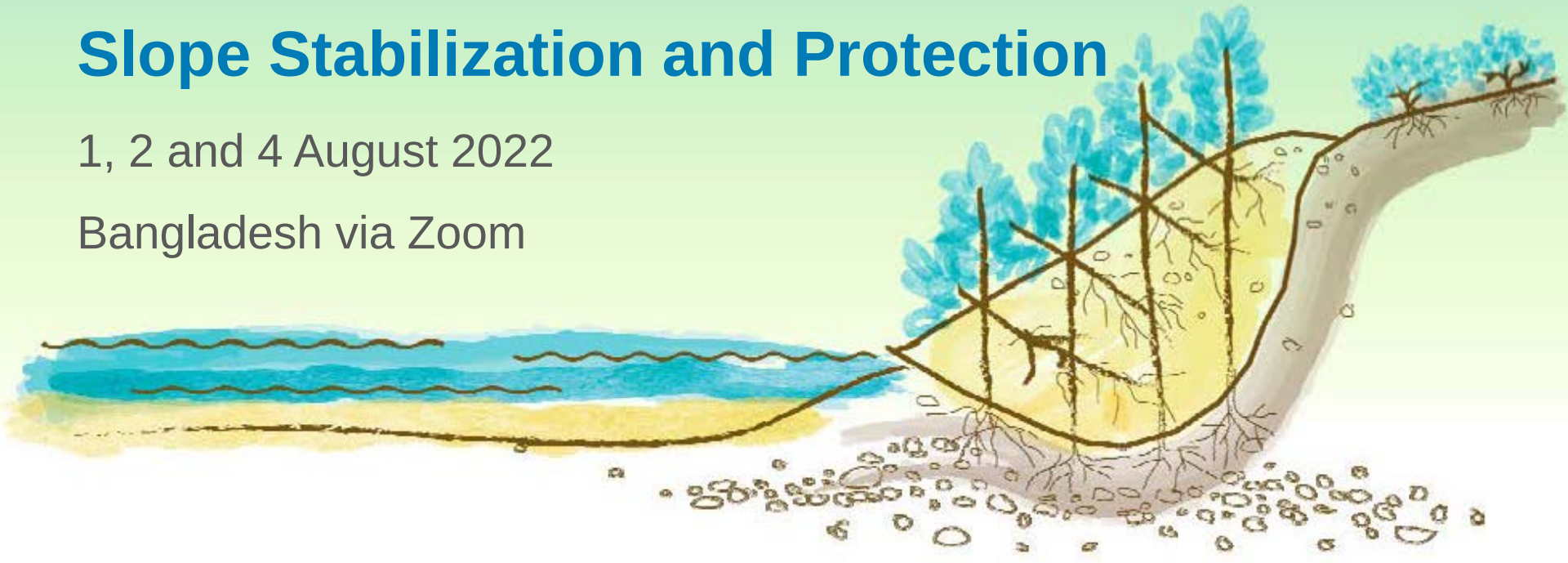
TRAINING ON

Bioengineering Nature-based Solutions for Linear Infrastructure Slope Stabilization and Protection

1, 2 and 4 August 2022

Bangladesh via Zoom



Source of Material

This training programme was compiled and delivered by Shankar Rai, working with assistance from Shuva Sharma, Dr. Mohammed Shariful Islam and Syed Abdur Rahim. Quality assurance was provided by John Howell.

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Session-01

Introduction to the Training

Self-introduction

- Trainers
- Participants

Training Content and Timetable

Day/Time (Bangladesh time)	Modules	Technical Content
1 August 2022	DAY 1: Introduction to bioengineering training course	
10:05 a.m.-12:00 p.m.	Module 1: Slope instability, failure and protection measures	Introduction to the training course
		Type of slope instability and components of an unstable slope
		Causes and mechanisms of slope failure
		Slope protection practice and bioengineering
12:00 p.m.-1:00 p.m.	Module 2: Introduction to bioengineering and designing structures with nature	Engineering design and functions in bioengineering systems
		Bioengineering structures and their design
		Site assessment and selection of bioengineering techniques
		Selection of plant species for bioengineering
1:00 p.m.-2:00 p.m.	Health Break	
2:00 p.m.- 2:50 p.m.	Module 3: Programming bioengineering works, rate analysis norms, and standard specifications	Bioengineering works for slope protection
		Bioengineering maintenance task and seasonal work programming of bioengineering works
		Rate analysis norms and standard specifications for bioengineering works
2:50 p.m.-3:00 p.m.	Open Discussion and Announcements	

Training Content and Timetable

Day/Time (Bangladesh time)	Modules	Technical Content
2 August 2022	DAY 2: Bioengineering nursery construction and collection of materials	
10:00 a.m.-10:05 a.m.	**Recap of Day 1 Training Session**	
10:05 a.m.-12:00 p.m.	Module 4: Bioengineering nursery site selection, design and construction	Siting bioengineering nursery
		Nursery components and size
		Nursery layout, design and nursery bed construction
12:00 p.m.-1:00 p.m.	Module 5: Collection of seed and vegetative plant materials	Seed collection and storage
		Collection of vegetative plant materials
1:00 p.m.-2:00 p.m.	Health Break	
2:00 p.m.-3:00 p.m.	Open Discussion and Announcements	

Training Content and Timetable

Day/Time (Bangladesh time)	Modules	Technical Content
4 August 2022	DAY 3: Bioengineering nursery operations and bioengineering works	
10:00 a.m.-10:05 a.m.	**Recap of Day 2 Training Session**	
10:05 a.m.-12:00 p.m.	Module 6: Bioengineering nursery operations	Compost production and filling polypots
		Seed sowing and planting cuttings in nursery
		Care of young plant in nursery
		Hardening, lifting and transporting to site
		Scheduling nursery work and record keeping
12: 00 p.m.-1:00 p.m.	Module 7: Site preparations and bioengineering works	Site preparation and spoil disposal
		Construction of vegetative structures
		Practical application of bioengineering works
		Application of rate analysis norms and standard specification for bioengineering works
1: 00 p.m.-2:00 p.m.	Health Break	
2: 00 p.m.-2:50 p.m.	**Open Discussion and Training Course Evaluation**	
2: 50 p.m.-3:00 p.m.	CLOSING SESSION: ADB	

Session-02

Type of Slope Instability and Components of an Unstable Slope

Slope Instability Examples

Slope Instability Examples

Slope Instability Examples

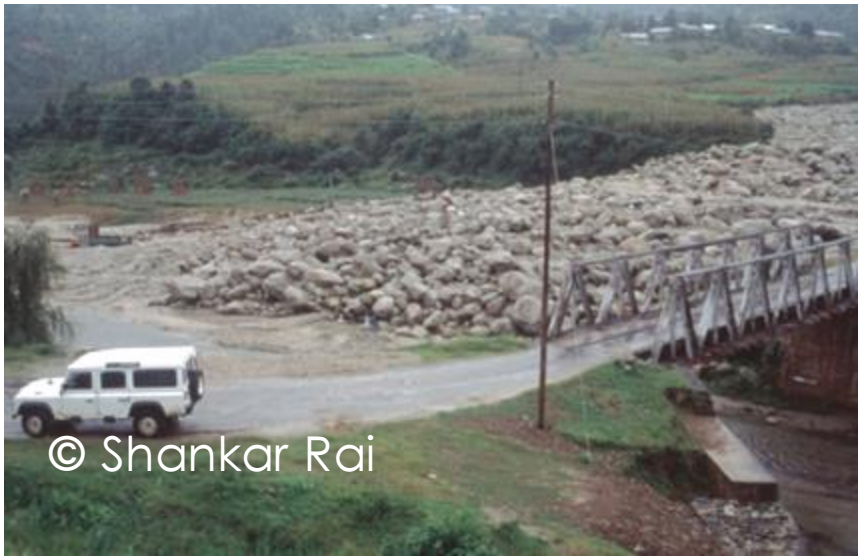
Slope Instability Examples

Slope Instability Examples

Disconnects transport/traffic

Loss of Assets

Sedimentation and Loss of Assets



Types of Slope Instability

- Erosion
  - Sheet erosion
  - Rill erosion
  - Gully erosion
- Rotational slide
- Translational slide
- Plane failure
- Toppling
- Wedge / block failure
- Piping

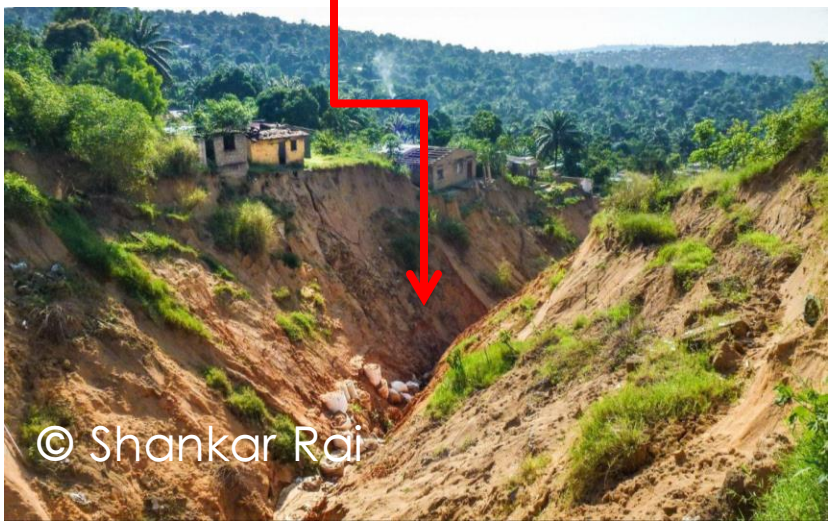
Types of Slope Instability

Sheet erosion

Rill erosion

Types of Slope Instability

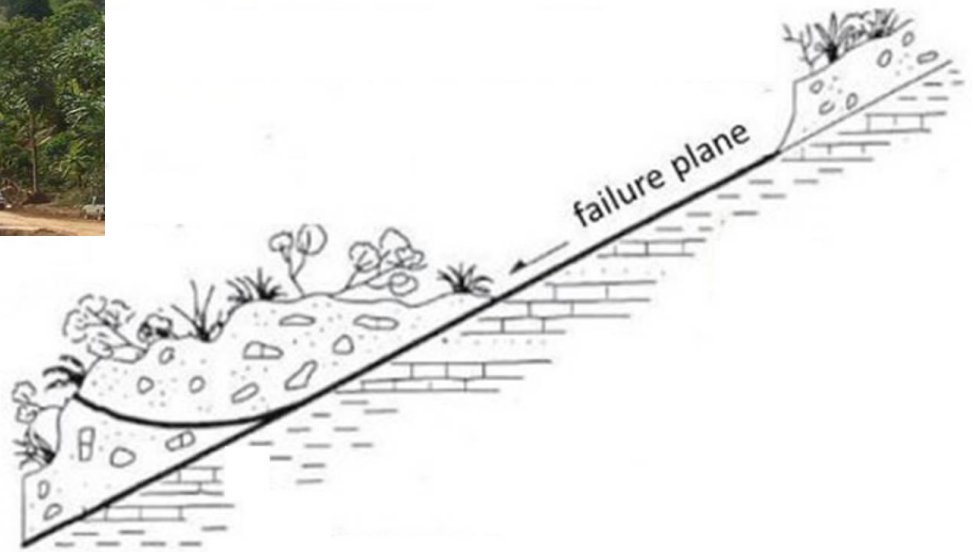
Gully erosion



Plane failure

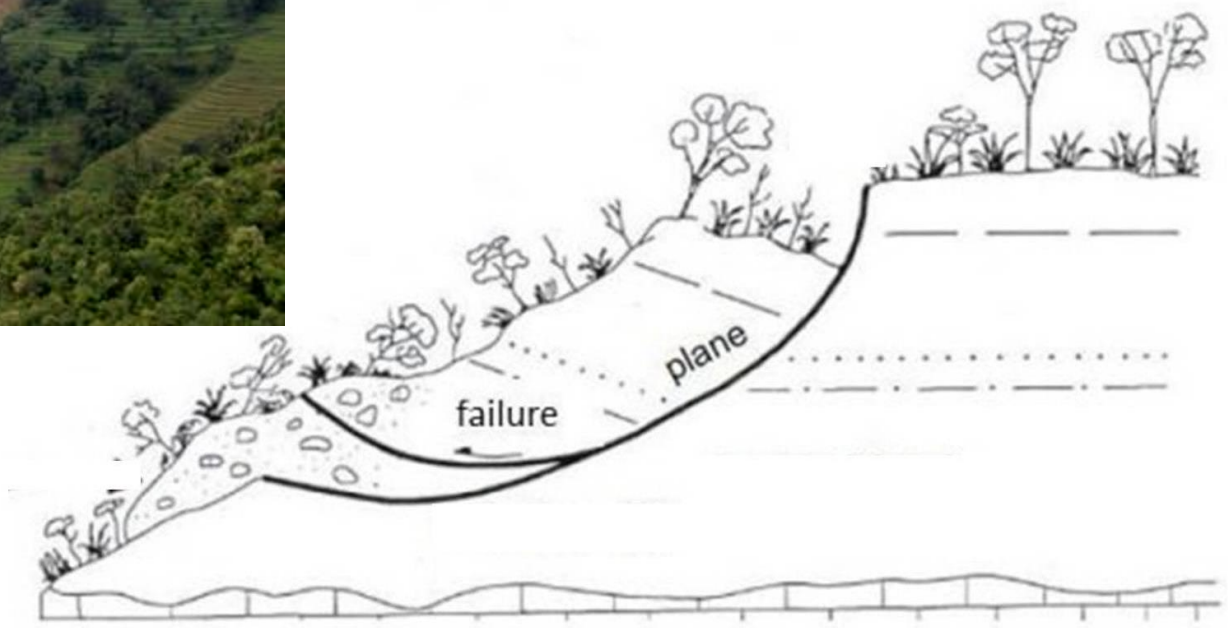
Types of Slope Instability

Translational failure



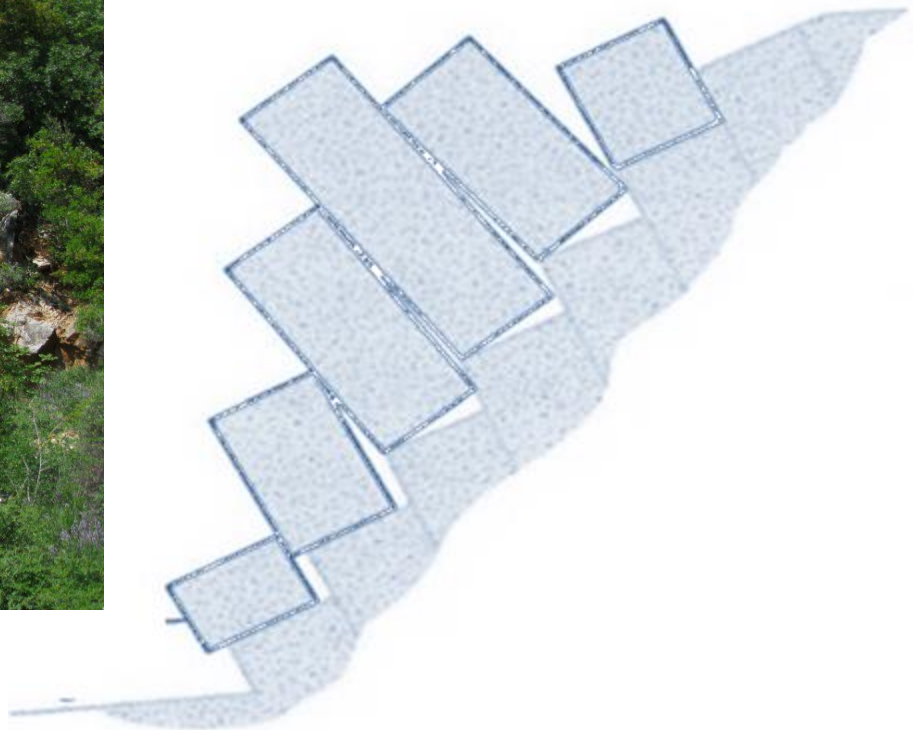
Types of Slope Instability

Rotational failure



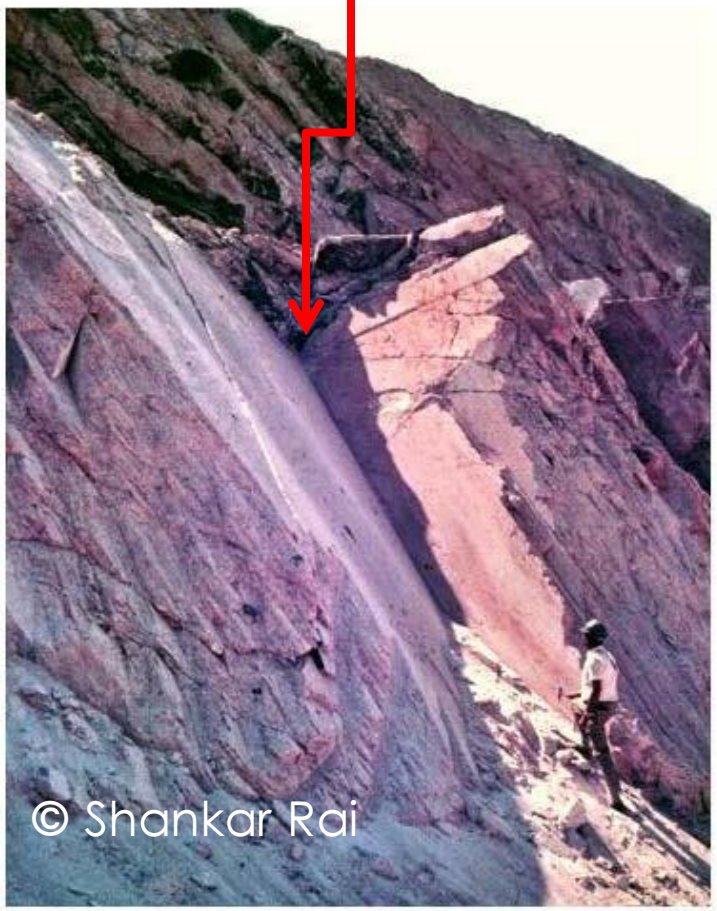
Types of Slope Instability

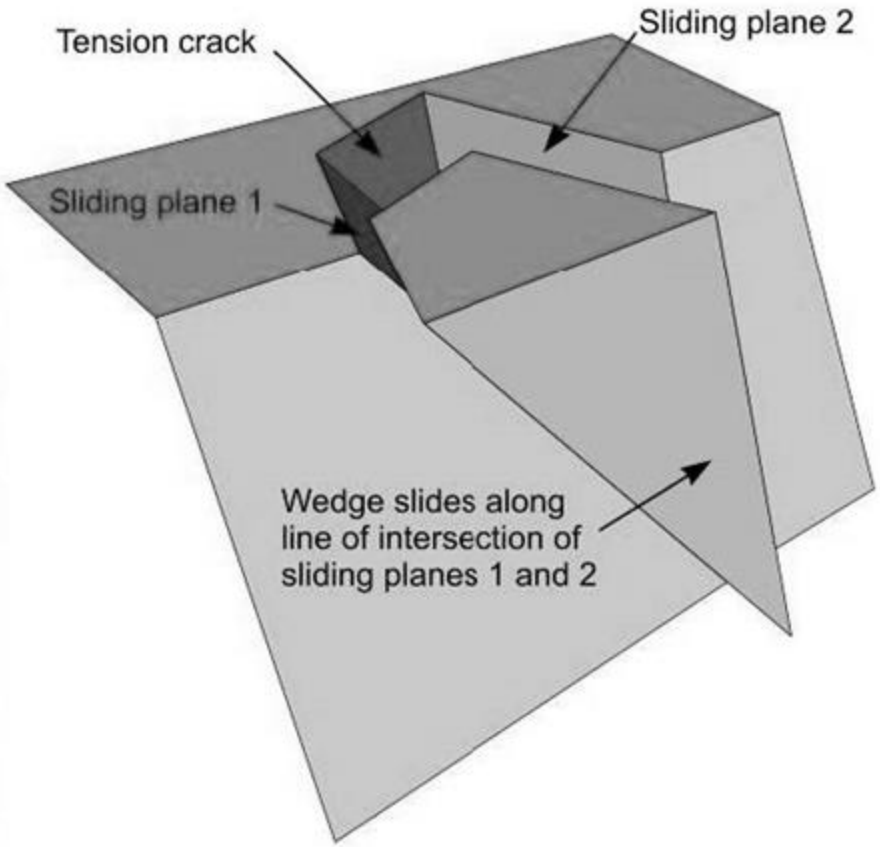
Toppling



Types of Slope Instability

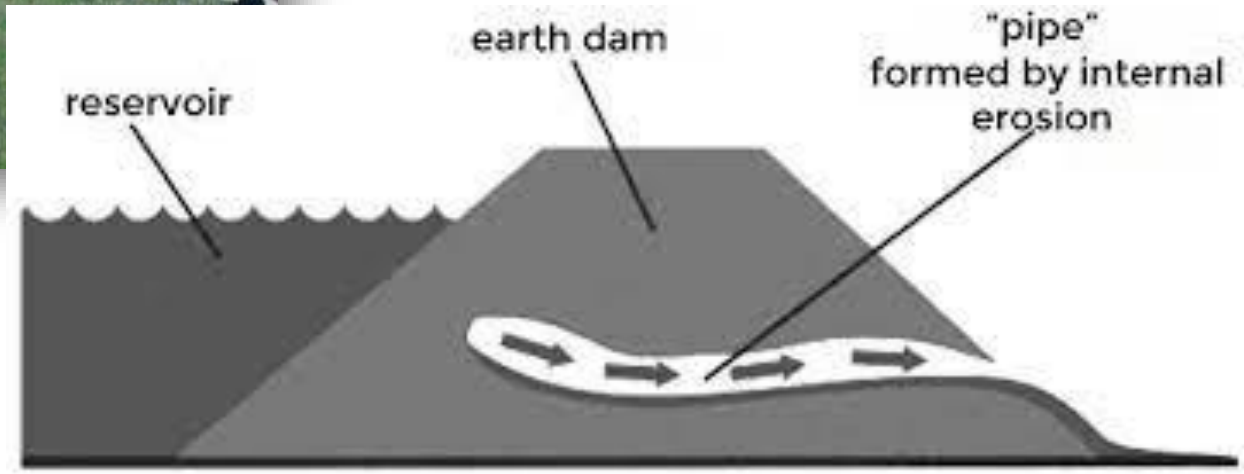
Wedge/block failure



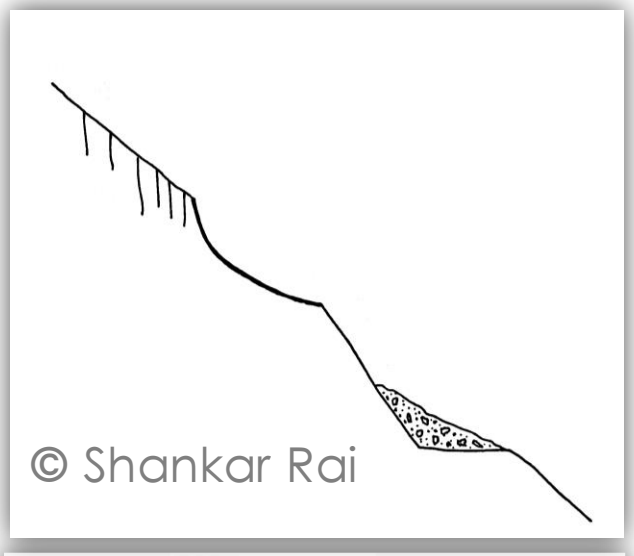


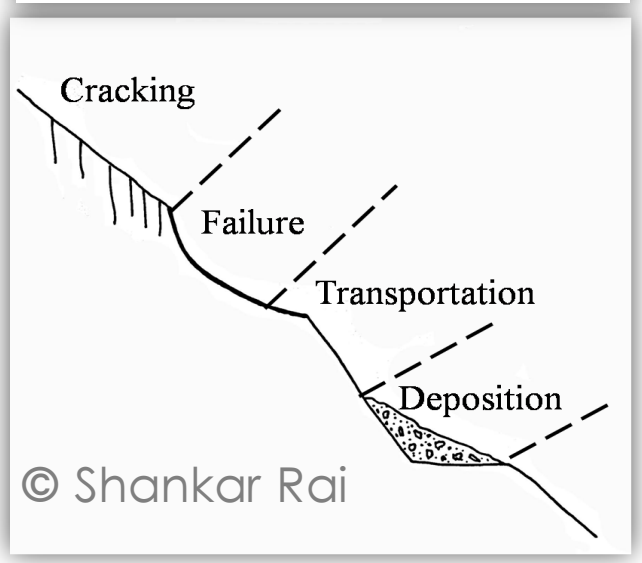
Types of Slope Instability

Piping

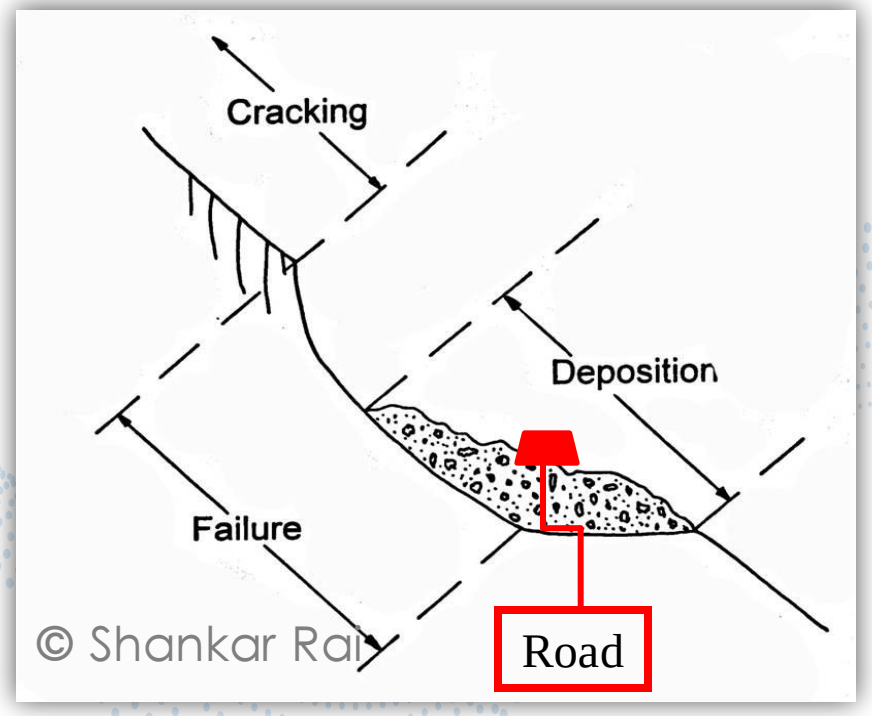


Components of an Unstable Slope

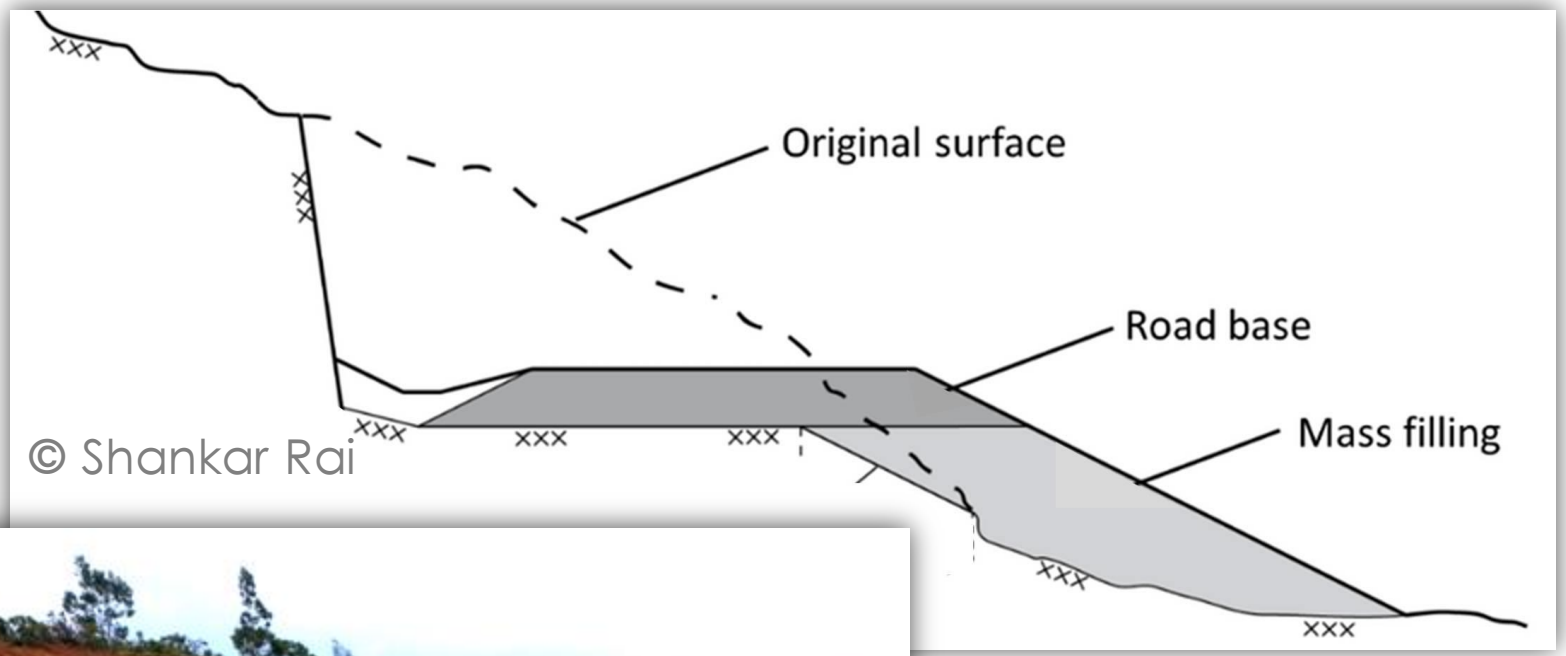




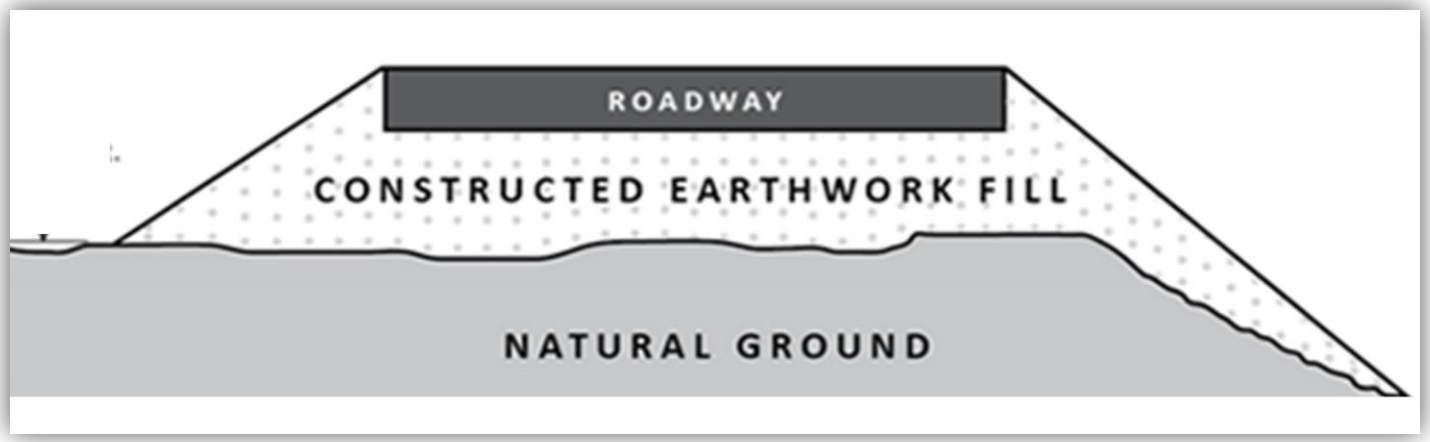
Components of an Unstable Slope



Slope Instability



Man-made Slope Instability



Session-03

Causes and Mechanisms of Slope Failure

Causes and mechanisms of slope failure

Cause of failure :

The condition that generates or triggers or starts failure.

Mechanism of failure :

The manner in which loss of strength occurs in the slope.

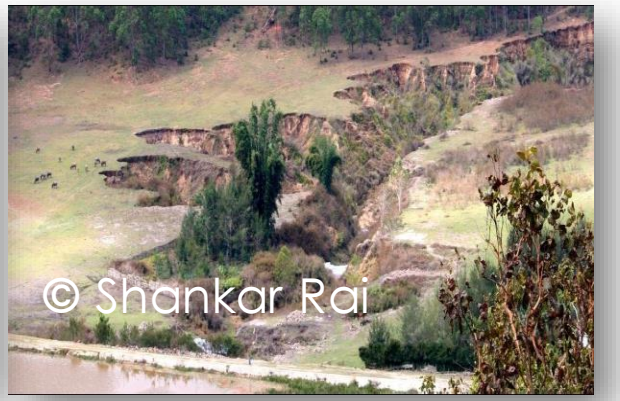
Causes of slope failure

- Water
  - Surface water
  - Ground water/Sub-surface water
- Undercutting of slope
- Weathering
- Additional load

Causes and mechanisms of slope failure

Cause → **Mechanism**

- Water
  - ~ Surface water
    - Sheet erosion
    - Rill erosion
    - Gully erosion



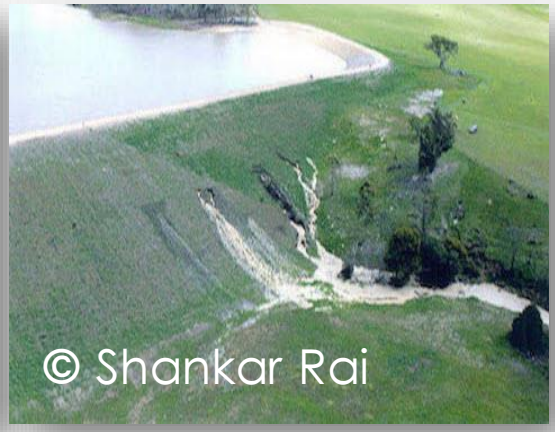
Causes and mechanisms of slope failure

Cause **Mechanism**

- Water

~ Ground water

-Translational failure
- Rotational failure
- Piping



Causes and mechanisms of slope failure

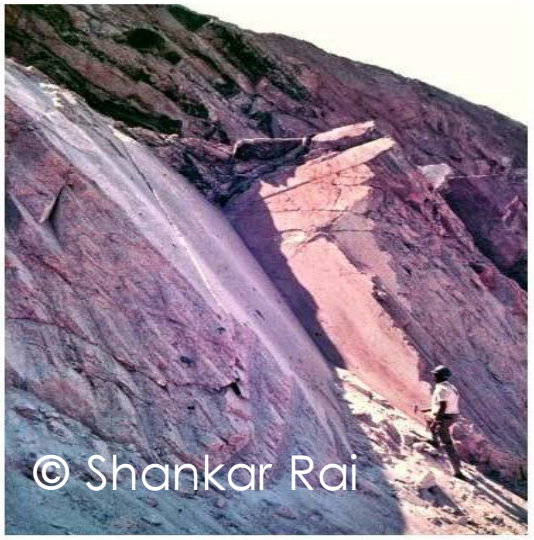
Cause → **Mechanism**

- Undercutting → -Translational failure
  - Rotational failure
  - Plane failure

Causes and mechanisms of slope failure

Cause → **Mechanism**

- Weathering → -Toppling
  -Wedge/Block failure



Causes and mechanisms of slope failure

Cause	Mechanism
• Additional load	-Translational failure - Rotational failure - Plane failure

Triggering factors of slope instability

- Human Activities

  - Undermining slopes

  - Tipping of spoil on slopes

  - Collapse of retaining structures

  - Sudden water discharge

  - Fire removing vegetation

  - Changed land use

Triggering factors of slope instability

- Natural events

  - Heavy rain

  - River floods (usually undercutting slopes)

  - Earthquakes

Session-4

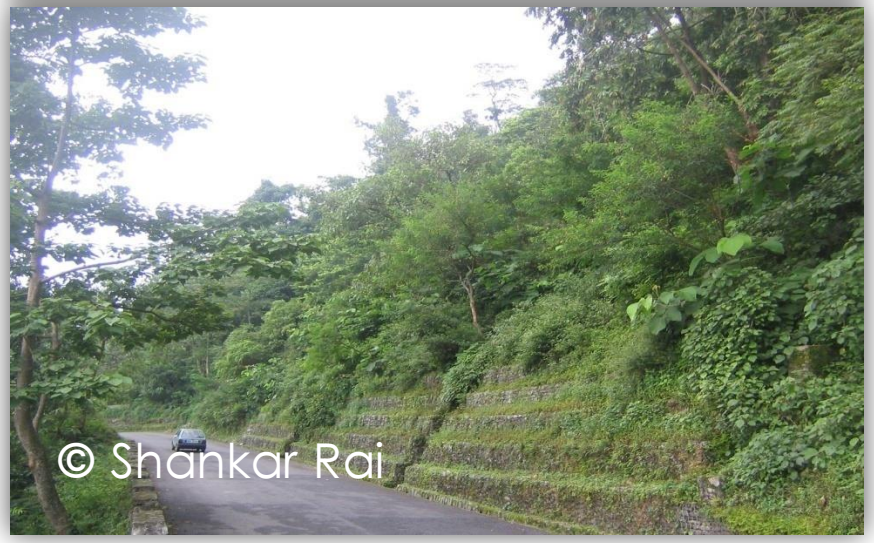
Slope Protection Practices

Conventional engineering practices for slope protection work

Conventional engineering practices for slope protection work

Bio-engineering methods for slope stabilization

Bio-engineering methods for slope stabilization



What is bio-engineering ?

Bio-engineering is the use of living plants for engineering purposes, either alone or in conjunction with the civil engineering structures and non-living plant material, to reduce shallow-seated instability and erosion on slopes.

What does bio-engineering do?

- Bio-engineering protects almost all slopes against erosion;

What does bio-engineering do?

- Bio-engineering reduces the instances of shallow planer sliding;
- Bio-engineering improves surface drainage;
- Bio-engineering reduces slumping (saturated slope failures).

Why bio-engineering?

- Bio-engineering systems work in the same way as civil engineering systems and have the same functions and
- Reducing instability and erosion (*curing* problems)
- Increasing the slope's factor of safety (*preventing* problems)

Why bio-engineering?

- Climate resilience and Nature-based Solution for slope protection and erosion control work;
- Cost-effectiveness;
- Socially advantageous;
- Versatility in application;
- Environmentally advantageous.

Session-5

Design Aspects of Civil Engineering Structures

and

Engineering Functions of Bio-engineering Systems

Design aspects of civil engineering structures

- to stop material falling or sliding down a slope:

  Catch

- to protect surfaces from erosion:

  Armour

- to hold particles together and reduce risk of shallow-seated movement:

  Reinforce

Design aspects of civil engineering structures

- to reduce the risk of deeper-seated movement:

Anchor

- to hold material on slope:

Support

- to remove excess water:

Drain

Design aspects of civil engineering structures

Engineering functions of civil engineering structures

1. Catch
2. Armour
3. Reinforce
4. Anchor
5. Support
6. Drain

Design aspects of civil engineering structures

Engineering functions of civil engineering structures?

Civil engineering structure	Engineering function
Check dam	Catch
Revetment wall, stone pitching	Armour
Earth reinforcement/soil nailing	Reinforce
Rock bolting	Anchor
Retaining wall	Support
Lined ditch/French drain	Drain

Design aspects of civil engineering structures

Small scale civil engineering structures

Coir/Jute netting

Design aspects of civil engineering structures

Small scale civil engineering structures

Wattle fence and crib wall

Design aspects of civil engineering structures

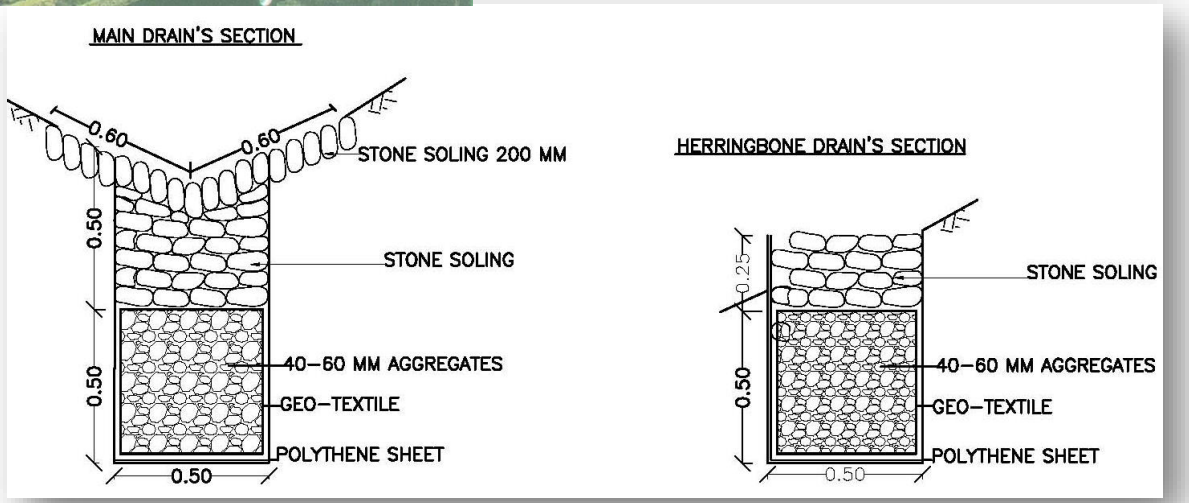
Small scale civil engineering structures

Prop wall

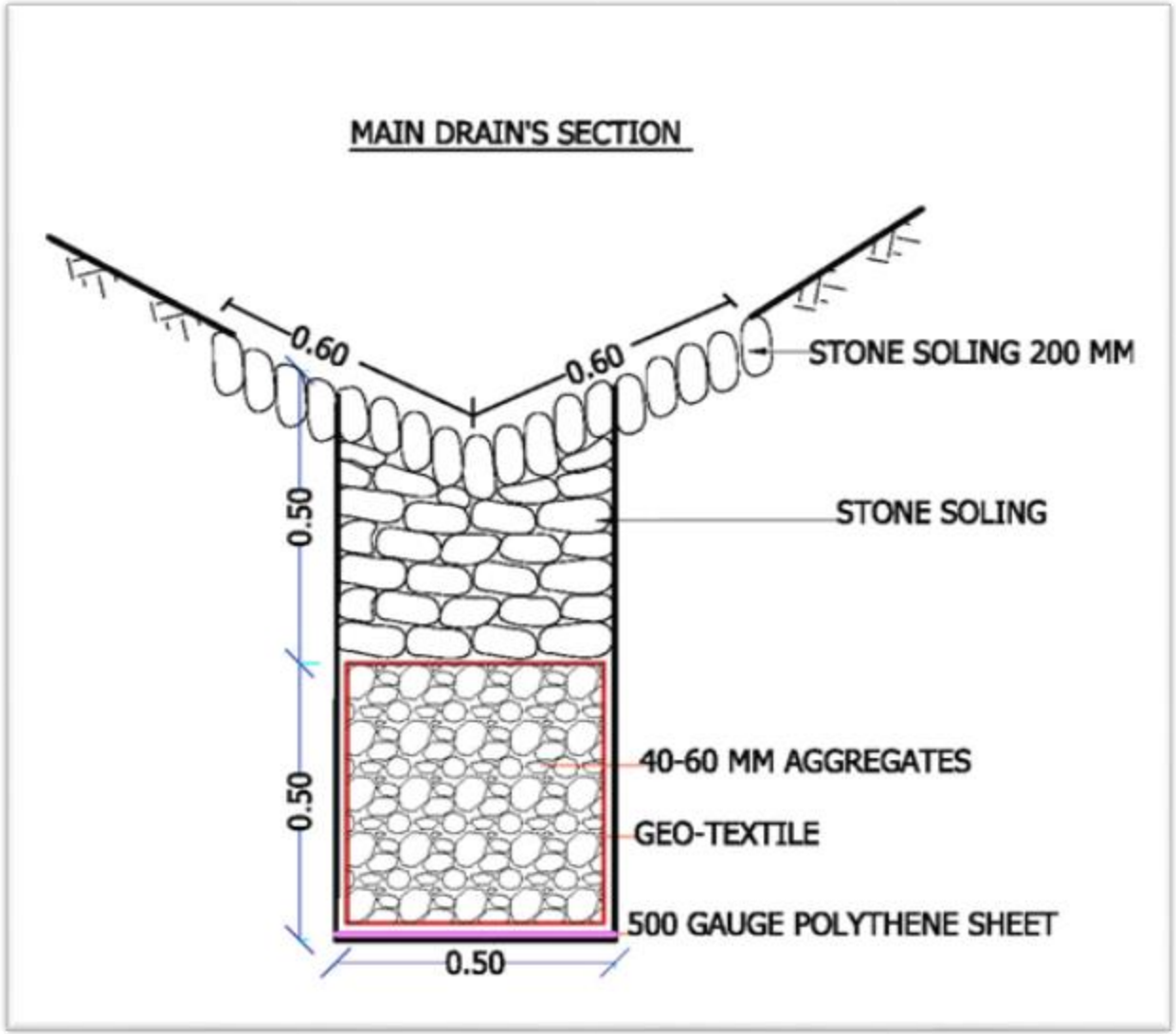
Dentition

Design aspects of civil engineering structures

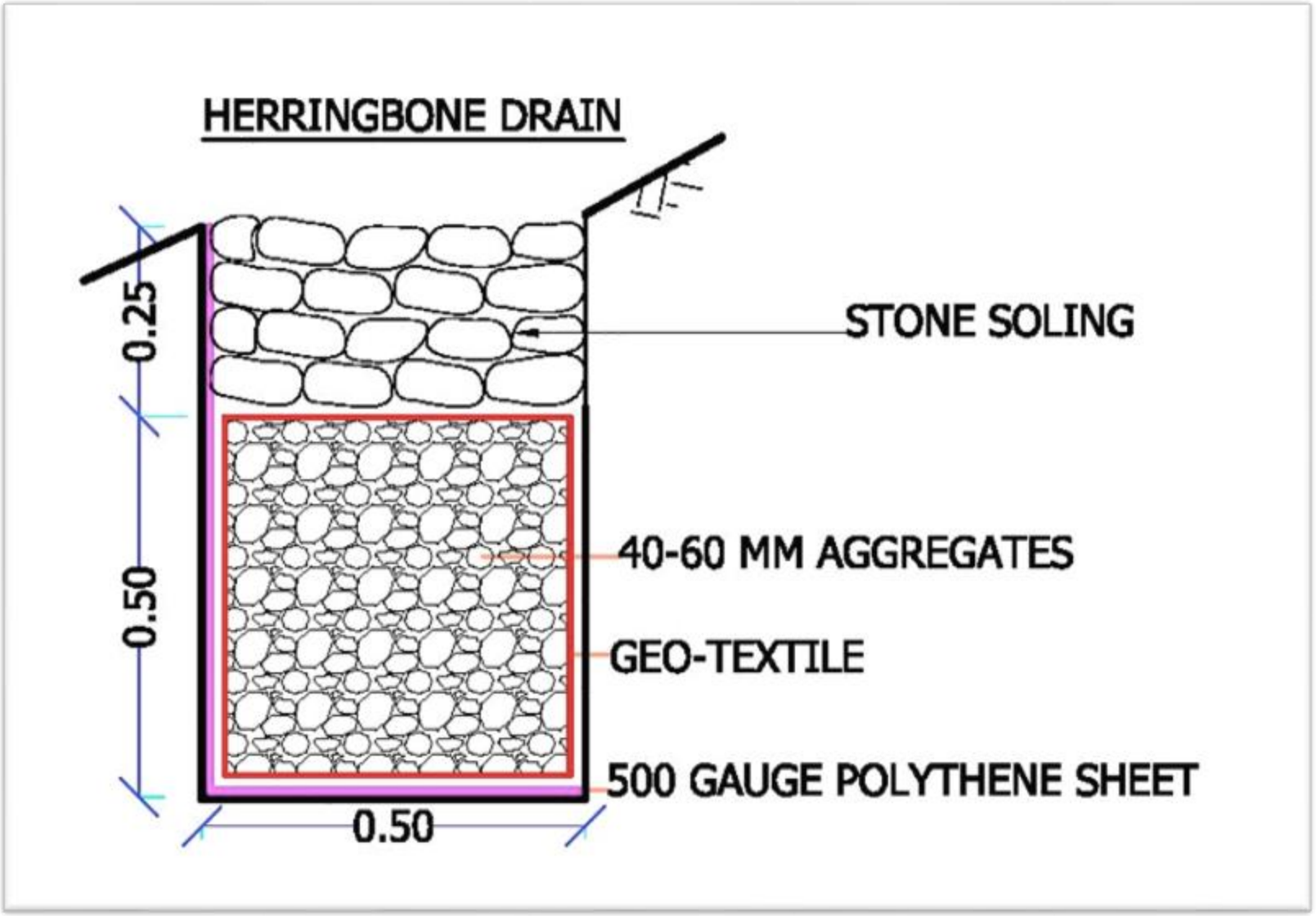
Small scale civil engineering structures



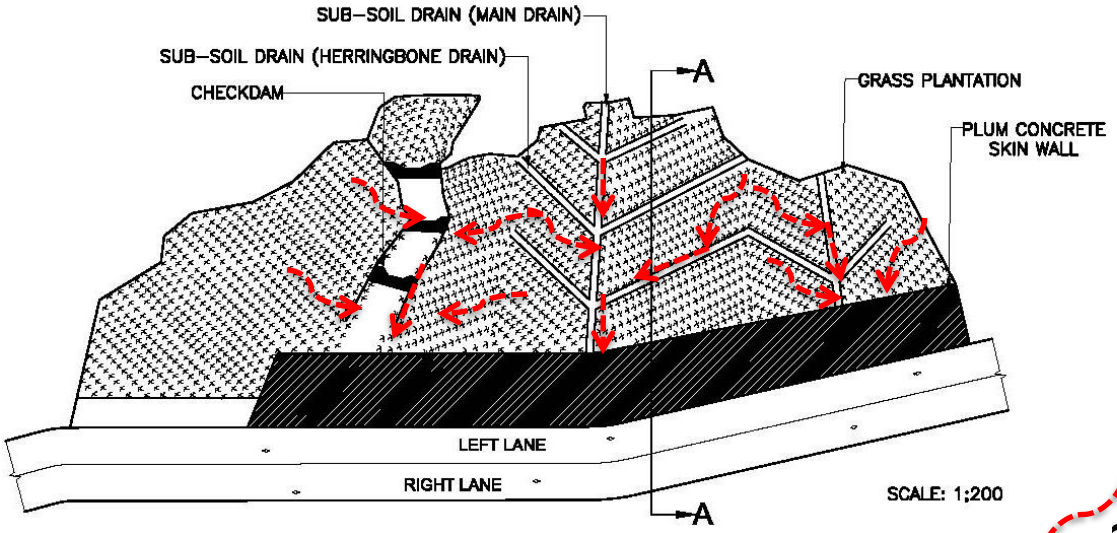
Sub-surface drain



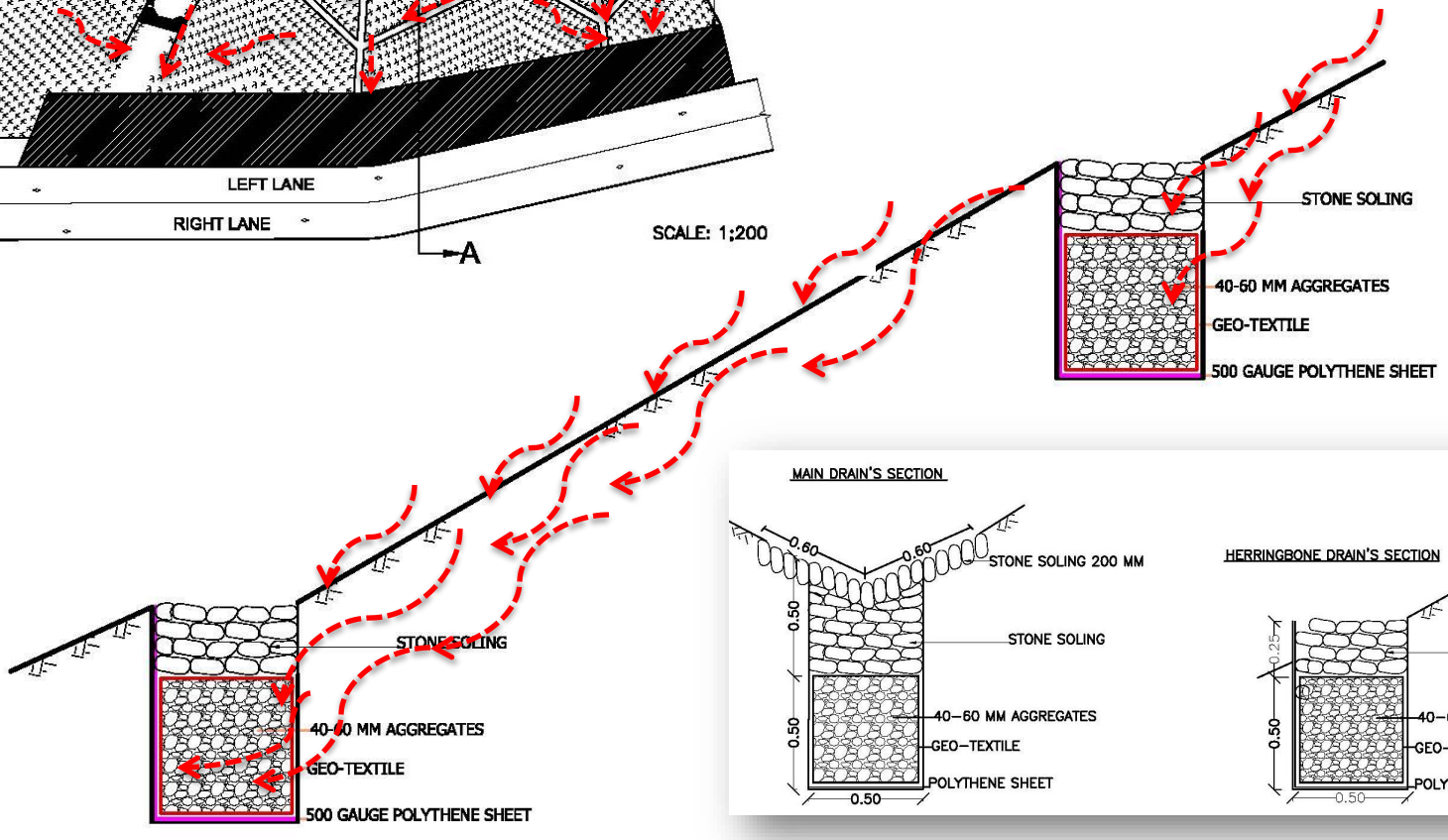
Sub-surface drain



ROADSIDE SLOPE PLAN AND PROPOSED BIO–ENGINEERING WORK



Herringbone drain



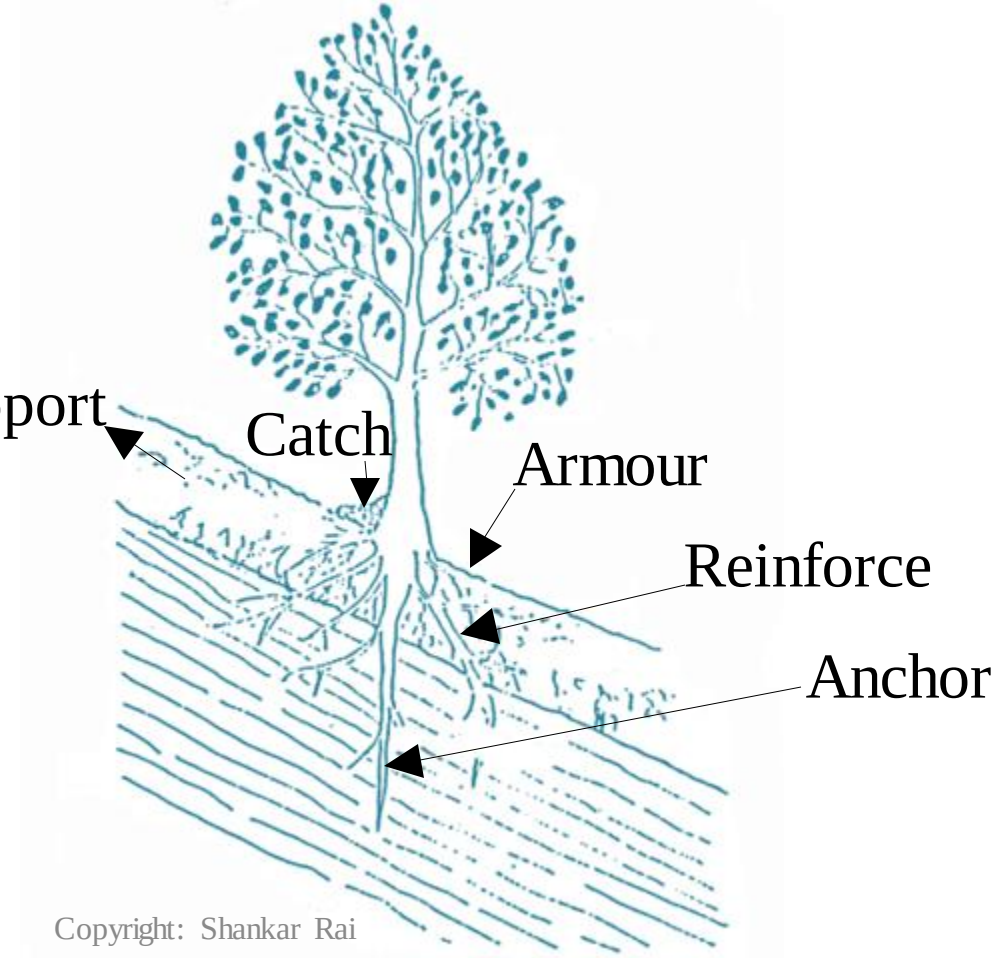
Engineering functions of bio-engineering systems

Engineering functions of civil engineering structures

1. Catch
2. Armour
3. Reinforce
4. Anchor
5. Support
6. Drain

Engineering functions of bio-engineering systems

Engineering functions of plants



Engineering functions of bio-engineering system

Plant has two further benefits too that are not supplied by civil engineering. These are :

- environmental improvement of the site: a cover of vegetation encourages other plants and animals to live on the slope: this makes it a nature-based solution;

- the rooting system of plants can interrupt the shear plane and stop it spreading further sideways in the current phase of active instability.

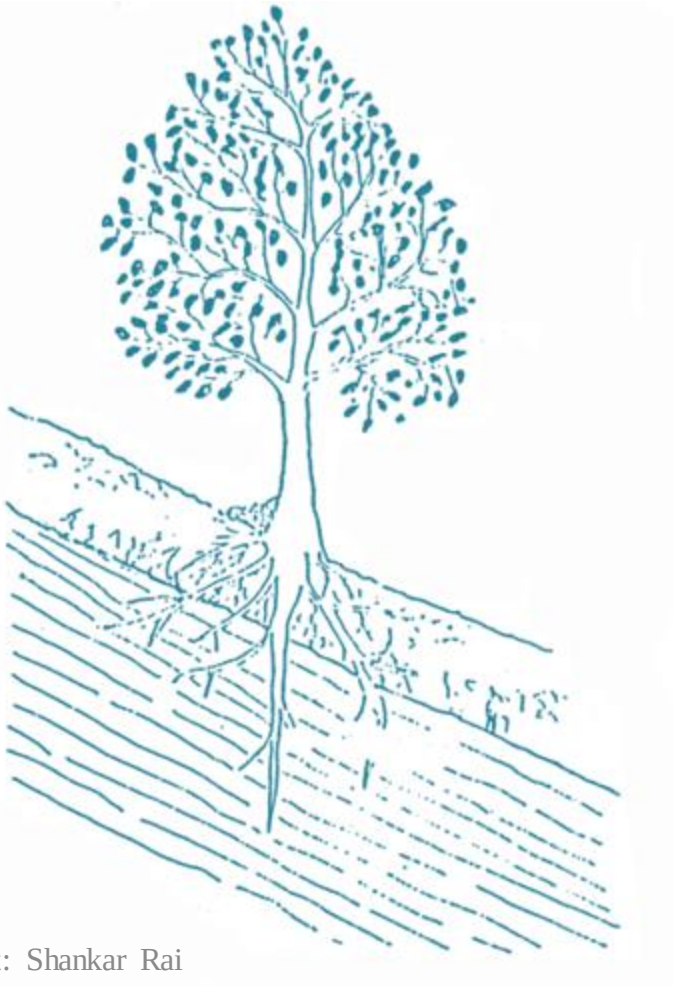
Engineering functions of bio-engineering system

Engineering functions

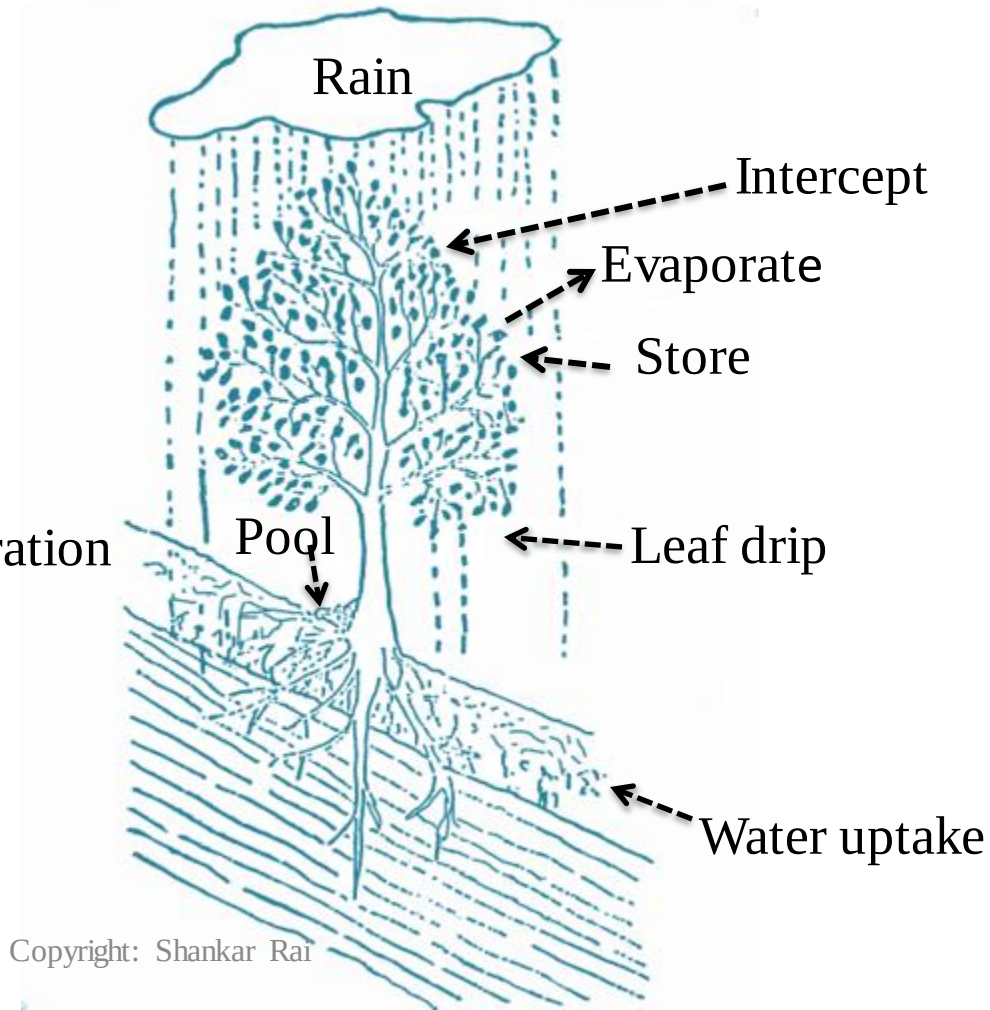
Engineering function	**Civil engineering system**	**Vegetative system**
Catch	Checkdam, Coir net	shrubs, bamboo (many stems);
Armour	Stone pitching, Revetment wall,	grass carpet (dense, fibrous roots);
Reinforce	Reinforced earth, soil nailing;	densely-rooting system
Anchor	Rock anchors, rock bolts	deeply-rooting trees
Support	Retaining wall, Prop wall	large trees
Drain	Lined drain, subsurface drain	plants are not currently used

Hydrological effects of plants

How plants affect rainwater on its way to the ground



Hydrological effects of plants



Mechanical effects of plants

Mechanical mechanisms	Effect
• Stems and trunks trap materials that are moving down the slope.	Positive
• Roots bind soil particles to the ground surface and reduce their susceptibility to erosion.	Positive
• Roots penetrating through the soil cause it to resist deformation.	Positive

Mechanical effects of plants

Mechanical mechanisms	Effect
• Some plants' woody roots may open the rock joints due to thickening as they grow.	Negative
• The root cylinder of trees holds up the slope above through buttressing and arching.	Positive
• Tap root or near vertical roots penetrate into the firmer stratum below and pin down the overlying materials.	Positive
• Vegetation exposed to wind transmits dynamic forces into the slope.	Negative

Hydrological effects of plants

Hydrological mechanisms	Effect
• Leaves intercept raindrops before they hit the ground.	Positive
• Water evaporates from the leaf surface.	Positive
• Water is stored in the canopy and stems.	Positive
• Large or localised water droplets fall from the leaves.	Negative

Hydrological effects of plants

Hydrological mechanisms	Effect
• Surface run-off is checked by stems and grass leaves.	Positive
• Stems and roots increase the roughness of the ground surface and the permeability of the soil.	Site dependent
• Roots extract moisture from the soil which is then released to the atmosphere through transpiration.	Weather-dependent effect

Session-6

Vegetative Structures and Design Aspects

Vegetative structures

Grass planting:

- Contour lines of grass planting
- Diagonal lines of grass planting
- Vertical lines of grass planting
- Chevron line of grass planting
- Random grass planting
- Grass seeding
- Sodding (Turfing)

Vegetative structures

- Brush layering
- Palisade
- Fascine
- Live checkdam
- Tree and shrub planting
- Bamboo planting

Vegetative structures

Grass planting

Contour lines

Diagonal lines

Vertical lines

Chevron

Grass seeding

Sodding

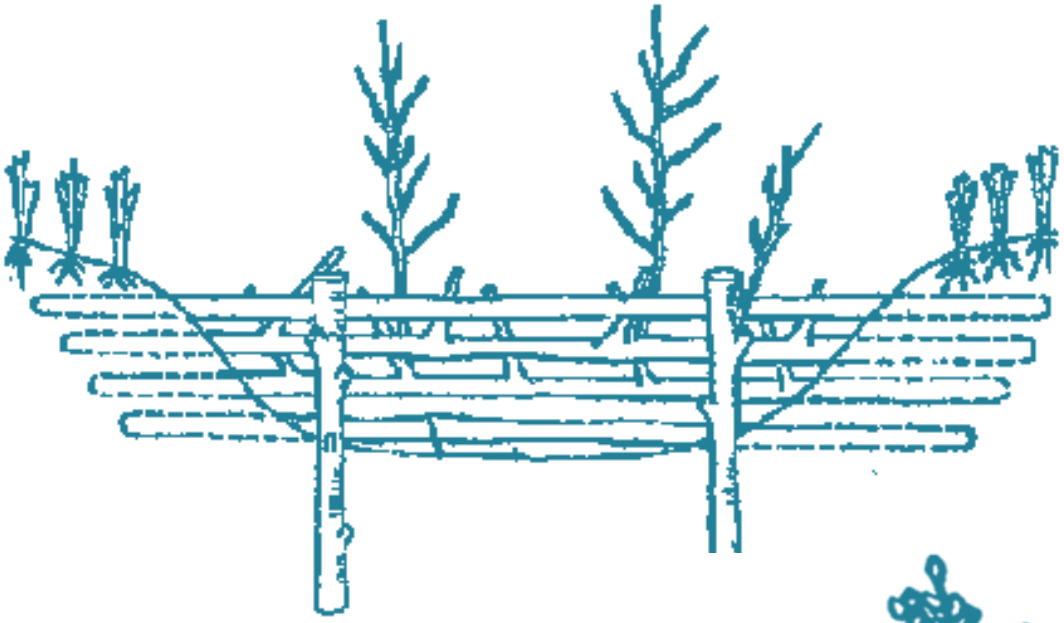
Vegetative structures

Fascines

Brushlayer

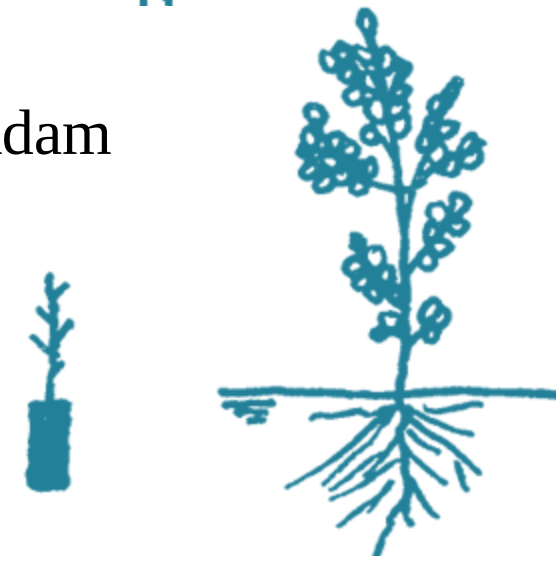
Palisade

Vegetative structures



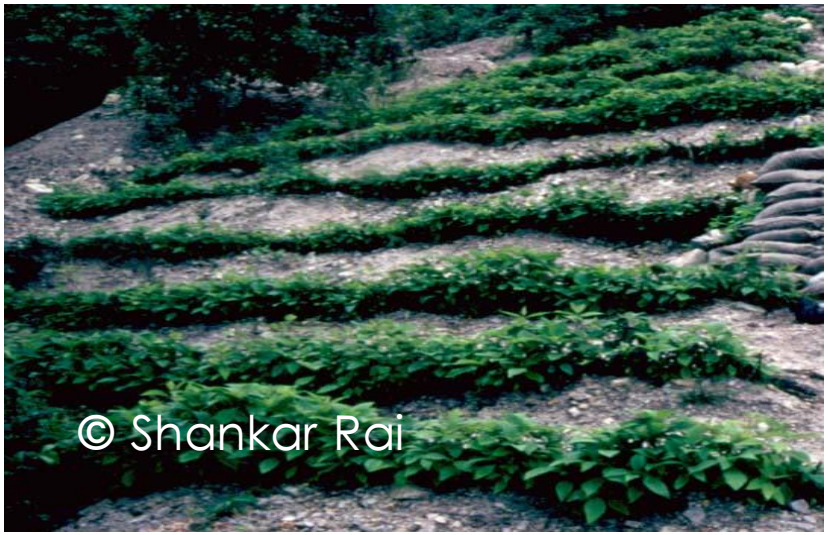
Live Checkdam

Bamboo planting



Tree and Shrub planting

Vegetative structures



Brushlayers

Live checkdams

Vegetative structures

Fascines

Palisades

Vegetative structures

Grass planting

Vegetative structures

Grass planting

Vegetative structures

Grass seeding

Design aspects of vegetative structures

System	Functions	Method of operation
Horizontal line grass planting	Catch, armour, reinforce	Dense lines retard surface water flow
Diagonal line grass planting	Armour, reinforce, catch	Dense lines guide water along the line
Grass seeding	Armour, Catch, reinforce	Dense grass, mat, rooting system

Design aspects of vegetative structures

System	Functions	Method of operation
Palisades	Catch, reinforce	Dense lines above and below the ground retard surface and shallow water flow
Brush layering	Catch, reinforce	Dense lines, strong buried branches retard surface and shallow ground water flow
Fascines	Catch, support, drain	Woody bundles, dense stems, porous, can drain soil if laid down slope

Design aspects of vegetative structures

System	Functions	Method of operation
Shrub planting	Catch, armour, reinforce, anchor	Bunchy leaves, multiple stems, lateral roots, tap roots
Tree planting	Support, reinforce, anchor	Lateral and near vertical rooting systems, root cylinder
Bamboo planting	Catch, armour, reinforce, support	Dense poles, massive rooting systems, dense leaves, grows all year

Vegetative structures and design aspects

Effect of vegetative structure

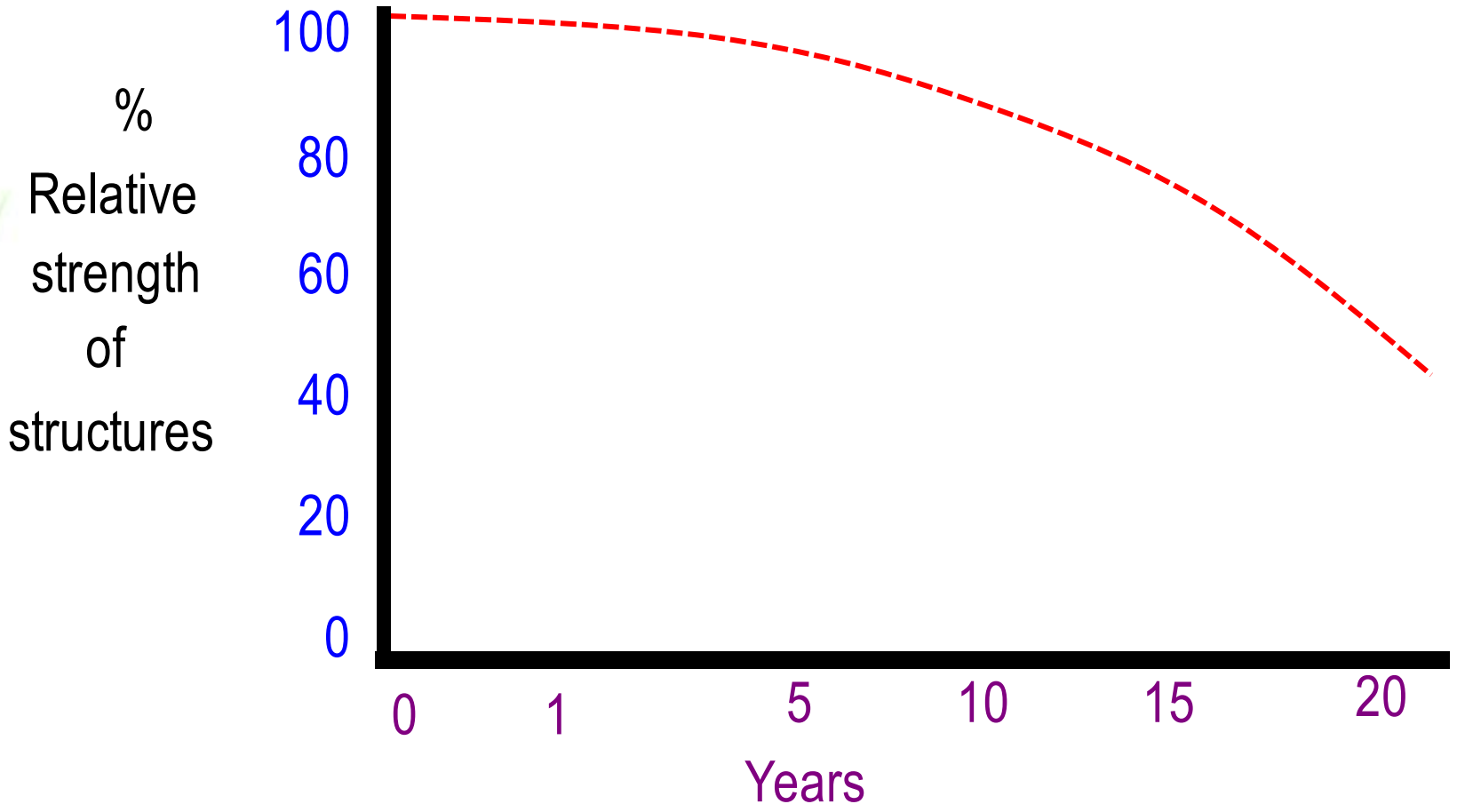
- immediate and longer term effect:

  Fascines, palisades and brush layering and live checkdams

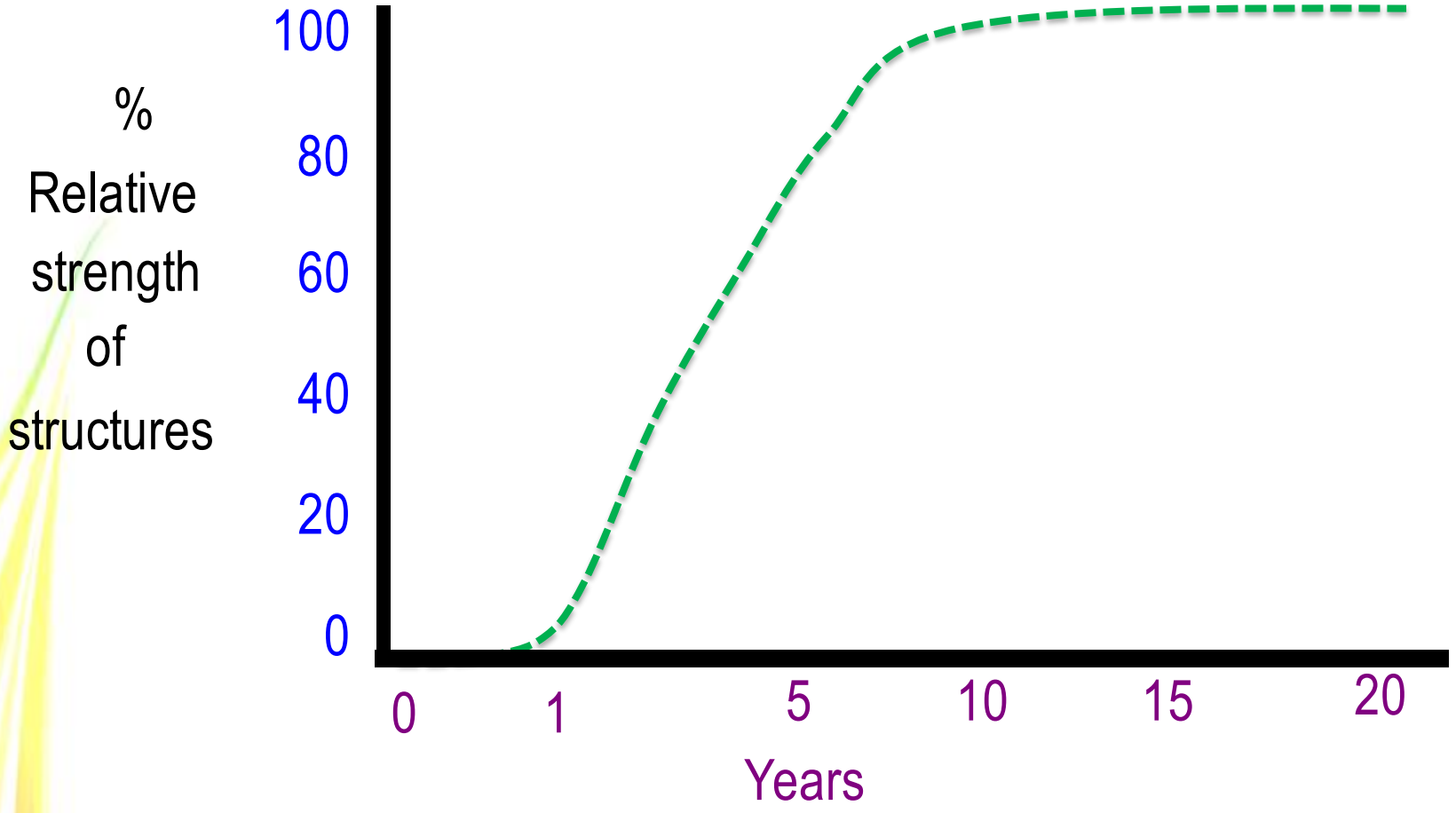
- longer term effect:

  Grass seeding and planting, tree and shrub planting.

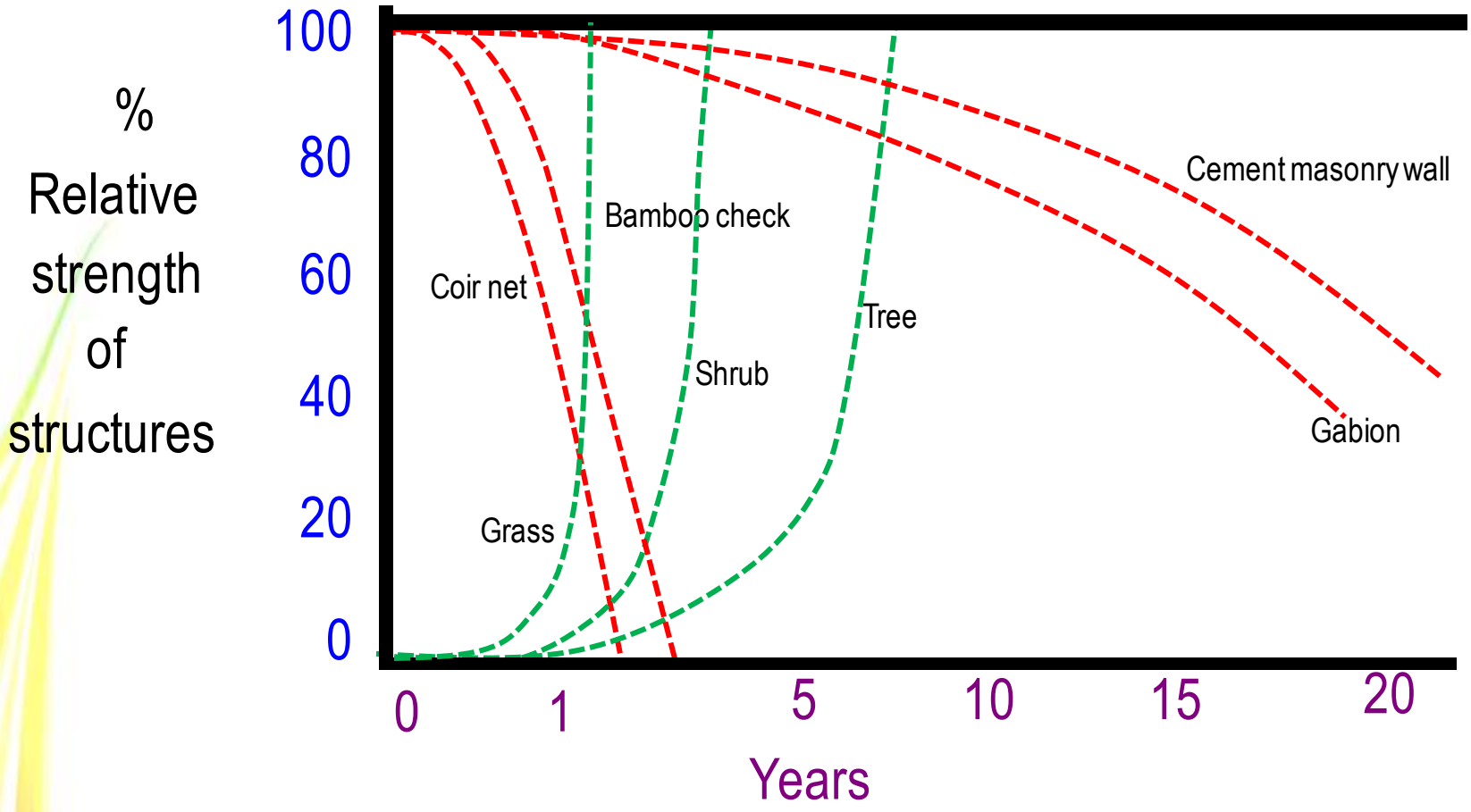
Life span and relative strength of civil engineering structures



Life span and relative strength of plants



Interaction between plant and civil engineering structure



Physical relationships between civil and vegetative engineering structures

- Toe wall below bamboo :

structure protects plant;

- Plants around end of toe wall :

plant protects structure;

Physical relationships between civil and vegetative engineering structures

- Trees above toe wall

plant improves performance of structure;

- Coir netting with grass plantation

plant replaces structure; (takeover and handover)

Compatibility of engineering structures

Civil engineering structure	Engineering function	Vegetative structure	Engineering function	Compatibility
Coir/jute netting	Catch	Tree planting	Support	No
Coir/jute netting	Catch	Shrub planting	Catch	No
Coir/jute netting	Catch	Grass planting	Catch	Yes

Session-7

Selection of Bio-engineering Techniques

Selection of Bio-engineering Techniques

Site assessment

Site Assessment Procedure Stages		Action
Stage 1	Location: Km. ..... - Above road - Below road - Through road (slide is above and below road) - Off road alignment but within responsibility	Observe and note
Stage 2	Type of failure : - Sheet erosion - Rill erosion - Gully erosion - Translation slide - Rotational slide, - Debris flow	Describe

Site assessment procedure

Site Assessment Procedure Stages		Action
Stage 3	Examine initial cause of failure - Surface water, - Ground water, - Under cutting, - Weathering, - Additional load	Describe
Stage 4	Failure depth - less than 25 mm. - 25-100 mm. - 100-250 mm. - 250-1000 mm. - More than 1000 mm.	Describe

Site assessment procedure

Site Assessment Procedure Stages		Action
Stage 5	**Draw plan and profile of site** - Illustrate the landslide zones	Draw, and note
Stage 6	**Dimension of site** - Length - Breadth - Slope angle - Aspect - Altitude of site	Measure and note

Site assessment procedure

Site Assessment Procedure Stages		Action
Stage 7	Material formation of slope • Alluvium debris - Unconsolidated debris - Consolidated debris • Colluvium debris - Unconsolidated debris - Consolidated debris • Residual soil, • Rock (Hard or Soft rock) • Alternating hard and soft rock	Describe

Site assessment procedure

<table>
<tr><th colspan="3">Site Assessment Procedure Stages</th><th>Action</th></tr>
<tr><td rowspan="3">Stage 8</td><td colspan="2">Rock orientation, weathering grade and degree of fracture</td><td rowspan="3">Measure and Note</td></tr>
<tr><td>Weathering grade and</td><td>Degree of fracture</td></tr>
<tr><td>Fresh
Faintly weathered
Slightly weathered
Moderately weathered
Highly weathered
Completely weathered</td><td>Fresh
Fractured
Highly fractured</td></tr>
</table>

Site assessment procedure

<table>
<tr><th colspan="3">Site Assessment Procedure Stages</th><th>Action</th></tr>
<tr><td>Stage 9</td><td colspan="2">Divide the slope into the segment</td><td>Draw and describe</td></tr>
<tr><td>Stage 10</td><td colspan="2">Examine cause and mechanism of failure of each segment</td><td>Describe</td></tr>
<tr><td rowspan="3">Stage 11</td><td colspan="2">Material drainage and moisture of each segment</td><td rowspan="3">Describe</td></tr>
<tr><td>Material drainage</td><td>Moisture</td></tr>
<tr><td>Well drain
poor drain</td><td>Dry
Wet
Spring
Seepage flow
Active seepage flow
Monsoon saturation</td></tr>
</table>

Site assessment procedure

Site Assessment Procedure Stages		Action
Stage 12	History of slide • Not moved within last 5 years • Moved this year for the first time • Moved within the last 5 years but not this year • Moves every year by initial mechanism - diminishing • Moves every year by initial mechanism – constant or getting worse	Describe

Site assessment procedure

Site Assessment Procedure Stages		Action
Stage 13	Life progression of slide • Stable slope formed or will stabilize naturally • Further movement expected, by less serious mechanism (post-slide adjustment) • Repeated movement expected by initial mechanism or another equally serious	Describe

Site assessment procedure

Site Assessment Procedure Stages		Action
Stage 14	Determine required engineering functions of each segments to stabilise the site • Catch • Armour • Reinforce • Anchor • Support • Drain	Describe

Site assessment procedure

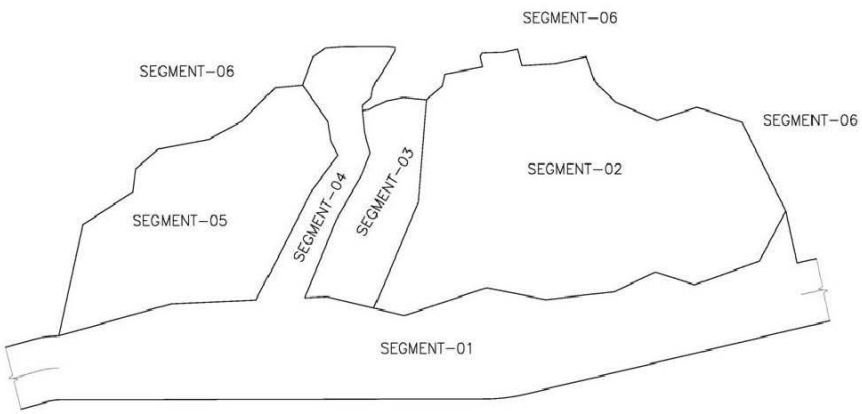
Site Assessment Procedure Stages		Action
Stage 15	Annual rainfall of site or region	Note
Stage 16	Land use pattern	Describe
Stage 17	Existing structures if any	Draw and describe
Stage 18	Surrounding vegetation – Trees – Shrubs – Grasses – Bamboo	Note

Site assessment procedure

Example of site assessment

1.	Location : Km. 9+300 above the road (Hillside)
2.	Type of failure : Translational failure
3	Initial cause of failure : Road undercutting
4.	Failure depth : 250-1000 mm
5	Dimension of slide : L =35m B= 60m
6	Slope angle : 35°-55° 7 Aspect : S/E
8	Altitude 1230m 9 Rainfall : 1050mm
10	Material : Colluvium debris (Unconsolidated)

Site assessment procedure

<table>
<tr><td colspan="3"> 
</td><td colspan="3">11 Cause and mechanism of failure</td></tr>
<tr><td colspan="3"></td><td colspan="3">Segment-01 : Road covered by debris</td></tr>
<tr><td colspan="3"></td><td>Segment-02 :</td><td>Cause: Surface and sub-surface water</td></tr>
<tr><td colspan="3"></td><td></td><td>Mechanism: Slumping</td></tr>
<tr><td colspan="3"></td><td>Segment-03 :</td><td>Cause: Surface water</td></tr>
<tr><td colspan="3"></td><td></td><td>Mechanism: Sheet and rill erosion</td></tr>
<tr><td>Segment -04 :</td><td colspan="2">Cause: Surface water</td><td>Segment-05 :</td><td>Cause: Surface water</td></tr>
<tr><td></td><td colspan="2">Mechanism: Gully erosion</td><td></td><td>Mechanism: Sheet and rill erosion</td></tr>
</table>

Site assessment procedure

Engineering function requirement for slope stabilization

Segment-01

- Support

Segment-02

- Drain (Surface+Sub-surface water)
- Armour
- Reinforce
- Catch

Site assessment procedure

Engineering function requirement for slope stabilization

Segment-03

- Armour
- Catch
- Reinforce

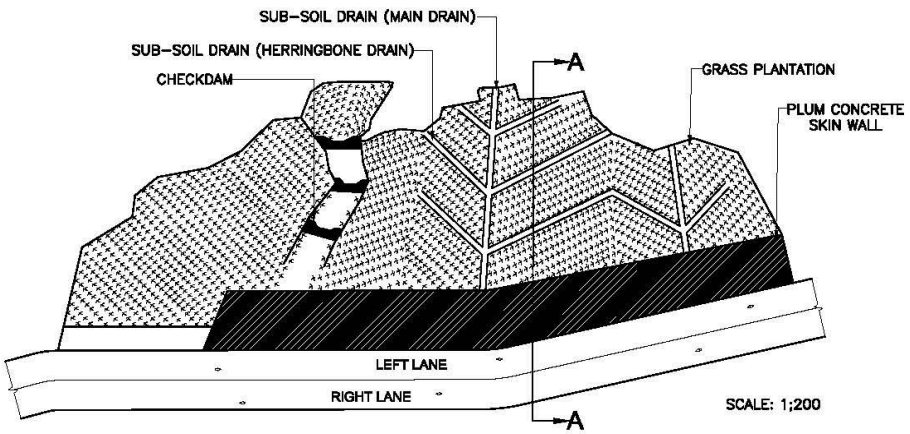
Segment-04

- Catch
- Armour
- Reinforce

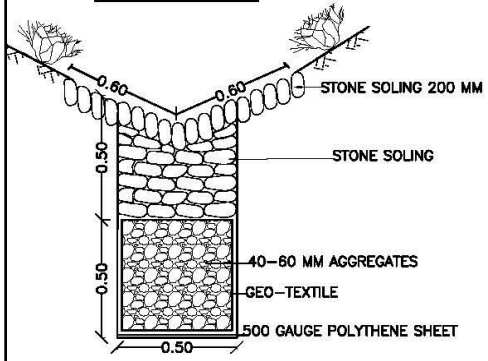
Segment-05

- Armour
- Catch
- Reinforce

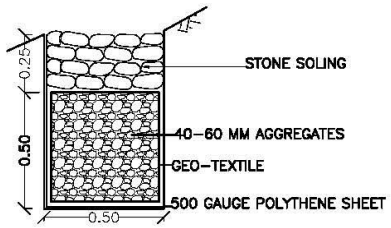
ROADSIDE SLOPE PLAN AND PROPOSED BIO–ENGINEERING WORK



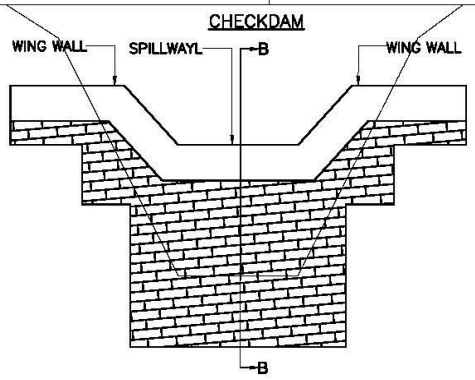
MAIN DRAIN'S SECTION



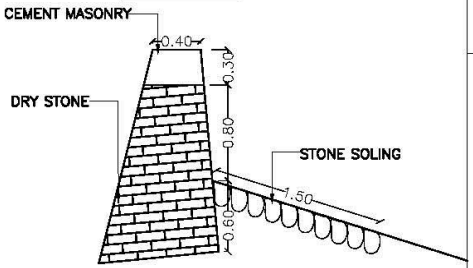
HERRINGBONE DRAIN'S SECTION



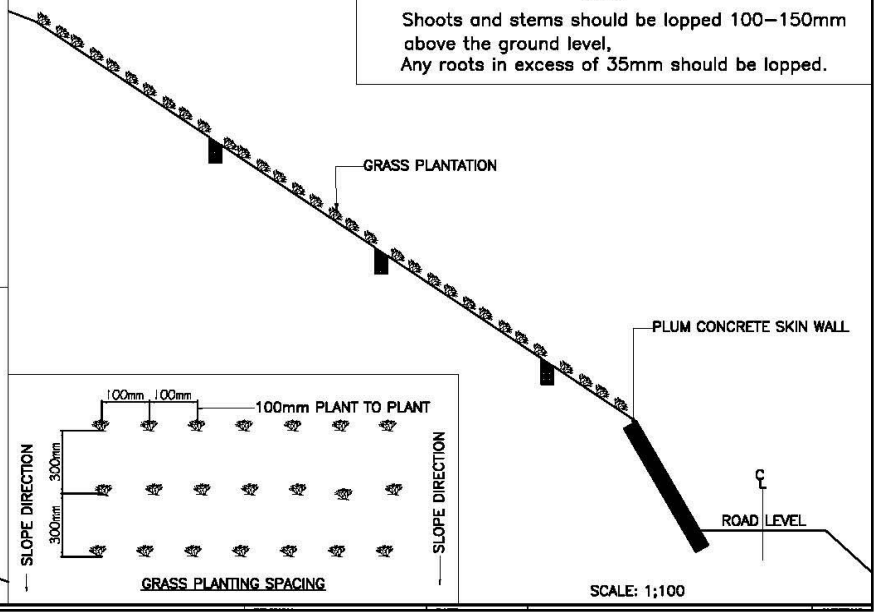
CHECKDAM



SECTION B–B



SECTION: A–A



GRASS SLIPS

Note:

Shoots and stems should be lopped 100–150mm above the ground level,
Any roots in excess of 35mm should be lopped.

Selection of bio-engineering technique

- Slope Angle
- Slope Length
- Material Drainage /Site Moisture
- Previous and Potential Problem
- Requirement of Engineering Functions

Selection of bio-engineering technique

Slope Angle	Slope Length	Material Drainage	Site Moisture	Previous/ Potential Problems	Functions Required	Technique(S)
> 45°	> 15 metres	Good	Damp	Erosion, slumping	Armour, reinforce	Diagonal grass lines
			Dry	Erosion	Armour, reinforce	Contour grass lines, jute/coir netting and grass planting
		Poor	Damp	Slumping, erosion	Drain, armour, reinforce	Rill and ridge formation and stone pitching on rills, chevron grass lines,
			Dry	Erosion, slumping	Armour, reinforce	Diagonal grass lines

Selection of bio-engineering technique

Slope Angle	Slope Length	Material Drainage	Site Moisture	Previous/ Potential Problems	Functions Required	Technique(S)
> 45°	< 15 metres	Good	Any	Erosion	Armour, reinforce	Diagonal grass lines or Jute/coir netting and randomly planted grass
		Poor	Damp	Slumping, erosion	Drain, armour, reinforce	Down slope grass lines or Diagonal grass lines or Rill and ridge formation and stone pitching on rills, chevron grass lines,
			Dry	Erosion, slumping	Armour, reinforce, drain	Jute/coir netting and randomly planted grass or Contour grass lines or Diagonal grass lines

Selection of bio-engineering technique

Slope Angle	Slope Length	Material Drainage	Site Moisture	Previous/ Potential Problems	Functions Required	Technique(S)
30°-45°	> 15 metres	Good	Any	Erosion	Armour, reinforce, catch	Horizontal bolster cylinders or Brushlayer and shrub planting/ Diagonal/Contour grass lines and vegetated stone pitched rills or Grass seeding with mulch and wide mesh jute/coir netting.
		Poor	Any	Slumping, erosion	Drain, armour, reinforce	Herringbone sub-soil drain and diagonal grass lines, shrub planting or Herringbone sub-soil drain and shrub planting grass seeding, mulch

Selection of bio-engineering technique

Slope Angle	Slope Length	Material Drainage	Site Moisture	Previous/ Potential Problems	Functions Required	Technique(S)
30°-45°	< 15 metres	Good	Any	Erosion	Armour, reinforce, catch	Brushlayer of hardwood cuttings or Contour grass lines or Contour fascines or Palisade of hardwood cuttings and grass seeding and cover with mulch.
		Poor	Any	Slumping, erosion	Drain, armour, reinforce	Herringbone sub-soil drain and diagonal grass lines, brushlayer, or shrub planting and grass seeding and cover with mulch or Herringbone fascines and shrub planting and grass planting or seeding with mulch

Selection of bio-engineering technique

Slope Angle	Slope Length	Material Drainage	Site Moisture	Previous/ Potential Problems	Functions Required	Technique(S)
<30°	Any	Good	Any	Erosion	Armour, catch	Site seeding of grass and shrub/tree planting or Shrub/tree planting
		Poor	Any	Slumping, erosion	Drain, armour, catch	Herringbone sub-soil drain, diagonal grass lines and shrub/tree planting or Herringbone sub-soil drain, shrub/tree planting and grass seeding with mulch
	< 15 metres	Any		Erosion	Armour, catch	Sodding and shrub/tree planting
	Base of any slope			Planar sliding or shear failure	Support, anchor, catch	Large bamboo planting or Large tree planting

Selection of bio-engineering technique

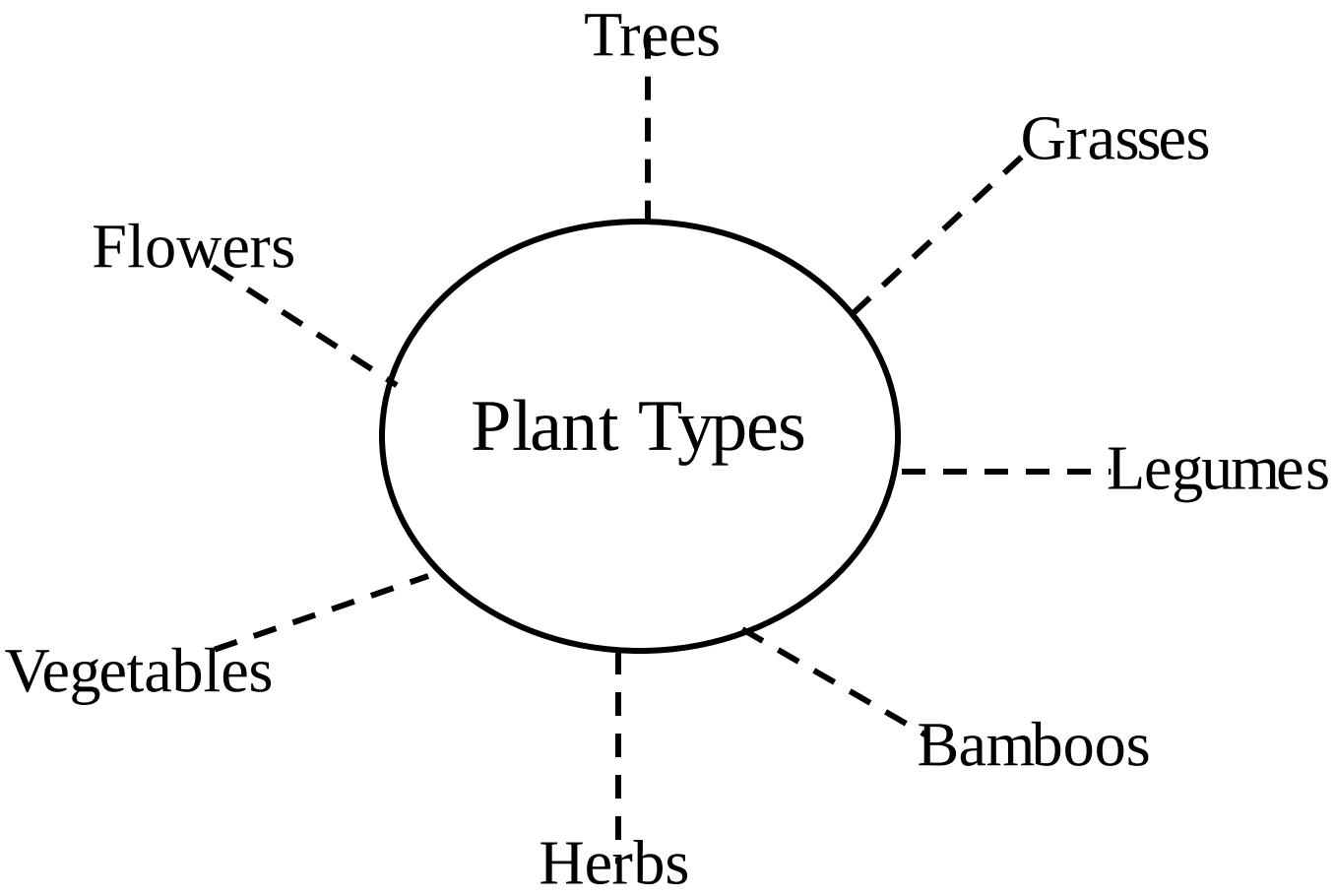
Gullies ≤45°	**Any gully**		Erosion	Catch, armour, reinforce	Large bamboo planting or Live check dam or Vegetated stone pitching
Special conditions					
>30°	Any	Any rocky material	Debris fall	Reinforce, anchor	Site seeding of shrubs/small trees
Any loose sand		Good	Any	Erosion	Armour, catch	Jute/coir netting and randomly planted grass
Any red soil		Poor	Any	Erosion, slumping	Armour, drain	Rill and ridge formation and stone pitching on rills, diagonal/chevron grass lines, shrubs/trees planting

Session-08

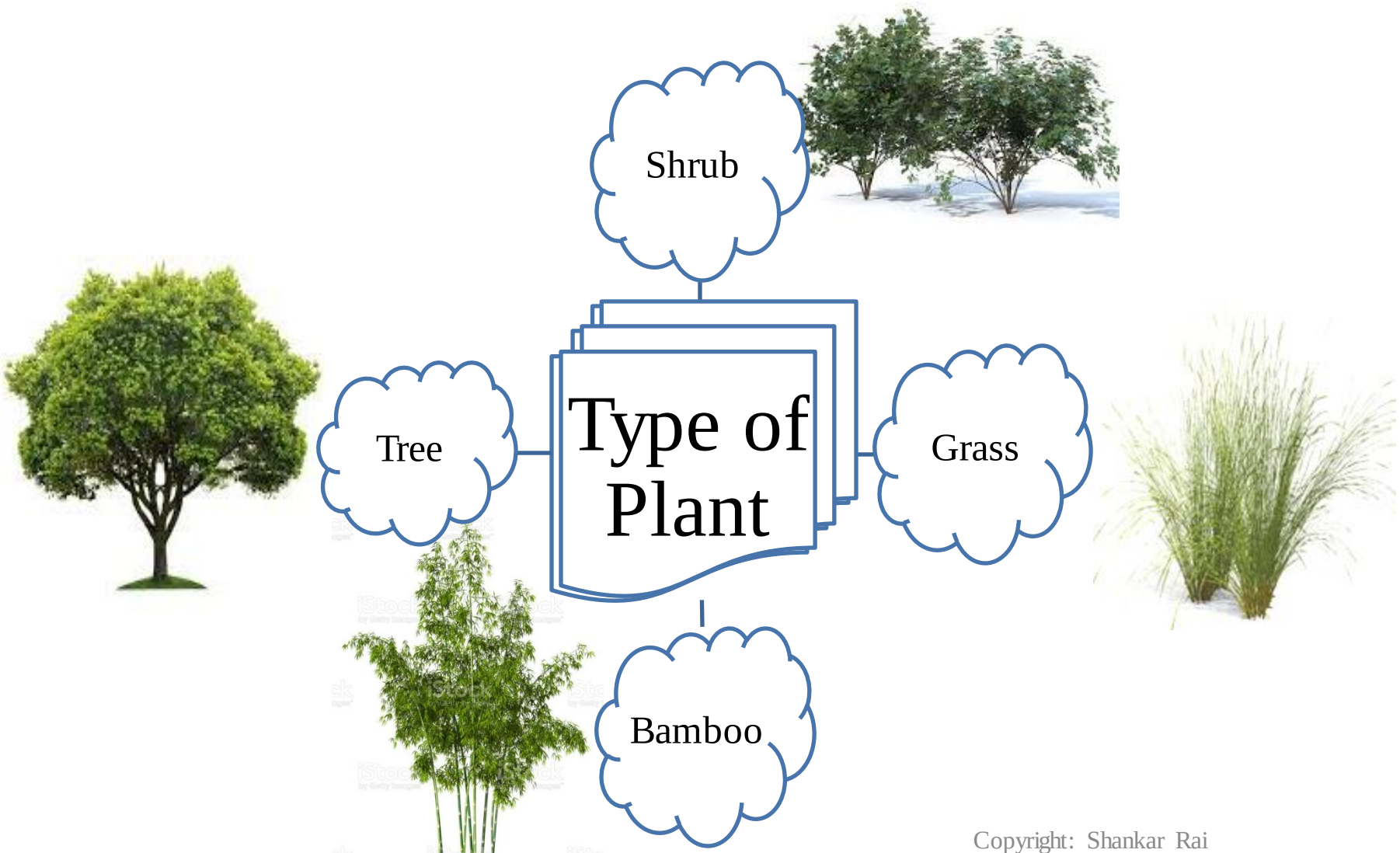
Selection of Plant Species for Bio-engineering

Selection of plant species for bio-engineering

General plant types



General plant types for bio-engineering



General plant types for bio-engineering

1. Woody

- Trees
- Shrubs
- Bamboos



2. Non- woody

- Grass
  - Clumping grass
  - Matting grasses


Performance of different types of plants in bio-engineering

Engineering functions	Woody			Non-woody	
	Trees	Shrubs	Bamboos	Clumping grasses	Matting grasses
Catch					
Armour					
Reinforce					
Anchor					
Support					

*** Excellent * Good

** Very good - No good at all

Performance of different types of plants in bio-engineering

Engineering functions	Woody			Non-woody	
	Trees	Shrubs	Bamboos	Clumping grasses	Matting grasses
Catch	*	***	***	**	*
Armour	*	*	**	**	***
Reinforce	***	***	***	*	-
Anchor	***	**	-	-	-
Support	***	*	***	-	-

*** Excellent * Good

** Very good - No good at all

Performance of different types of plants in bio-engineering

Hydrological effects	Woody			Non-woody	
	Trees	Shrubs	Bamboos	Clumping grasses	Matting grasses
Intercept					
Evaporate					
Store					
Leaf drip					
Retard					
Infiltrate					

*** Excellent * Good

** Very good - No good at all

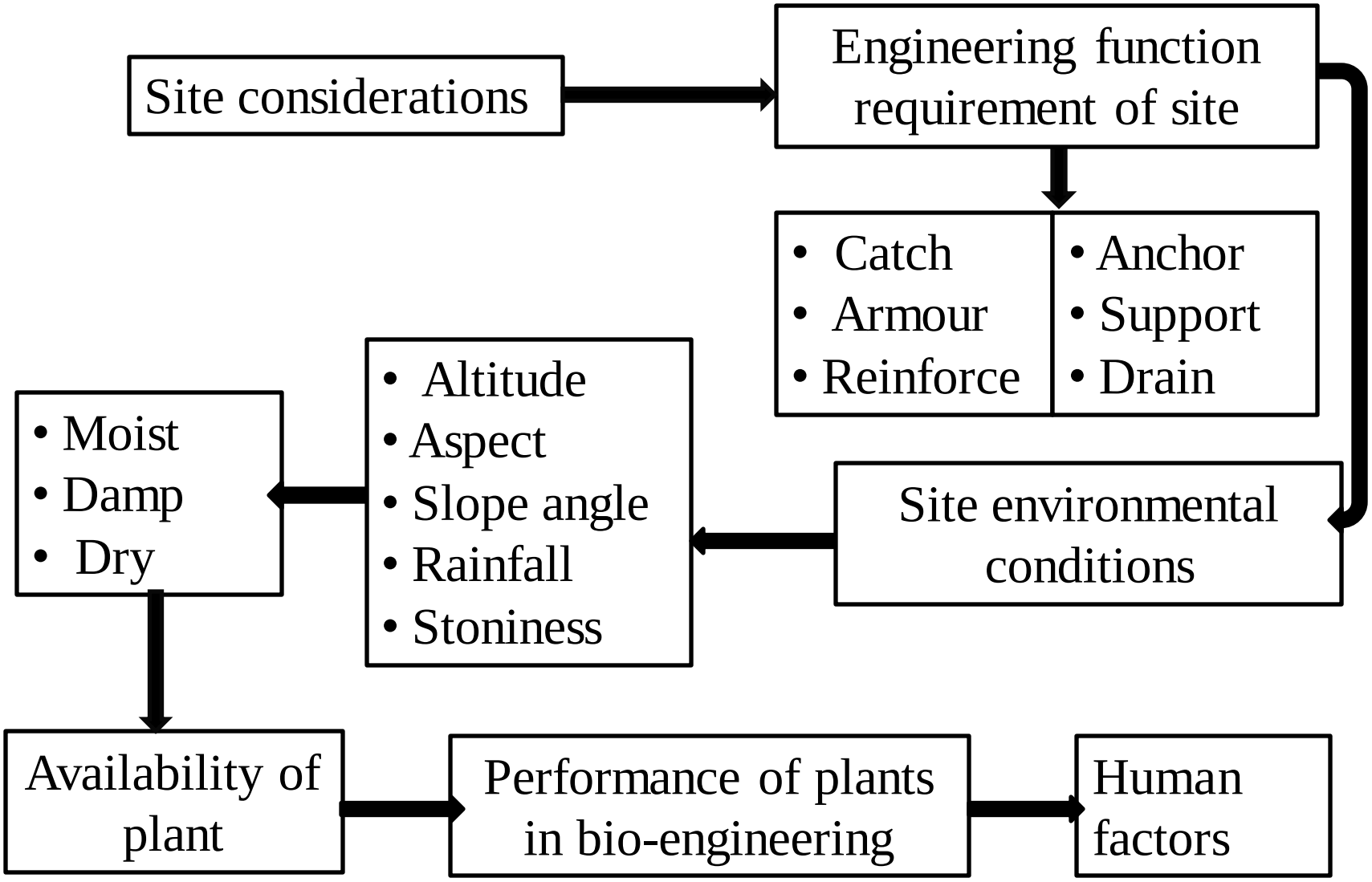
Performance of different types of plants in bio-engineering

Hydrological effects	Woody			Non-woody	
	Trees	Shrubs	Bamboos	Clumping grasses	Matting grasses
Intercept	**	**	***	***	**
Evaporate	***	**	***	*	*
Store	**	**	***	**	-
Leaf drip	***	**	*	-	-
Retard	*	**	**	**	***
Infiltrate	***	***	***	***	***

*** Excellent * Good

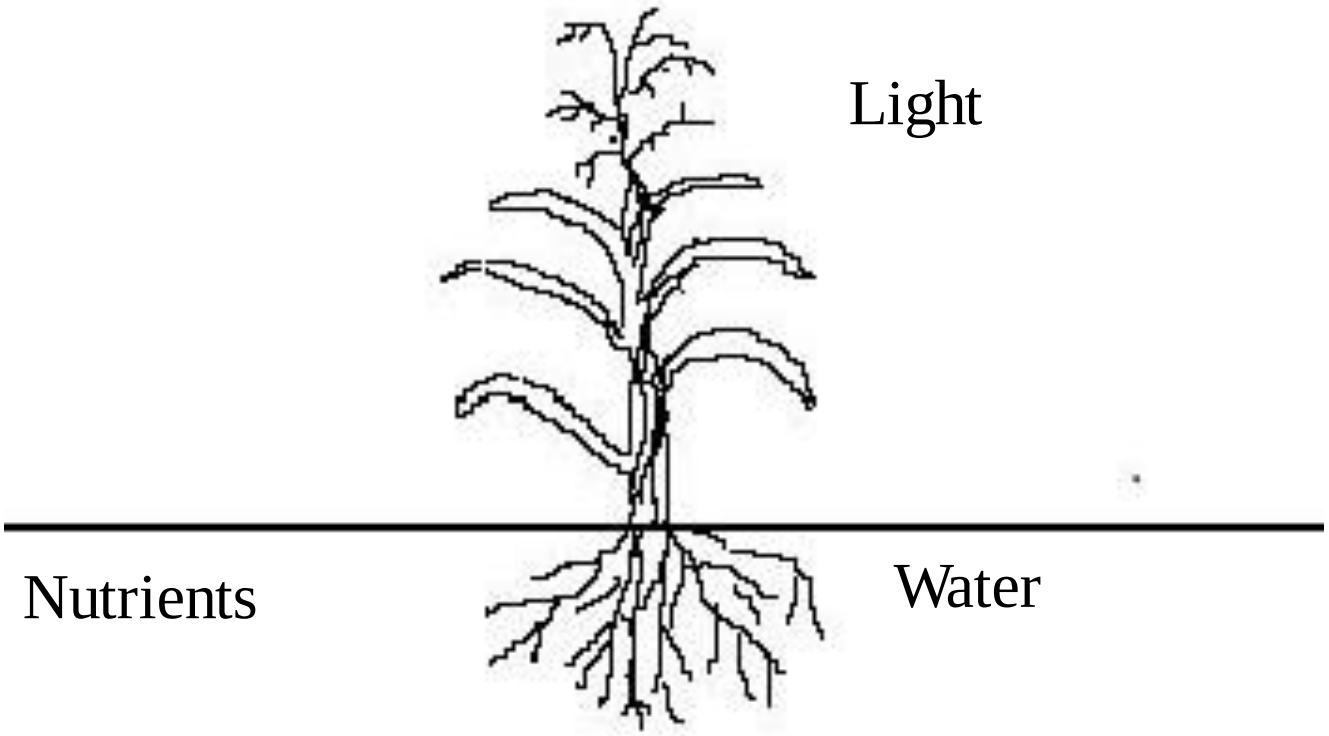
** Very good - No good at all

Selection of plants for bio-engineering



Selection of plants for bio-engineering

Competition of plants

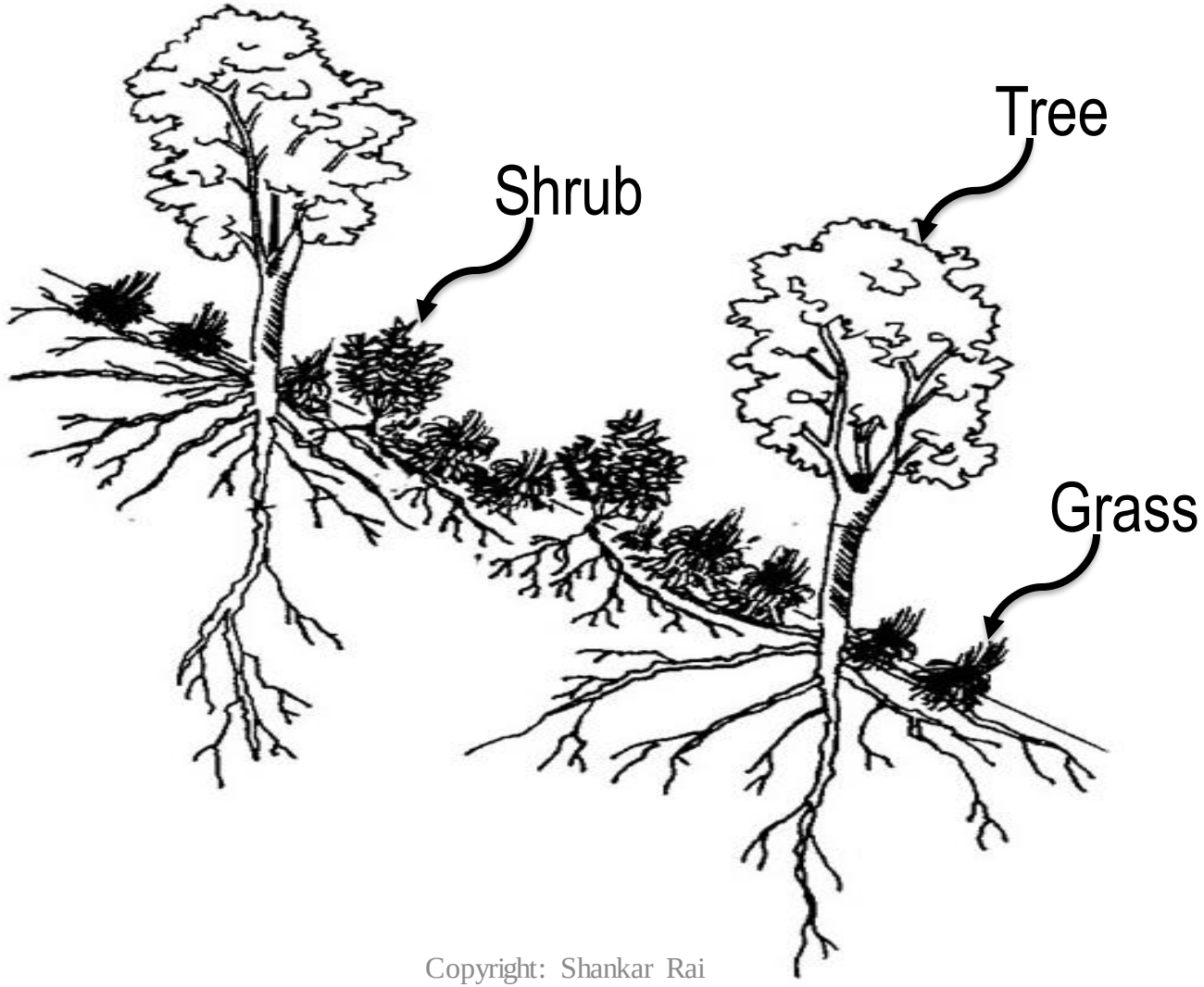


Plant community for bio-engineering

Plant community

An established group of plants living more-or-less in balance with each other and their environment. The group can be natural or managed.

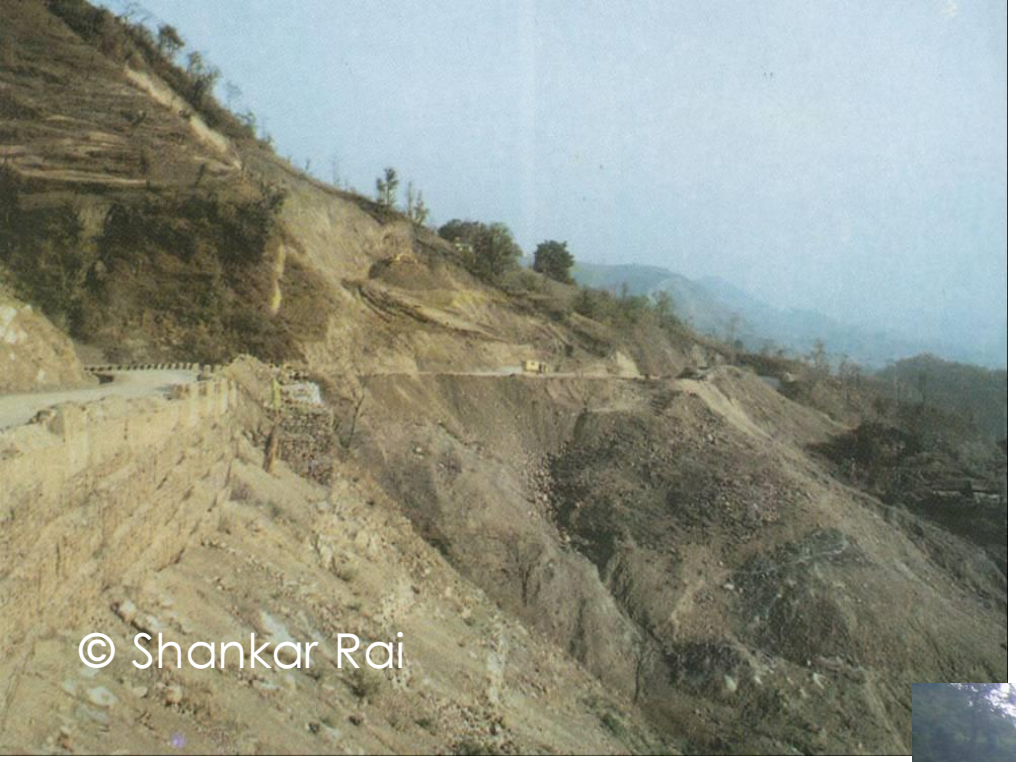
Plant community for bio-engineering

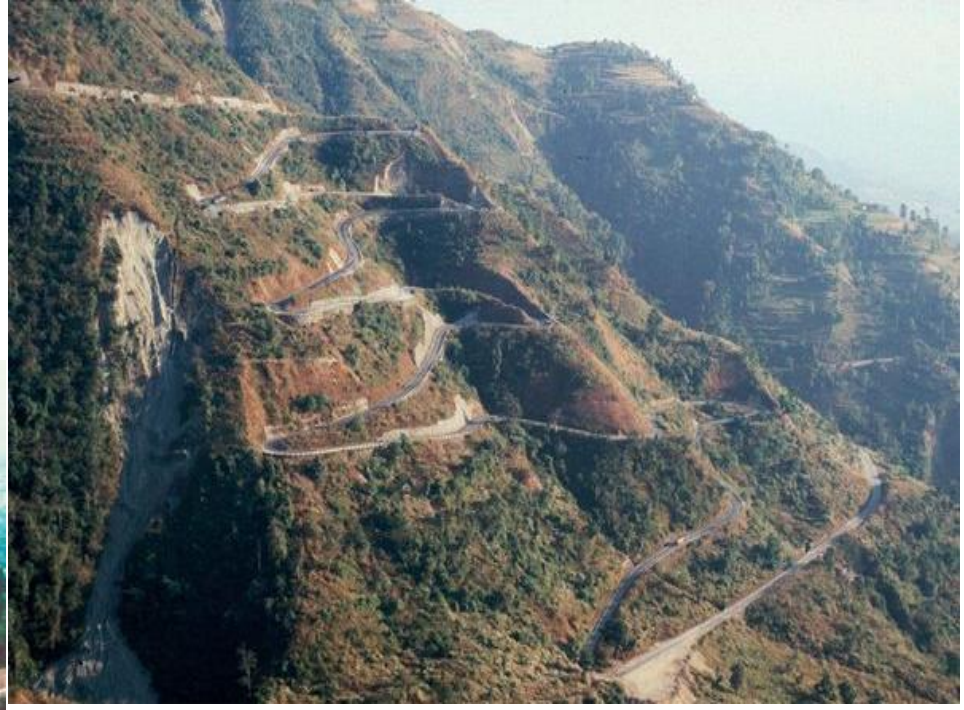


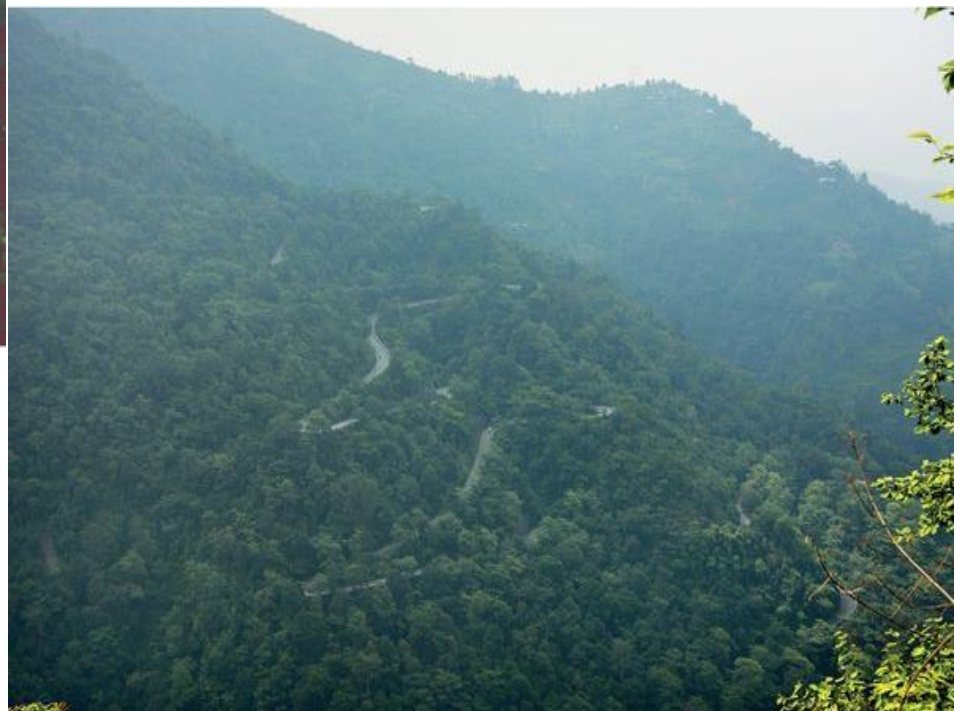

BREAK
TIME

Session-9

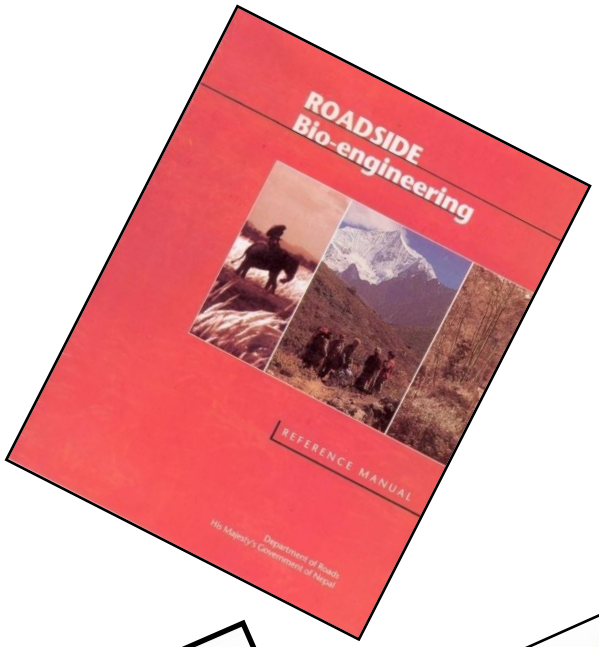
Bio-engineering Works for Slope Protection

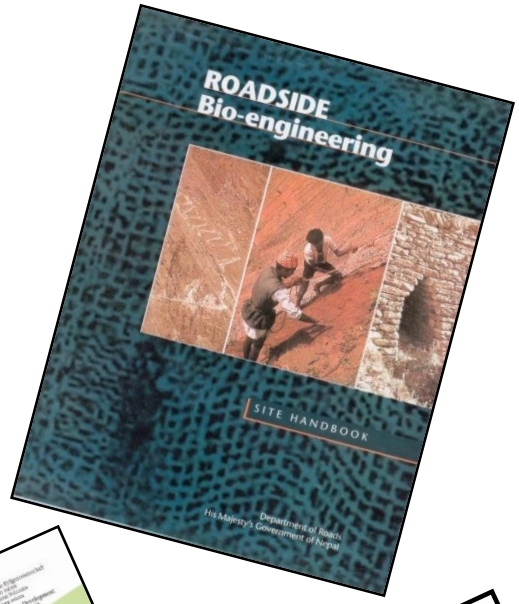


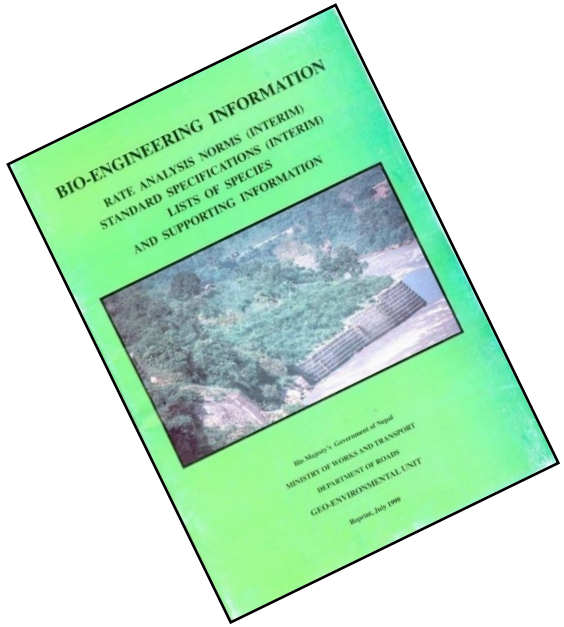


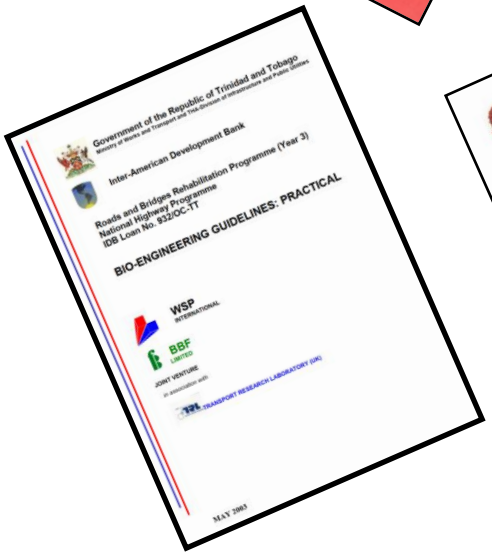


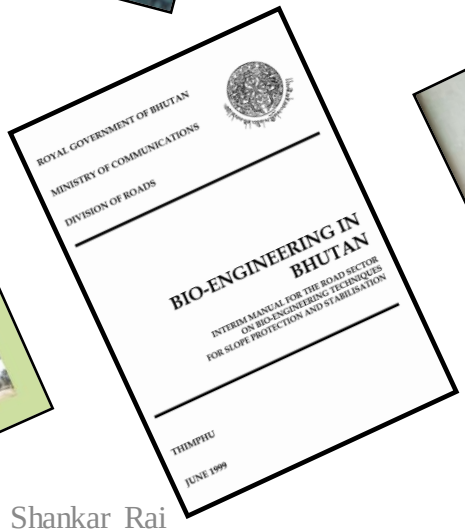
Manuals and guidelines





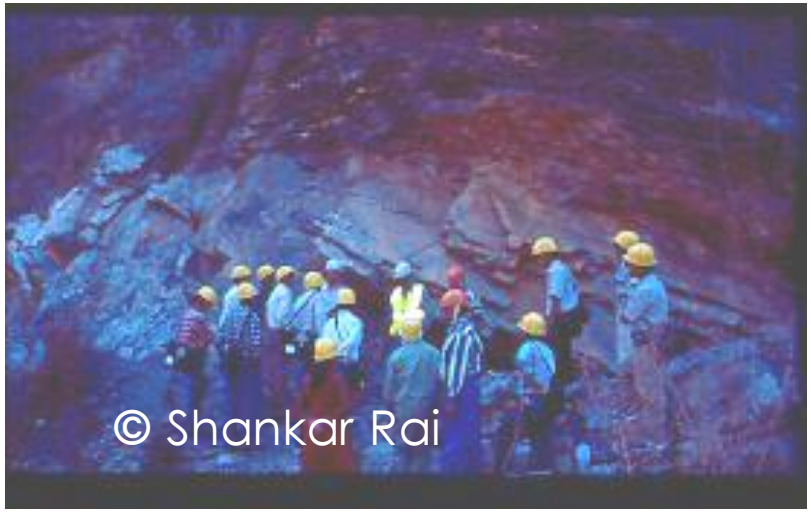






Training

Training



Timor-Leste

Training

DEMOSTRATION TO SUPERVISION TEAM AND CONTRACTOR AT SITE

DEMOSTRATION TO SUPERVISION TEAM AND CONTRACTOR AT SITE

REPÚBLICA DEMOCRÁTICA DE TIMOR LESTE

MINISTÉRIO DAS OBRAS PÚBLICAS, TRANSPORTES E COMUNICAÇÕES

DIRECTORATE GENERAL FOR PUBLIC WORKS

NATIONAL DIRECTORATE FOR ROADS, BRIDGES AND FLOOD CONTROL

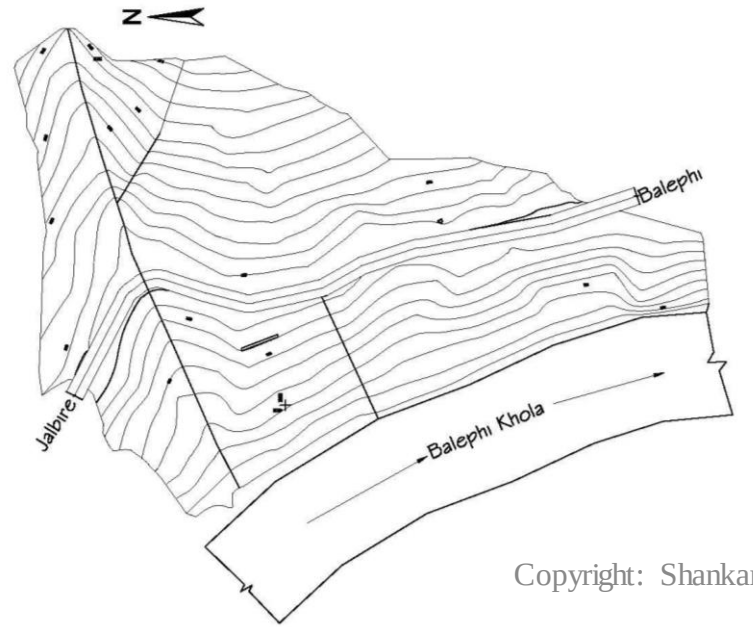
PROJECT MANAGEMENT UNIT

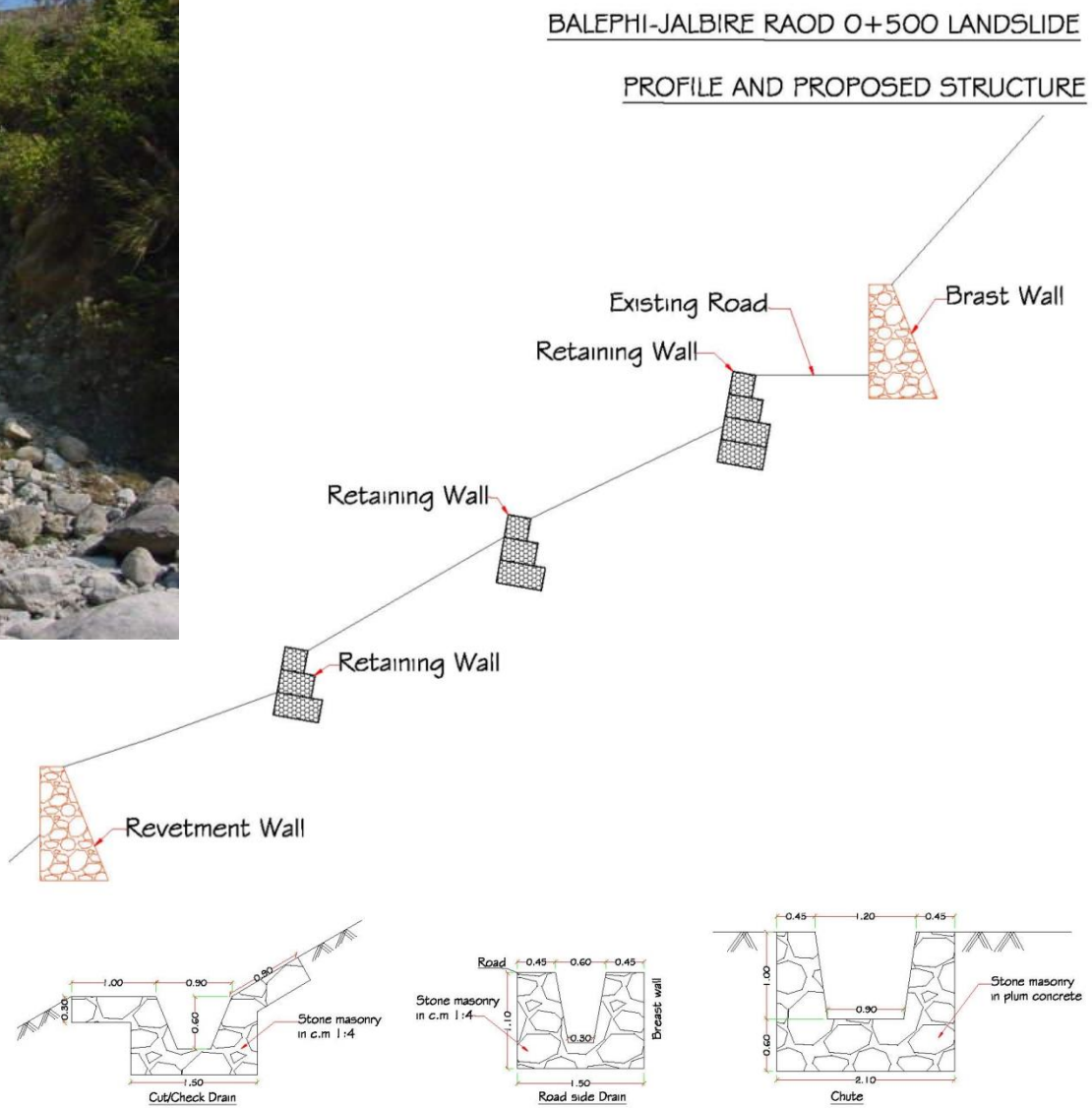
GUIDELINES ON SOIL BIO-ENGINEERING PRACTICES FOR ROADWORKS & SLOPE STABILISATION, TIMOR-LESTE

AUGUST 2017

Cost comparison of Conventional and Bio-engineering Techniques for Slope Stabilization

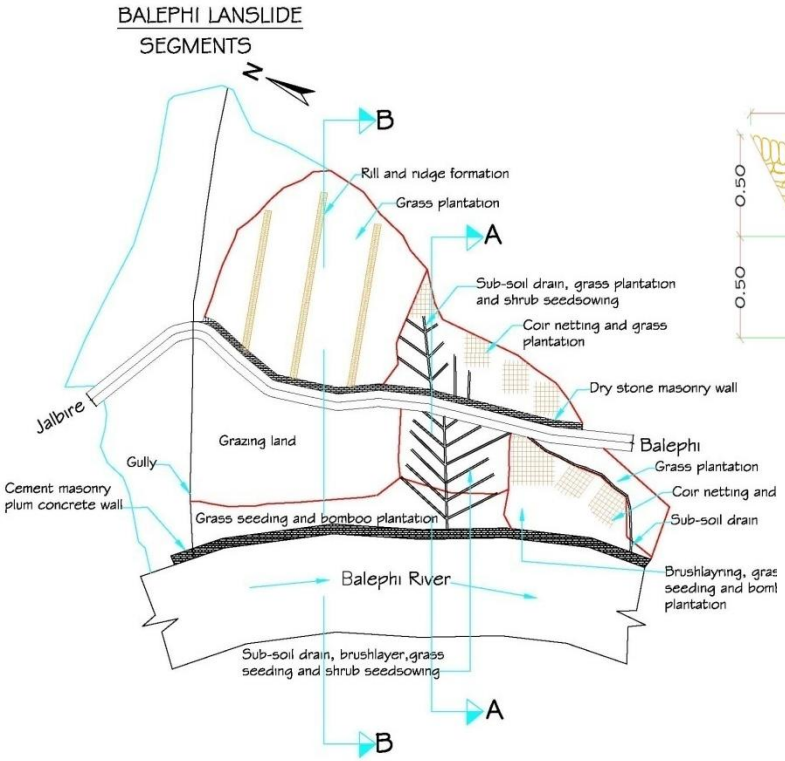
Conventional Engineering Solution Designed

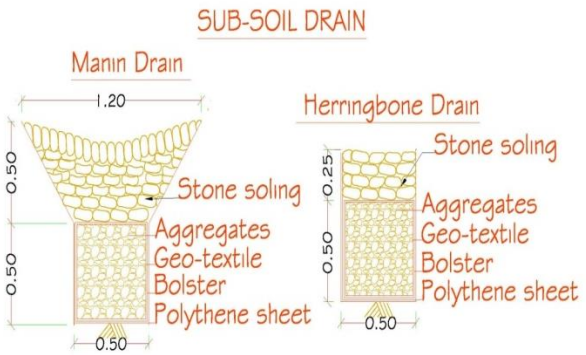


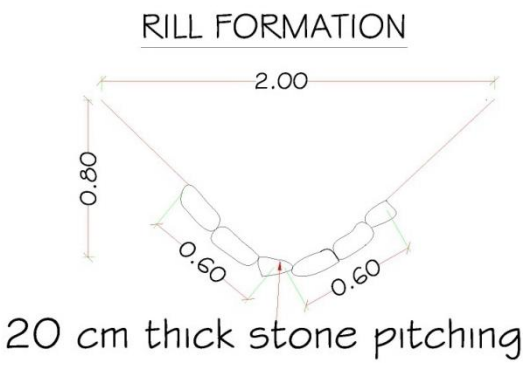


NRs. 12,201,833.00 =USD 101,680

Bio-engineering solution design and applied

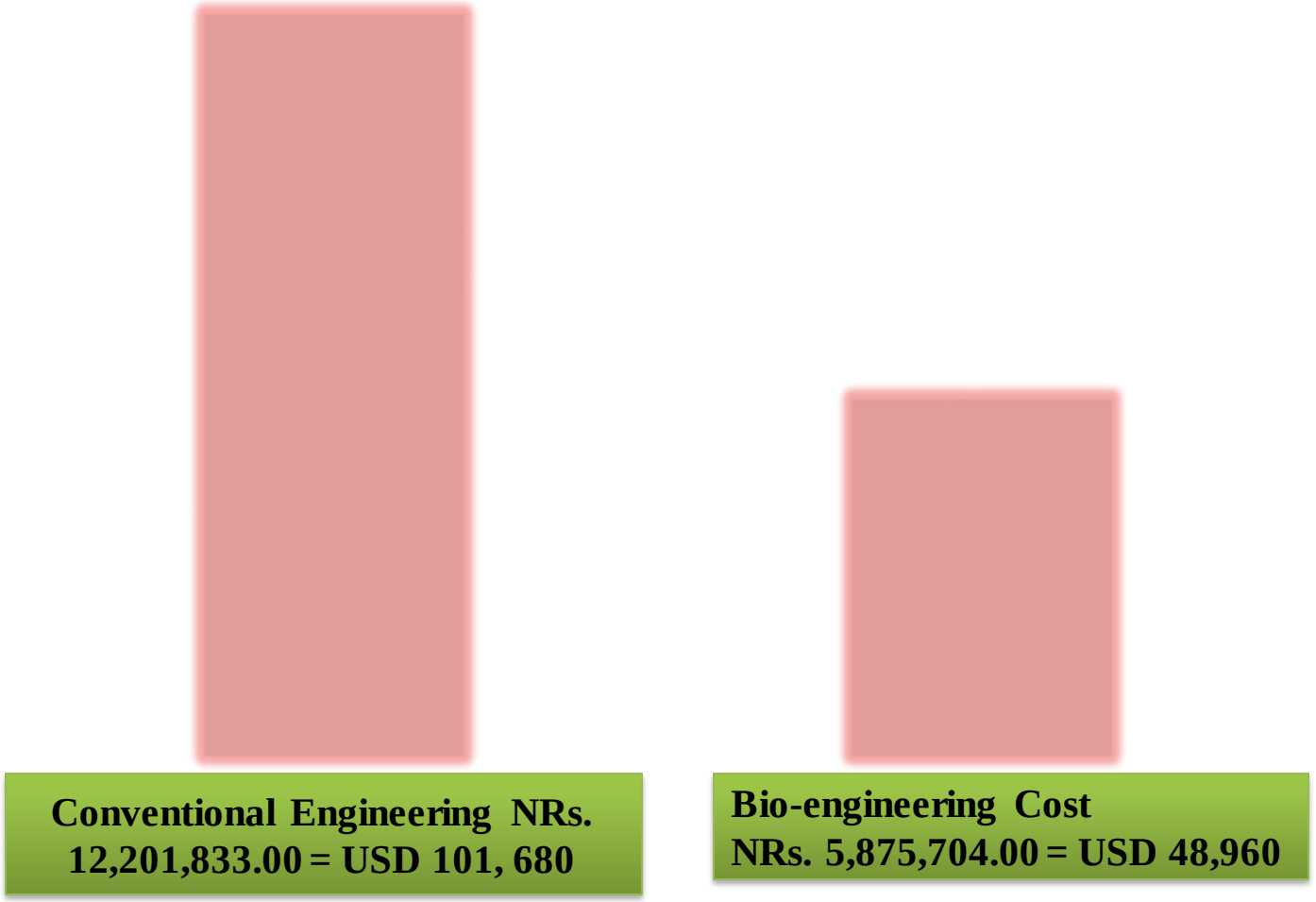




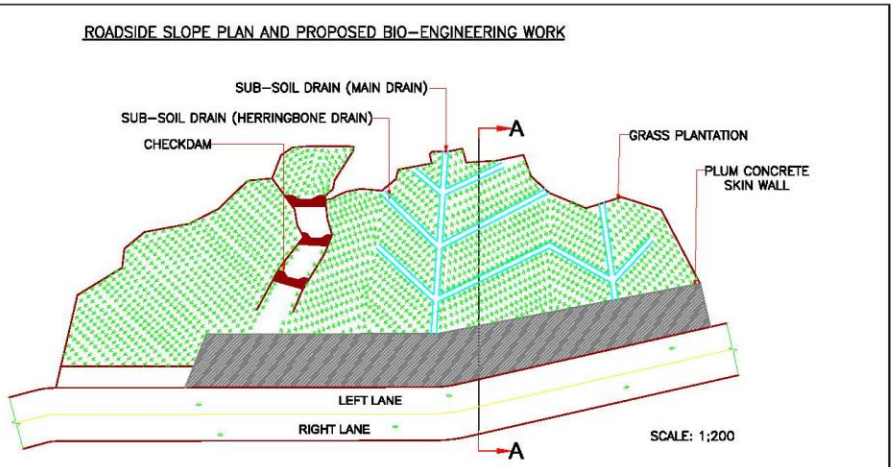


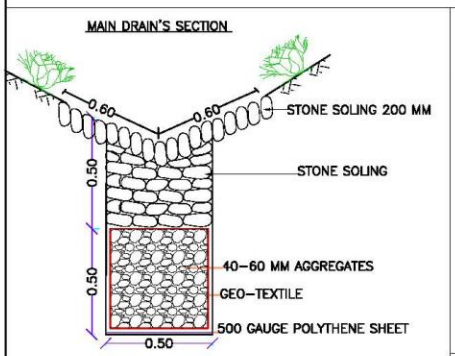
NRs. 5,875,704.00 = USD 48,960

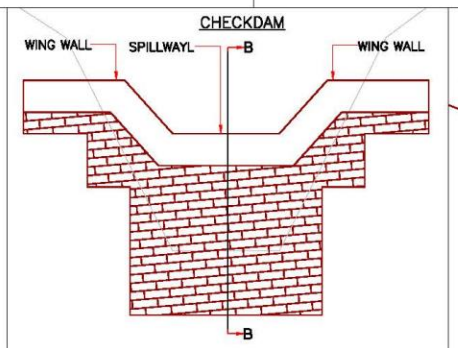
Cost comparison of conventional and Bio-engineering techniques for slope stabilization

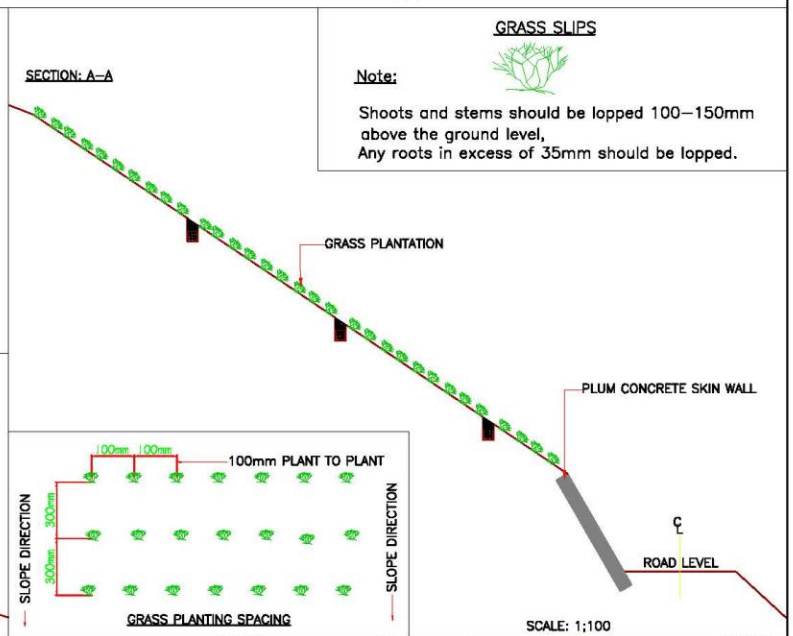


Bio-engineering design





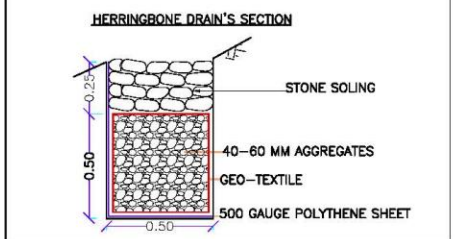


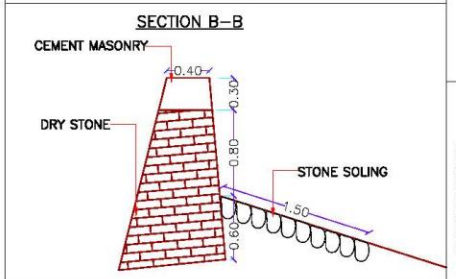


GRASS SLIPS

Note:

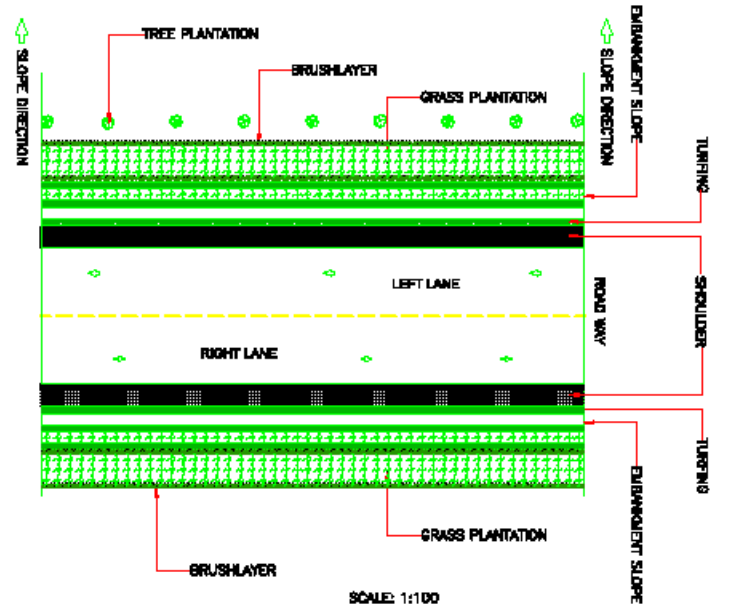
Shoots and stems should be lopped 100–150mm above the ground level,
Any roots in excess of 35mm should be lopped.





DISTRICT DEVELOPMENT COMMITTEE OKHALDHUNGA LOCAL ROADS IMPROVEMENT PROGRAMME ROAD TO PROGRESS	TITLE ROADSIDE BIO-ENGINEERING WORK RAMPUR-PRAPCHA-SHREECHAUR ROAD CH: NO.: 9+000 GAU KHOLA	SHEETS CONTENTS CHECKDAM, SUB-SOIL DRAIN AND GRASS PLANTATION SCALE AS SHOWN	REVISION	DATE	DRAWN BY : SHANKAR RAI DESIGNED BY : SHANKAR RAI CHECKED BY :	SHEET NO. H-04

ROAD EMBANKMENT PLAN AND PROPOSED BIO–ENGINEERING WORK



SCALE: 1:100

HARDWOOD CUTTING

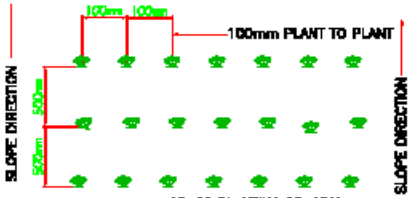
Note:
Hardwood cutting should be 45 cm long and 2–5cm dia with 2–3 buds

GRASS SLIPS

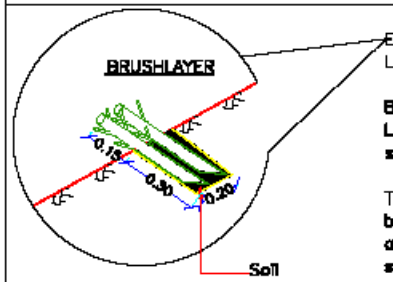
Note:
Shoots and stems should be lopped 100–150mm above the ground level, Any roots in excess of 35mm should be lopped.

SOD FOR TURFING

Note:
Sod size minimum of 30 x 20cm and 3–5cm thick



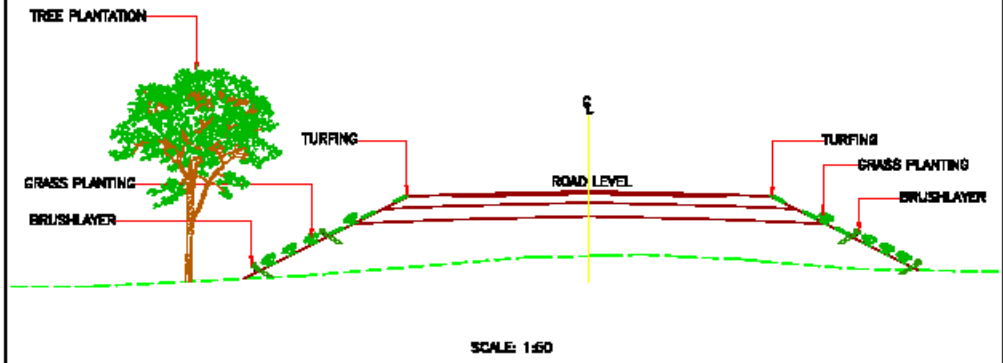
BRUSHLAYER



Excavate 0.20 cm wide and 0.30 cm depth trench, Lay first layer of cuttings in trench at 10 cm apart.

Backfill the first layer of cutting with 0.05 meter soil, Lay second layer of cuttings in trench the cuttings should be in stagger position of first layer of cuttings.

Then backfill the trench with soil and gently compact by foot, Planting rows of brushlayer should be spaced at 1.5–2 meter interval, Hardwood cuttings of brushlayer should be 0.45 cm long and 2–5 cm in diameter.



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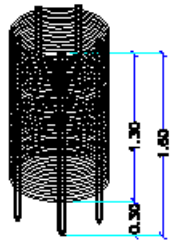
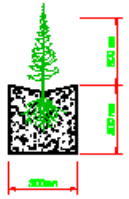
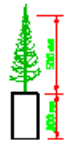
BAMBOO TREE GUARD



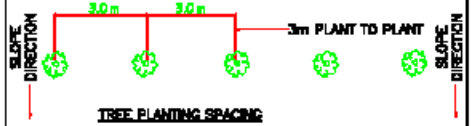
Note:
Bamboo tree guards should be 0.60 meter in dia. See details at sheet No. H–01

TREE PLANTING PITS AND PLANT SIZE





Note:
Plants should be healthy and 50 cm high.



REPÚBLICA DEMOCRÁTICA DE TIMOR-LESTE MINISTÉRIO DAS OBRAS PÚBLICAS, TRANSPORTES E COMUNICAÇÕES ASIAN DEVELOPMENT BANK	DONGBUNG ENGINEERING CO., LTD. In Joint Venture with KUMHWA ENGINEERING AND CONSULTING CO., LTD.	PROJECT TITLE ROAD NETWORK UPGRADING SECTOR PROJECT ROAD LINK AD1-6 : LAGA-LAUTEM SECTION PACKAGE 2 : STATION 142+840 – STATION 182+045	DRAWING CONTENTS BRUSHLAYER, TURFING, GRASS AND PLANTATION (TYPICAL SECTION 6) SCALE AS SHOWN	REVISION / DATE	DRAWN BY : ANSONIO M. LOPES DESIGNED BY : SHANKAR RAI CHECKED BY : MYUNG JAE, KO SHEET NO. H-05

Session-10

Bio-engineering Maintenance Tasks and Seasonal Programming of Bio-engineering Works

Bio-engineering maintenance tasks

What are the possible causes of damage to bio-engineering works?

- slips;
- cultivation practices;
- grazing;
- failure of fascines;
- fire;
- water accumulation;

Bio-engineering maintenance tasks

Possible causes of damage to bio-engineering works

- encroachment;
- firewood collecting;
- drought;
- overgrowth of trees;
- competition from weeds;
- deterioration with age.

Bio-engineering maintenance tasks

Categories of maintenance tasks

a) Protection works:

e.g. protection of plants and planting sites from grazing, theft of firewood and timber, and fire protection works;

b) Plant treatment:

e.g. weeding, mulching, trimming, pruning, grass cutting and thinning of plants;

Bio-engineering maintenance tasks

Categories of maintenance tasks

c) Repair to vegetation structures:

e.g. repairs to palisades, fascines and brush layering, and turfing and vegetation enrichment;

d) Repairs to inert structures:

e.g. repairs to revetment and prop walls, gabion walls, bolsters, jute netting and wire netting, and sealing cracks;

Bio-engineering maintenance tasks

Categories of maintenance tasks

e) Geophysics:

e.g. small slope trimming, small slip clearance, cleaning subsoil drain outlets.

Bio-engineering maintenance tasks

Frequency of maintenance activities

a) Routine maintenance:

this is carried out continuously, though not necessarily at the same location repeatedly;

- Protection of site
- Weeding
- Mulching
- Grass cutting

Bio-engineering maintenance tasks

Frequency of maintenance activities

b) Periodic maintenance:

periodic maintenance is carried out at longer intervals;

- Thinning and pruning of trees and shrubs
- Repair of vegetative structures
- Vegetative enrichment
- Removal of trees and shrubs

Bio-engineering maintenance tasks

Frequency of maintenance activities

c) Emergency maintenance:

this is needed to deal with emergencies and problems calling for immediate action e.g. when the soil slope is threatened.

Yearly and seasonal programming of bio-engineering works

Annual activity of bio-engineering works

Month	Activities
July	• Site plantation works: all grass slips and seedlings; all shrub and tree seedlings and hardwood cuttings; all remaining direct seeding • Observation of newly planted sites and maintenance as required
August	• Site plantation works: all grass slips and seedlings; all shrub and tree seedlings and hardwood cuttings; all remaining direct seeding • Observation of newly planted sites and maintenance as required

Yearly and seasonal programming of bio-engineering works

Annual activity of bio-engineering works

Month	Activities
September	• Observation of newly planted sites and maintenance as required
October	• Preparation of nurseries for operations • Observation of newly planted sites and maintenance as required • Conduct post-monsoon survey of roadside slopes, prioritise problem areas and begin planning for remedial works

Yearly and seasonal programming of bio-engineering works

Annual activity of bio-engineering works

Month	Activities
November	• Nursery operations in full swing • Preparation for seed collection: final establishment of quantities required and planning of seed sources • Compost and mulch making
December	• Nursery operations in full swing • Seed collection, treatment and storage • Preparation for physical site works: planning, programming, contracting, etc. • Compost and mulch making

Yearly and seasonal programming of bio-engineering works

Annual activity of bio-engineering works

Month	Activities
January	• Nursery operations in full swing • Seed collection, treatment and storage • Begin to prepare nurseries for operations in the spring • Preparation for physical site works: planning, programming, contracting, etc.
February	• Nursery operations in full swing • Site works: slope trimming, start of construction of civil works, etc. • Seed collection, treatment and storage • Carry out pruning and thinning of large trees

Yearly and seasonal programming of bio-engineering works

Annual activity of bio-engineering works

Month	Activities
March	• Nursery operations in full swing • Site works: slope trimming, civil works construction, etc. • Carry out pruning and thinning of large trees
April	• Nursery operations in full swing • Site works: slope trimming, civil works construction, etc.

Yearly and seasonal programming of bio-engineering works

Annual activity of bio-engineering works

Month	Activities
May	• Nursery operations in full swing • Site works: slope trimming, civil works construction, etc.
June	• Nursery operations continue • Site plantation works: all grass slips and seedlings; all shrub and tree seedlings and hardwood cuttings; all direct seeding

Yearly and seasonal programming of bio-engineering works

No	Work activity	FISCAL YEAR: 2020/2021												2021/2022	
		Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Jul.	Aug.
1	Complete 2019/2020 site planting														
2	Seed collection: grasses														
	other species														
3	Seed treatment														
4	Seed storage														
5	Site assessment														
6	Planning civil/site preparation works														
7	Tendering and arranging contracts														
8	Implementing civil /preparation works														
9	Planning bio-engineering needs														
10	Bio-eng stock production (in nursery)														
11	Final site preparation														
12	Implementing vegetative structures:														
	- Grass seed sowing on site														
	- Shrub seed sowing on site														
	- Brushlayering, Palisade, Fascine, Live checkdam														
	- Grass planting														
	- Tree/shrub planting														
	Routine activities														
13	Protection														
14	Monitoring														
15	Maintenance														

Session-11

Rate Analysis Norms and Standard Specifications for Bio-engineering Works

Bio-engineering Rate Analysis Norms

TA-9461 REG: Protecting and Investing in Natural Capital in Asia and the Pacific

Developing Bio-engineering Capacity for the Local Government Engineering Department's Operations in the Chittagong Hill Tracts, Bangladesh

BIO-ENGINEERING RATE ANALYSIS NORMS (DRAFT)

FEBRUARY 28, 2022

Bio-engineering Rate Analysis Norms

Rate Analysis Norms

1. Seed Collection and Preparation
2. Grass and Hardwood Cuttings Collection for Vegetative Propagation
3. Nursery Bed Preparation
4. Seed Sowing and Transplanting
5. Hardwood Cuttings Planting

Bio-engineering Rate Analysis Norms

Rate Analysis Norms

6. Raised Materials Preparation for Nursery Extraction
7. Production of Compost and Mulch
8. Direct Seeding on Site
9. Grass Planting on Site
10. Turfing (Sodding)
11. Tree, Shrub and Cuttings Planting on Site

Bio-engineering Rate Analysis Norms

Rate Analysis Norms

12. Construction of Vegetative Palisades, Brushlayers, Fascines and Live Check dams
13. Bamboo Planting
14. Site Clearance
15. Earthwork Excavation
16. Gabion Work
17. Uncoursed Rubble Stone Masonry Work

Bio-engineering Rate Analysis Norms

Rate Analysis Norms

18. Brick Masonry Work
19. Cement Concrete Work
20. Stone Pitching Work
21. Coir/Jute Netting Works
22. Gabion Bolster Cylinders Fabrication and Construction
23. Sub-soil Drains Construction
24. Tree Guards

Bio-engineering Rate Analysis Norms

Bio-engineering Rate Analysis Norms

Standard Specification for Bio-engineering Works

TA-9461 REG: Protecting and Investing in Natural Capital in Asia and the Pacific

Developing Bio-engineering Capacity for the Local Government Engineering Department's Operations in the Chittagong Hill Tracts, Bangladesh

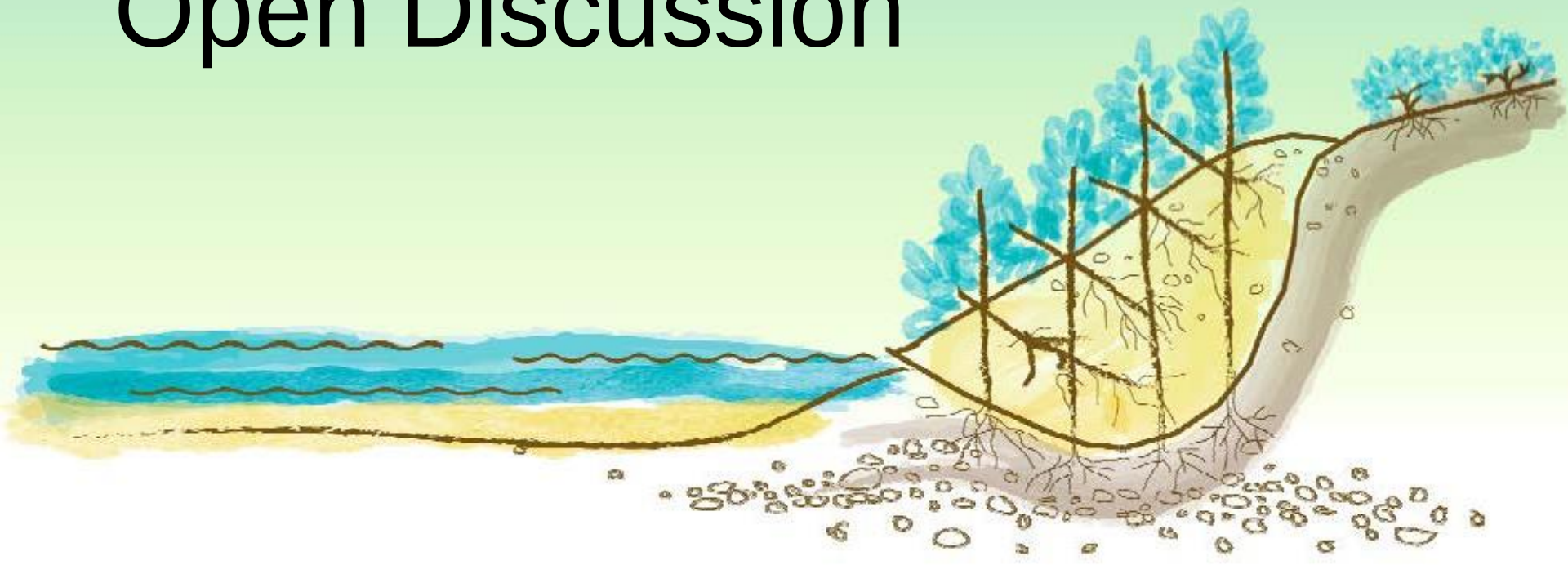
STANDARD SPECIFICATIONS FOR BIO-ENGINEERING WORKS (DRAFT)

FEBRUARY 28, 2022

Standard Specifications for Bio-engineering Works

Standard Specifications for Bio-engineering Works

Open Discussion



Feedback on training

Feedback on training by participants

Thank you for your kind attention

Shankar Rai
shankar.rai@gmail.com