical Name	Common Name	Altitude	Bio-Engineering properties of the species.	Habit of species	Propagation method	Uses
1	2	3	4	5	6	7	8
40	Salix alba	Willow	Up to 1800m	Used in various bio-engineering techniques	Deciduous tree	Seeds/cuttings	Fodder
41	Salix tetrasperma	Biunse	Up to 1800m	Used in various bio-engineering techniques	Deciduous tree	Seeds/cuttings	Fodder
42	Solanum jasminoides.	Jas,night shade	Up to 2000m	Hardy plant ground cover/covering civil eng. Structures also	Evergreen	Cutting	Omamental
43	Sapindus mukorossi	Ritha	Up to 1800m	Bee flora, used in detergent poweder, soaps etc.	Deciduous, large tree	Seeds	Medicene/soaps etc.
44	Salix babilonica	Majnu	Up to 1500m	Used in various bio-engineering techniques	Deciduous large tree	Seeds/cuttings	Omamental
45	Saccharum spontanium	Sarkanda	Up to 1200m	Used in various bio-engineering techniques	Evergreen grass	Seeds/slips.	Grass
46	Tinospora cordifolia	Galoi.	Up to 1800m	Used in lot of Aurvedic medicine	Deciduous, long creeper	Cuttings	fodder
47	Thysanolaena maxima	Broom grass	Up to 2000m	Used in varuoud bio-engineering techniques	Evergreen	Seeds/slips.	Grass
48	Vitex negundo	Shamalu	Up to 1800m	Prefer moist, shady, stony, hot dry road cuts	Hedging	Cuttings	Medicene/soaps etc.
49	Vitis vinifera	Jungli angure	Up to2000m	Prefer shady spot,spreading on the canopy of tree	Deciduous	Seeds	Tree/building cover
50	Vitis lenata	Jungli angure	Up to 1500m	Prefer shady spot spreading on the canopy of tree	Deciduous	Seeds	Tree/building cover
51	Vetivera zizanioides	Vetiveria.	Up to 2500m	Used in various bio-engineering techniques	Evergreen	Seeds/slips.	Grass
52	Zoysia japonica	Korean grass	Up to 2000m	May be used as good ground cover for slops etc.	Evergreen	Seeds/slips.	Grass
53	Zisyphus spp.	Jungli ber	Up to 1800m	Deciduous stong light demander, coppice/pollard well	Medium sized tree	Seeds	Fruits/fodder

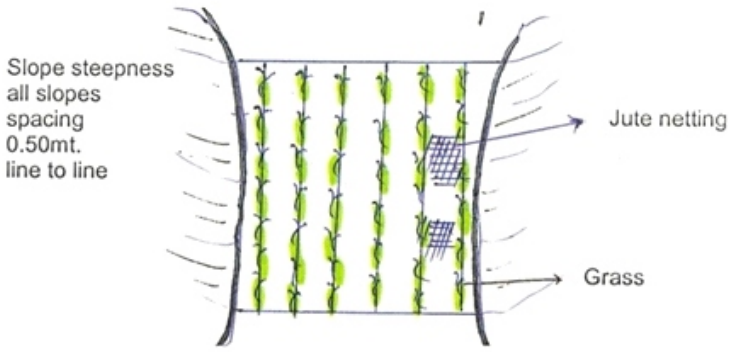
GRASSING

Annexure-2
Clause-352.5.6

CONTOUR / HORIZONTAL



DOWN SLOPE / VERTICAL

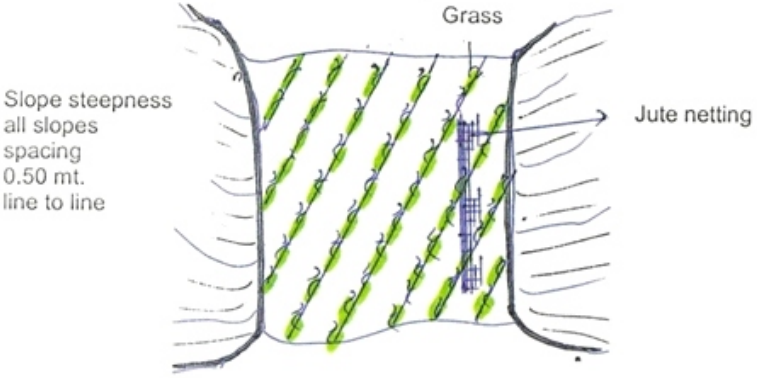


NOTE

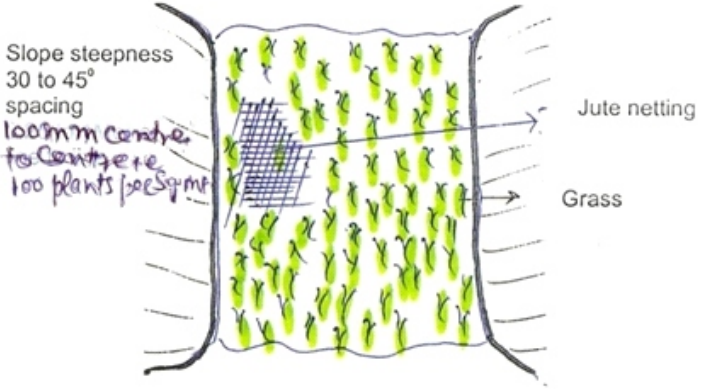
Spacing slip to slip-10 cms. slips should be lopped off 10cms. above ground level.

Grass Spp.: Thysanolaena; Eulaliopsis; Sacharum, Vetivera; Pennisetum-purpureum etc.

DIAGONAL



RANDOM PLANTING

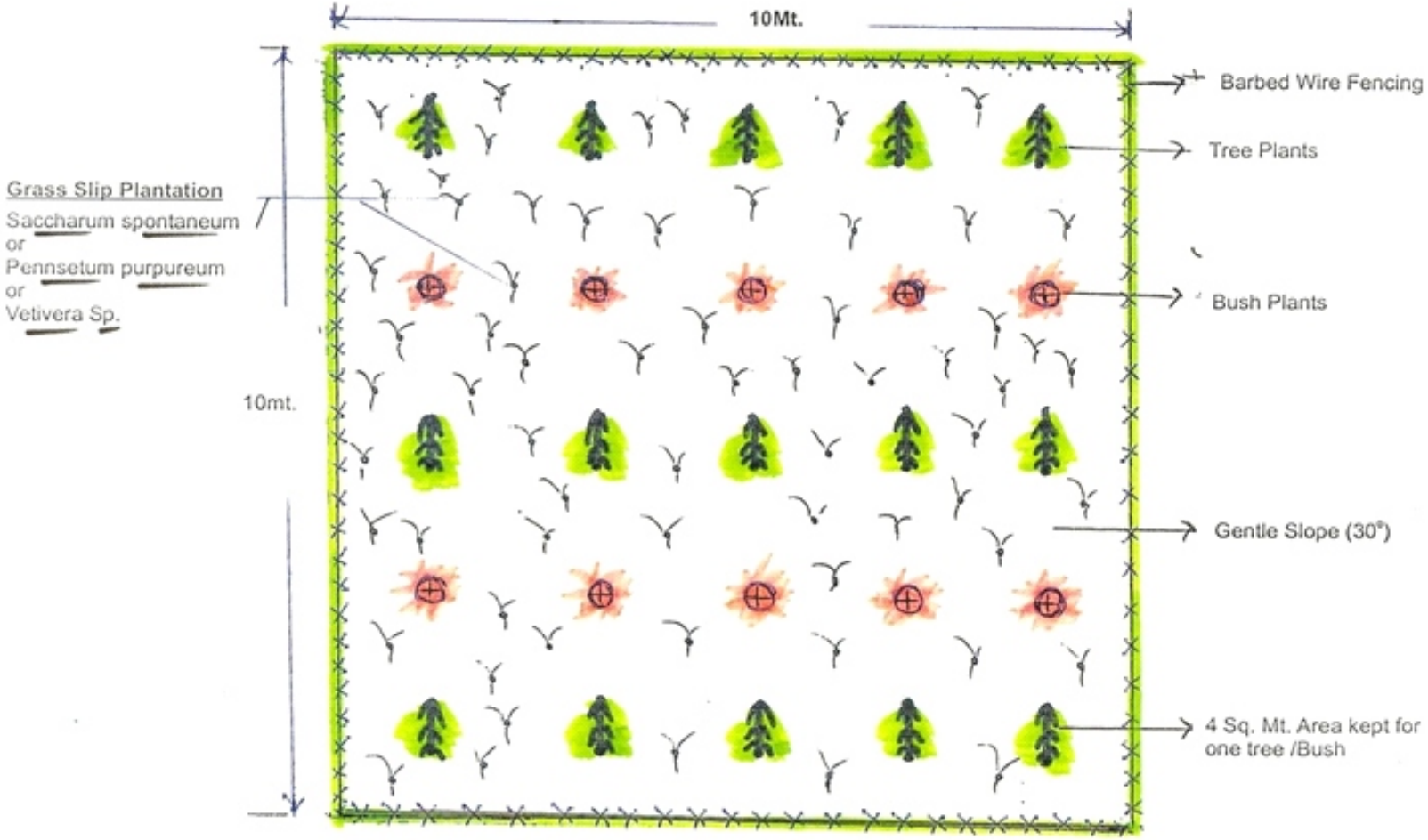


BIO-ENGINEERING-TECHNIQUES (GRASSING)

Annexure-3
Clause-352.6.5

TREE AND SHRUB PLANTATION

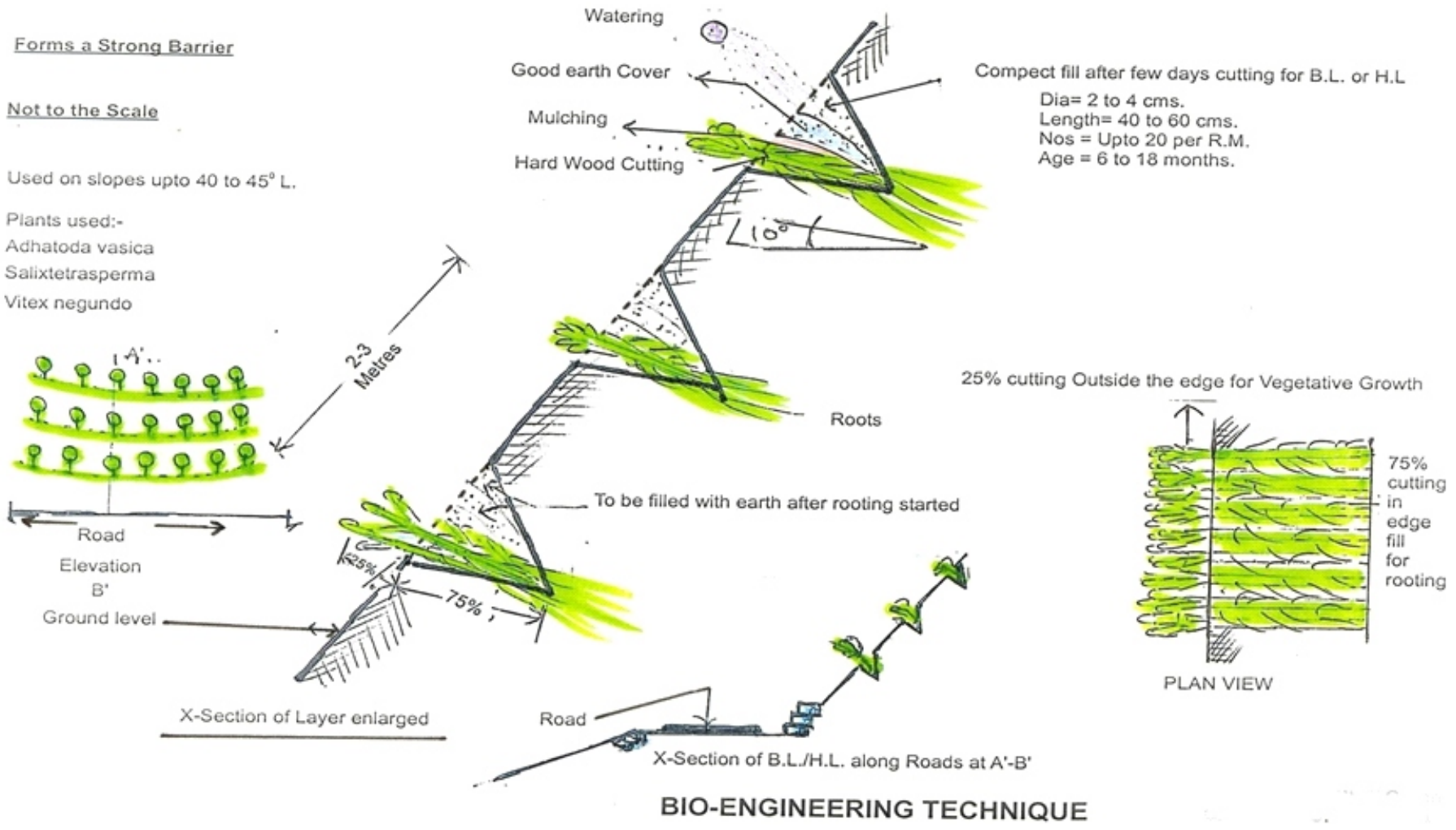
for Slope Stabilization



BIO-ENGINEERING-TECHNIQUE

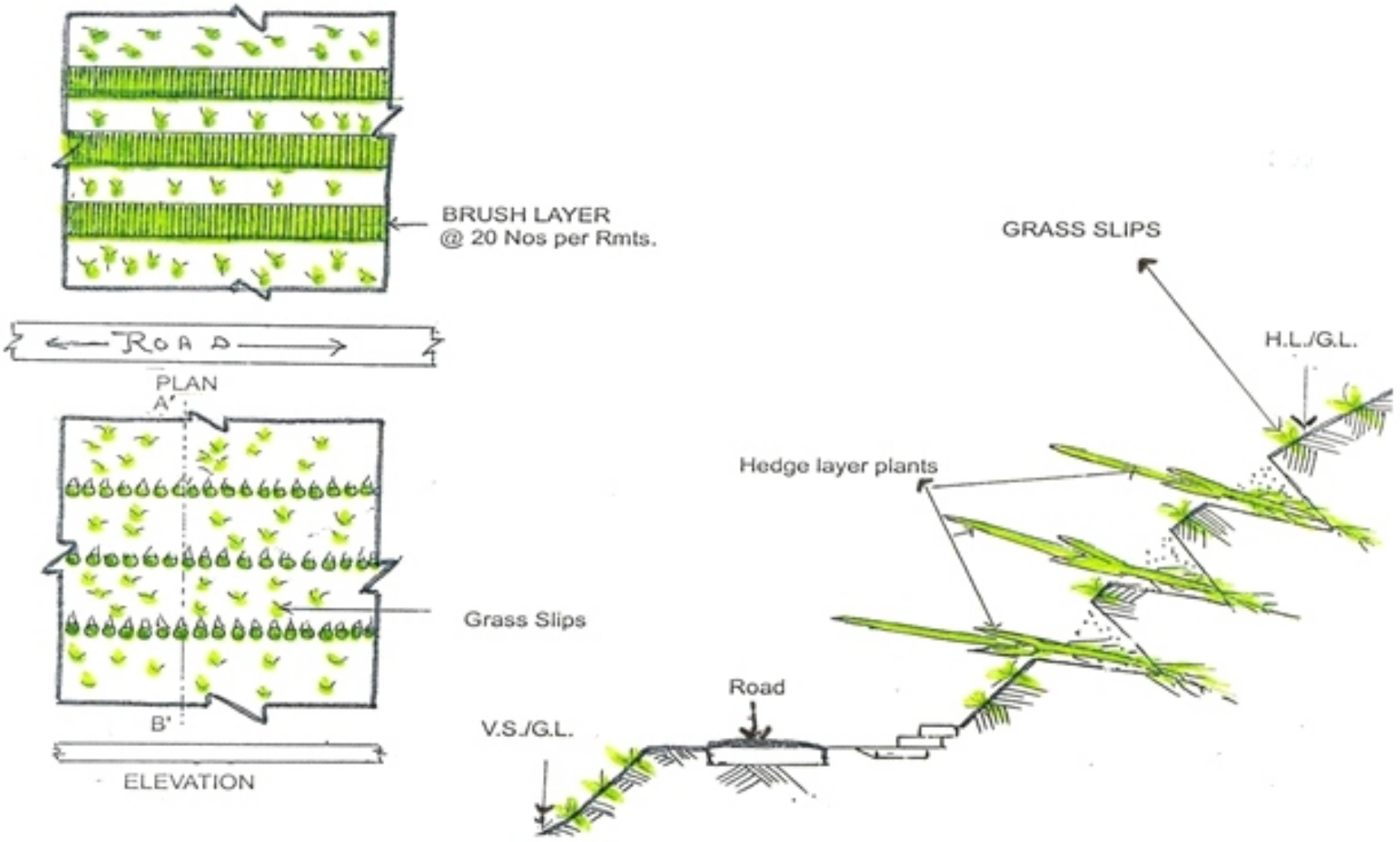
Annexure-4.1
Clause-352.8.6

BRUSH LAYER / HEDGE LAYER



BIO-ENGINEERING TECHNIQUE

BRUSH LAYER / HEDGE LAYER DRAWING
Bio-Engineering Technique

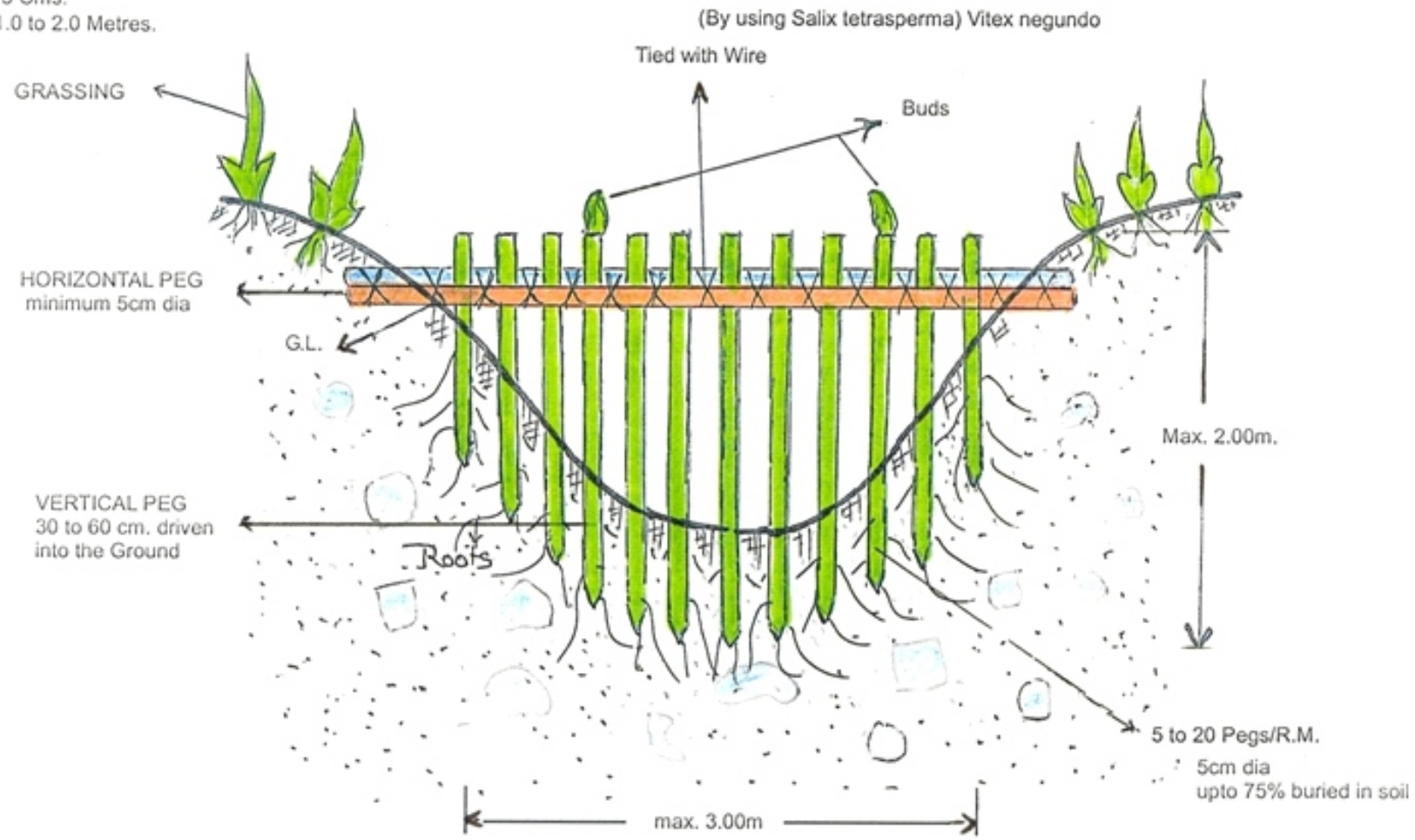


X-Section of B.L./H.L. at A'-B'

Annexure-5.1
Clause-352.9.6
(Strong Barrier)

VEGETATIVE PALISADE IN RILLS (ELEVATION)

Salix tetrasperma cuttings
Age: 6 to 18 Months
Dia: 2 to 5 Cms.
Length: 1.0 to 2.0 Metres.



BIO-ENGINEERING TECHNIQUE ((NOT TO SCALE)

Annexure-5.2
Clause-352.9.6

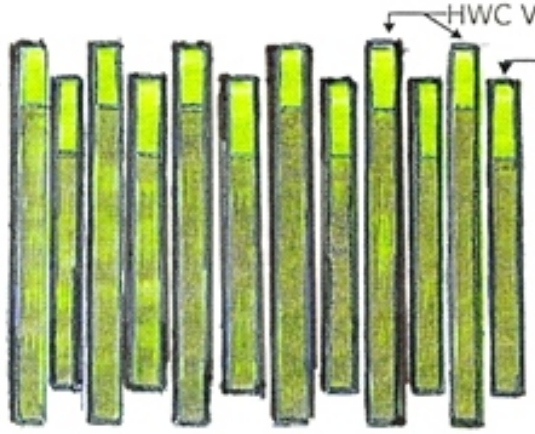
PALISADE (STAGGERED)

PLAN OF STAGGERED HOLES

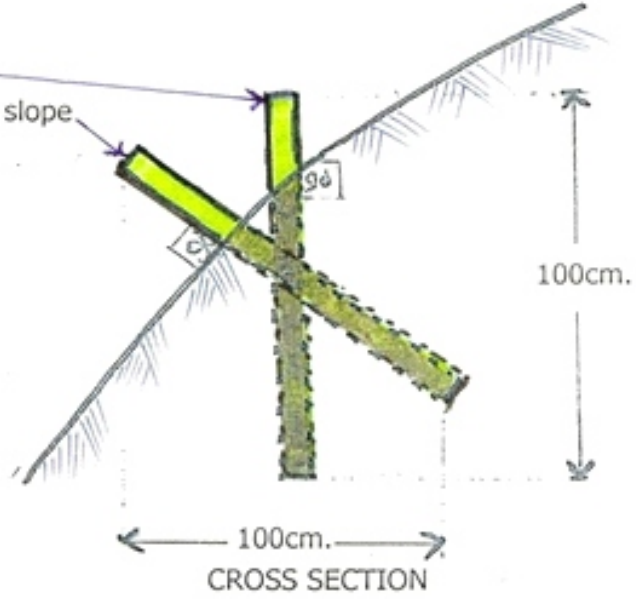
Note: (Spacing between two palisade 2 Mtr. <30° slope 1 Mtr. 30-60° slope)

Staggering -distance as required

Plan showing staggered H.W.C. of Plants.



FRONT ELEVATION

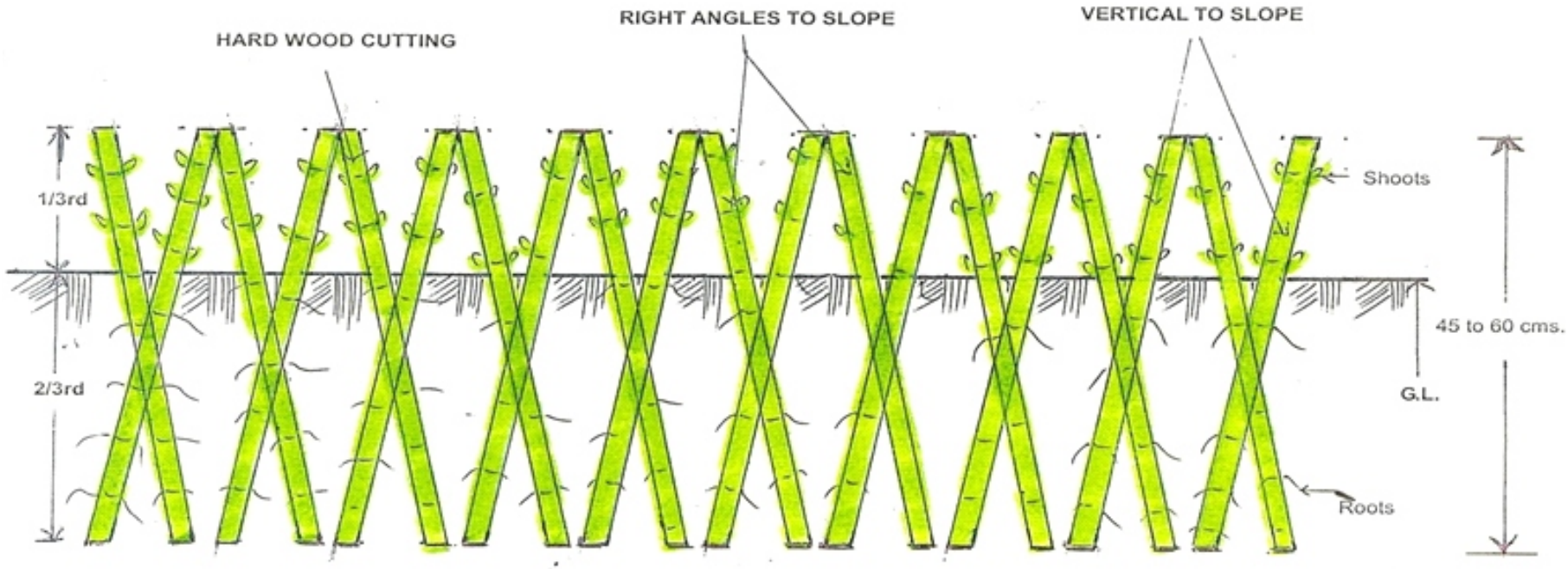


CROSS SECTION

A BIO-ENGINEERING TECHNIQUE

Annexure-5.3
Clause-352.9.6

PALISADE
WITH STAGGERED-HOLES

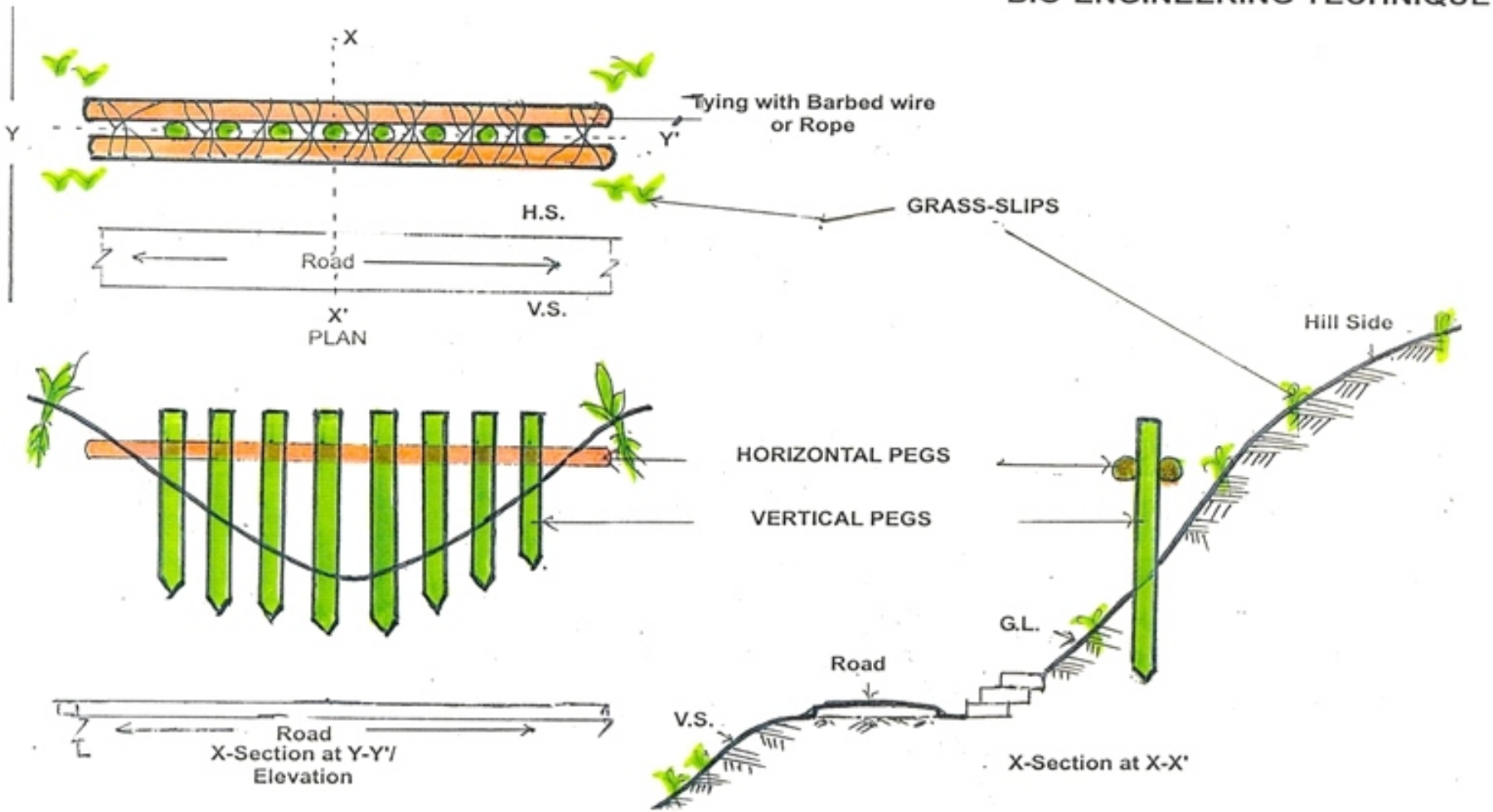


Hard Wood Cuttings Used 20 Per R.Mt.

BIO-ENGINEERING TECHNIQUE

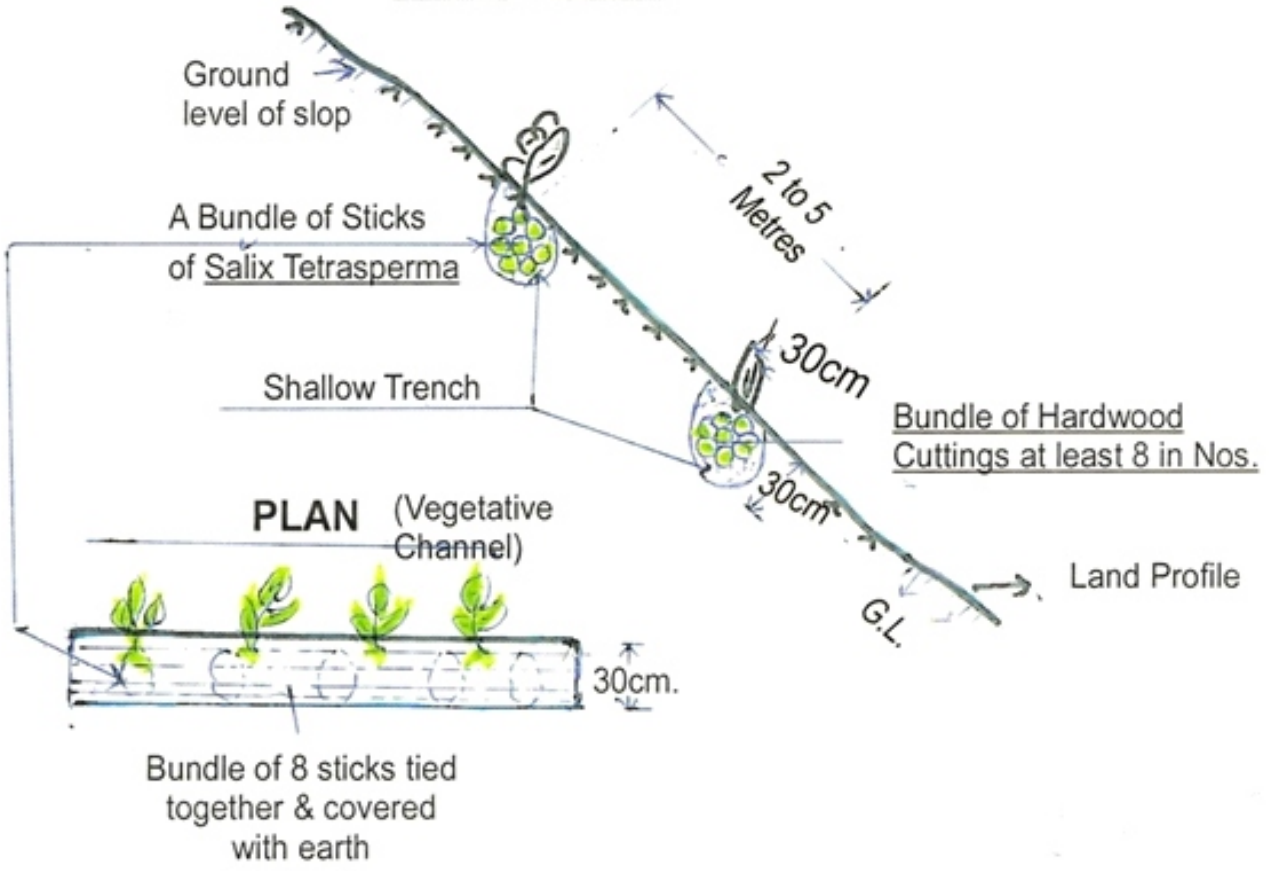
VEGETATIVE PALISADE DRAWING

BIO-ENGINEERING TECHNIQUE



A-BIO-ENGINEERING TECHNIQUE
DRAINAGE FASCINES

Cross Section



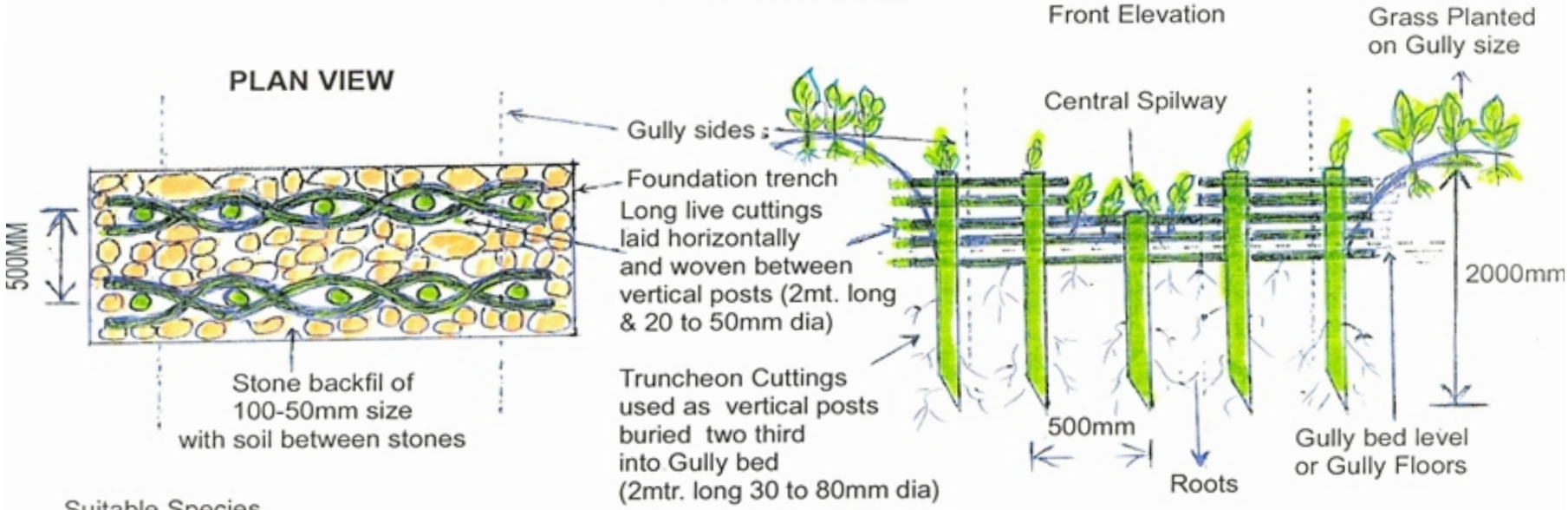
Not to be scale

Annexure - 7

Clause - 352.12.6

BIO-ENGINEERING TECHNIQUE FOR GULLY

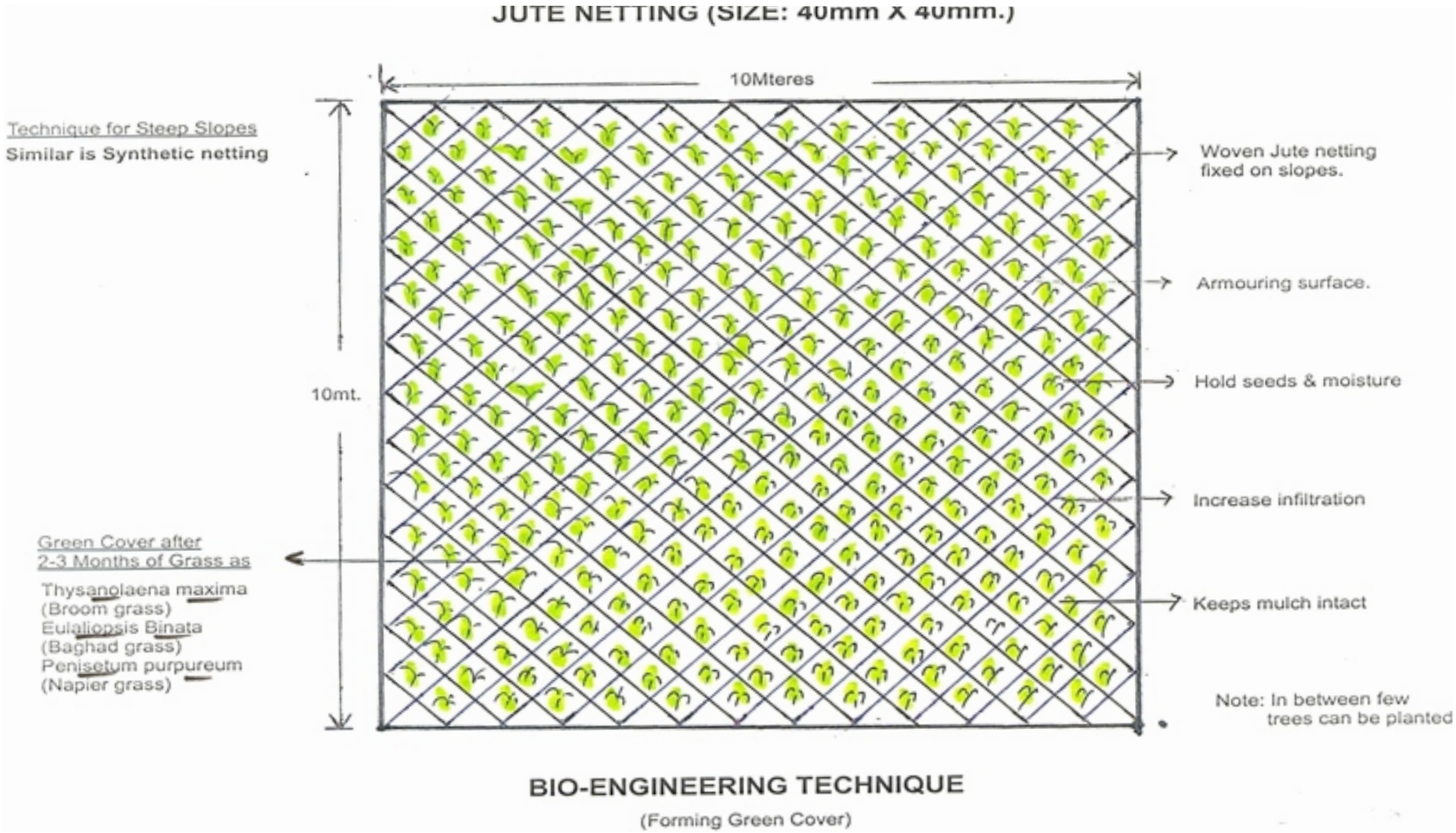
LIVE CHECK DAM



Suitable Species
Adhatoda Vasica
Salix Tetrasperna
Ipomea Batata
Vitex Negundo

Components of a Live Check Dam
suitable on Weak Foundation where Civil Engineering Structure
can easily be scoured around.

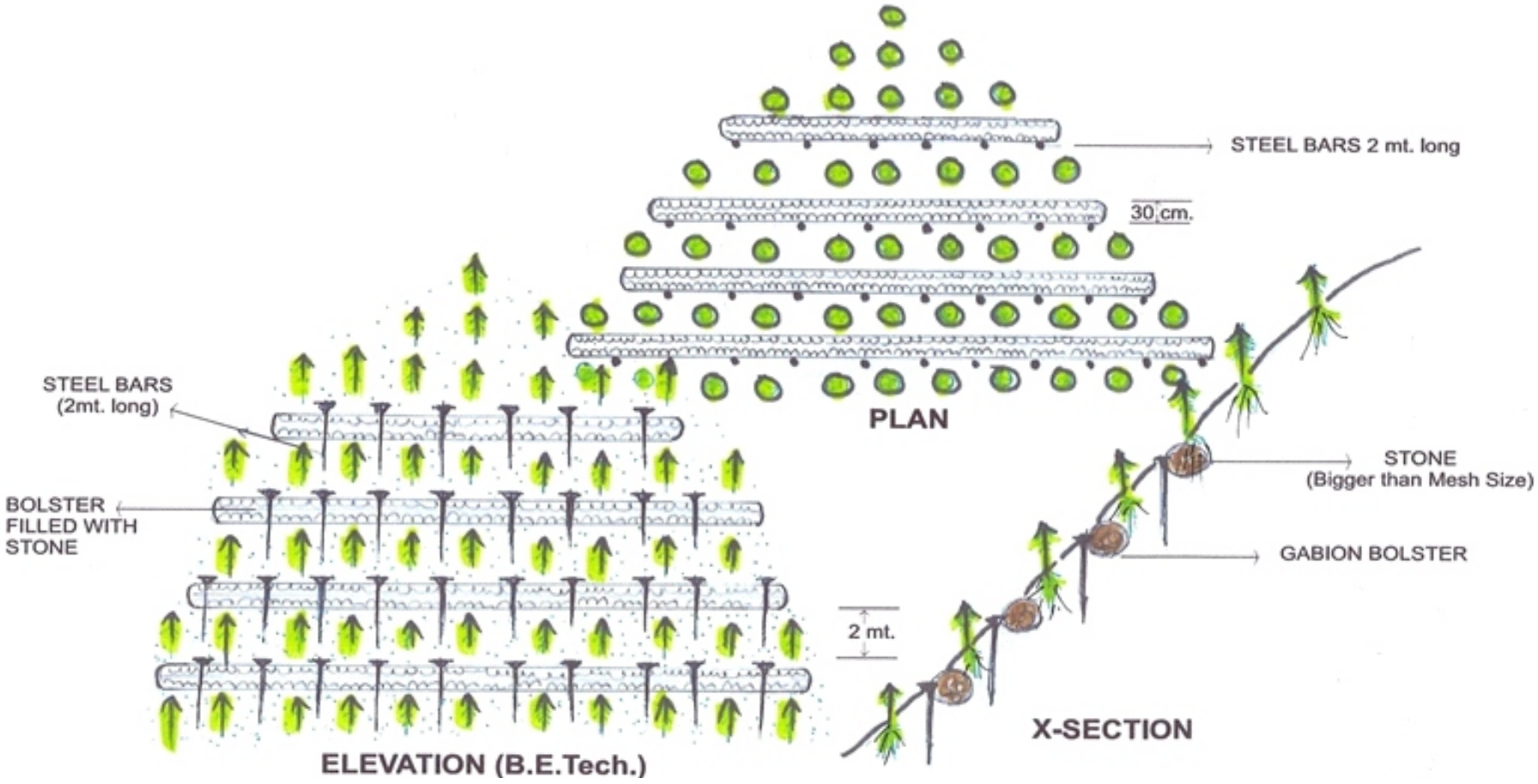
Annexure-8
Clause-361.6



WIRE BOLSTER ALONG CONTOUR (WELL DRAINED)

(TO RE-INFORCE INTERMITANT ARMOURING FUNCTION)

NOT TO SCALE

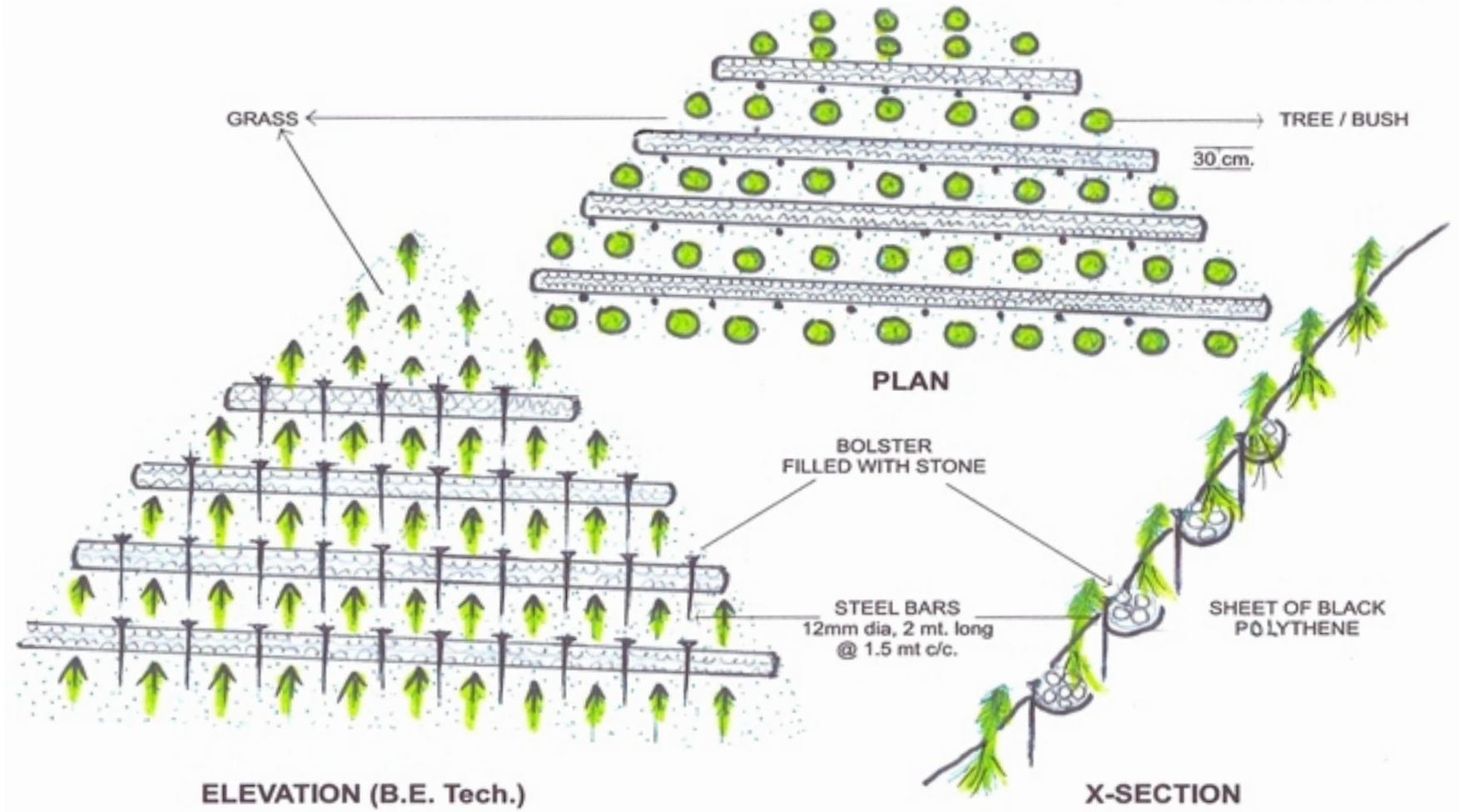


Annexure - 9.2
Clause - 362.6

HERRINGBONE BOLSTER IN POORLY DRAINED SOIL

(MOISTURE LOVING SPECIES USED)

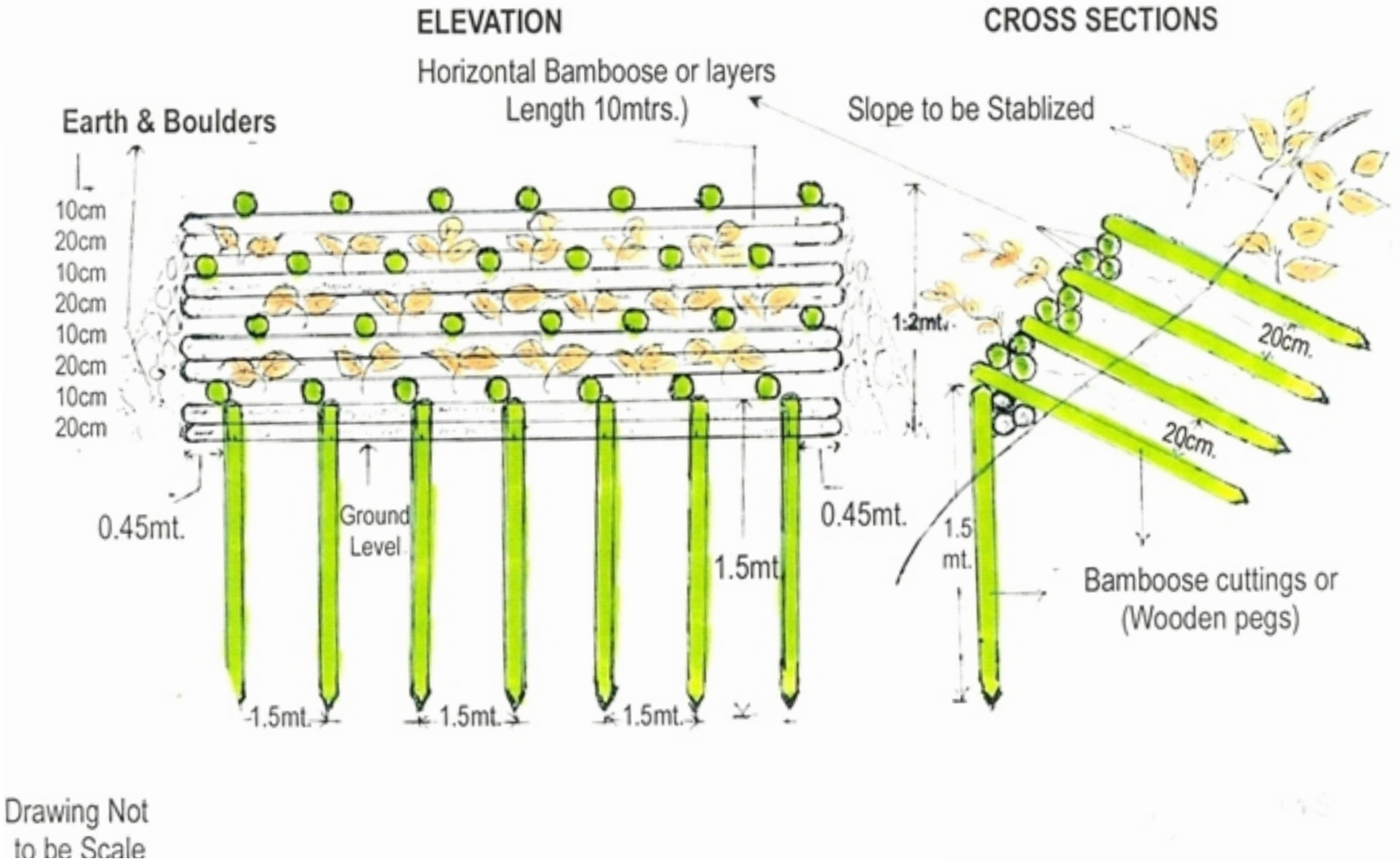
NOT TO SCALE



Annexure-10
Clause-352.19

CRIB-FORMATION

A-Technique of Bio-Engineering for Slope Stabilization



Drawing Not
to be Scale

PHOTOGRAPHS OF BIO-ENGINEERING WORKS/DEMONSTRATIONS

BEFORE

AFTER

(Bamboo Crib Wall Formation : Barsar-Jahu Road, Chainage 67+200)

(Brush Layer : Ranital-Kotla Road, Chainage 17+415)

BEFORE

AFTER

(Brush Layer : Sarkaghat-Jahu Road, Chainage 75+035)

(Brush Layer : Ranital-Kotla Road, Chainage 26+305)

BEFORE

AFTER

(Brush Layer : Kumarhatti-Nahan Road, Chainage 45+330)

(Hedge Brush Layer : Bhawarna-Jaisinghpur Road, Chainage 25+600)

BEFORE

AFTER

(Hedge Brush Layer : Kumarhatti-Nahan Road, Chainage 68+220)

(Hedge Brush Layer : Una-Barsar Road, Chainage 19+540)

BEFORE

AFTER

(Hedge Brush Layer : Sungal-Nog Road, Disstt. Bilaspur, Chainage 02+525)

(Grassing : Kumarhatti-Nahan Road, Chainage 00+500)

DEMONSTRATION

(Construction of Palisade : Kumarhatti-Nahan Road, Chainage 59+620)

(Hedge Brush Layer : Kumarhatti-Nahan Road, Chainage 45+330)

(Brush Layer : Draman-Sihunta Road, Chainage 09+500)