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Date:
Page:

1. Bio-engineering method for slope stabilization.

a) Significance
→ to assess the stability of slopes under short term & long term condtn.
→ to assess the possibility of landslides involving natural or existing engineered slopes.
→ failure mechanisms & influence of envtl. factors.

a) Vegetative plantings
→ conventional plantings of grasses & shrubs in order to prevent surface erosion. living material is not used with structural meaning. erosion prevention function is carry out only once the vegetation is established.

b) True - Bio - engineering.
plants or parts of plants itself provide both the vegetative & structural components of design. Eg. brush layers, wattling, Bamboo fencing etc.
cutting or branch parts acts as initial & primary soil reinforcing & stabilizing material. During growing season develop roots and sprouts foliage. It becomes a major structural component which grows stronger with time.

c) Bio- technical engineering.
Plants are combined with non living or structural materials. Vegetative & structural components work together in mutually reinforcing & have complimentary roles. Eg. Live crib walls, vegetated stone pitching etc
→ structural elements provide immediate resistance to sliding, erosion & washout. As vegetation becomes established, roots invade & penetrate the slope, binding it together.

Date:
Page:

→ Benefit of applying Bio-engineering method are;

* bio engineering technique require locally available excavation equipment. As a result there is less cost & less impact on slope.

→ Installation of bioengineered systems while the site problem is small will provide economic savings & minimize potential impacts to the slope & adjoining resources.

* Use of native plant materials and seed may provide additional savings. Indigenous plant species are usually readily available & well adapted to local climate & soil conditions.

→ Bioengineering work is often useful on sensitive where easy accessibility is not feasible.

→ years of monitoring have demonstrated that bioengineering systems are strong initially and grow stronger with time as vegetation becomes estd. Even if plants die, roots and surface organic litter continues playing an imp. role during reestablishment of other plant.

2. Process of Landslide Mapping.

a) Geomorphic situation

* ~~Geomorphic~~ General locality & situation.
* Orientation of rocks.
* Outcropping, planes of weakness.
* Movement of water along fractures.
* other sites with similar geomorphic situation.

GOOMO

b) Sketch the site from good observation point.

* proportionate sketch
* Estimate the length & width.

PE

3) Look of landslide zone.

* Scar
* failure
* Transport
* Debris.

SFTD

4) Examine the material forming the slope

DSHA
* Debris
* Hard rock
* soft rock
* Alternate bands of hard & soft rock.

5) sketch the slope profile of the site (Draw)
* relative steepness.
* detailed slope measurement.

6) Sketch the surface water drainage.
* stream springs.

7) Sketch the rock outcrop.

8) Landmarks.
Existing structures, Trees, houses, villages.

9) Walkover survey.
→ from toe to crown.
→ Major failure slope.
→ Throughout the site.

10. Rock. (measure & Describe.)
→ visit each exposure.
→ Measurement of bedding plane
→ Physical properties of rock.
→ Degree of fracturing and weathering.
→ water movement.

11) Debris & slope.
* Area & location.
* Amt. & extent.
* Depth of failure plane
* Deflected engineering structures
* composition & wetness
* Depth of debris.
* Tilted tree, anti-slope and seepage.

(A)

Date:
Page:

12. Margins & tops. → cracks *Topography.
→ Streams & springs.
→ Drainage structures

13. Base of side.
→ Ground condtn
→ Material type.

14) Cause & Mechanism of Instability
*failure cause.

15) History & life progression of slide *Time & timing.

16) Severity of instability
*scores of accessing severity of slope

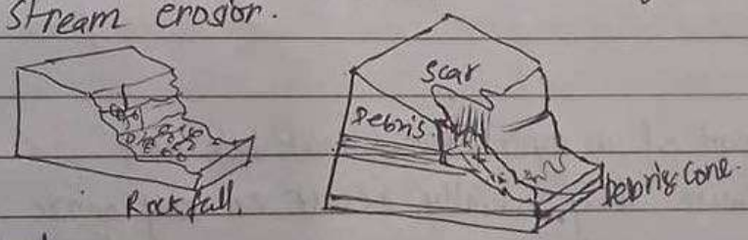
GSLESSSLWRDMBCHS

3) ~~Types of land slit landslides.~~

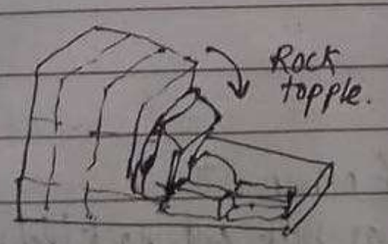
a) ~~Falls~~.

~~Types of landslides.~~
~~a) Falls~~
3. Landslides.
→ downward & outward movement of mass of rock or debris down slope. result from failure of the materials which make up the hill slope & are driven by the force of gravity.

→ Types; (FTSLC)
a) Falls.
- abrupt movements of slope material that becomes detached from steep slopes.
→ Movements occurs by free-fall, bouncing & rolling.
Result → rockfall, soil fall, debris fall, earth fall, boulder fall & so on.
→ Typical slope angle of occurence of falls is from 45-90 degrees & all types of falls are promoted by undercutting, differential weathering, excavation or stream erosion.



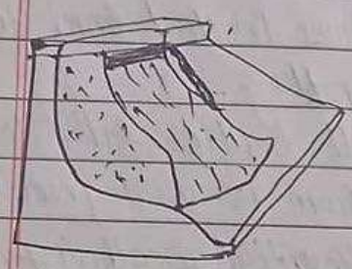
b) Topples.
→ block or serial of block that tilts or rotates forward on a pivot or hinge point & then seperates from the main mass, falling to the slope below, and subsequently bouncing or rolling down the slope.



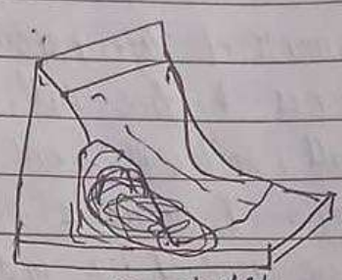
c) Slide.
→ movement of soil or rock along a distinct surface of rupture, which seperates the slide material from more stable underlying material.

a) Rotational.
→ movement on a circular surface or failure.
Eg slump.
→ Generally occur on slopes of homogenous clay, deep weathered & fractured rocks & soil.

b) Translational slide.
→ non rotational block slides involving mass movements on more or less planar surfaces.
Robbina.

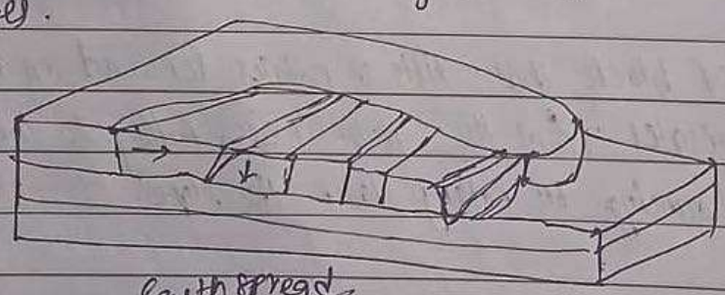


Rotational.



Debris slide.

d) Lateral spreads.
→ horizontal movement of un consolidated materials and are distintive because they usually occur on very gentle slopes.



Earth spread.

e) Complex.
→ combination of two or more types of movements.
→ huge - scale movements are complex. as rock fall, rock/debris avalanches.

Eg - slump. Earthflow with rockfall debris.

4) Repair with bio-engineering.

Priorities.
→ Technical capability.
→ Financial status.
→ Level of intrest.
→ condtn of people's participation.
→ Loss of lives & property.
→ cost benefit ratio
→ other factors
→ setting Repair priorities.

→ setting repair priority.
→ Inspect road & make list of the sites that require treatment.
Prioritise according to importance of stabilization.

Predicted consequence if site is not treated	Priority Rating
threatnes houses.	1 Highest
complete loss of road.	2
partial loss of road.	3
complete road blockage.	3
Debris may fall on top of pedestrians or vehicles	3
threatnes loss of productive farmland.	4
blockage of drains.	4 (lowest)

Steps.
1) Severity Rating (SR)
1 & 2 → High.
3 & 4 → Less.
2) History & life of Progress of slide.

3) Depth of failure.

Date:
Page:

4) Geological Division of Nepal.

→ Situated in central part of Great Himalayan Arc which extends 2400 km from Punjab Himalaya ~~is result of major mountain~~ in west to Assam Himalaya at east.

→ five zones;

a) Terai zone. (Gangetic plane).

→ southern zone. of Nepal Himalaya.

→ alluvial formation of sediments & composed gravels, sands & silts, origin within the last 10 million years.

→ Terai plane ranges in elevation from 60 to 400 m. above sea level.

→ width varies betw^n 10 to 50 km and forms a nearly continuous belt from east to west.

Slope stablity problems related to roads are confined to embankment protection.

i) three parts.

(i) Bhabar zone → south of Churia range.

(ii) Middle terai. → south of bhabar zone.

(iii) Southern Terai → lowest terrain of Nepal.

→ Boulders, gravels, sands, silt & clay.

b) The sub-Himalayan zone (Siwaliks or churia hills).

→ limited south by MFT. & North by MBT

→ southernmost hill range with 8 to 50 km.

→ ~~Churia~~ Siwalik Group has thrust over Terai plain along MFT

→ Churia hills of sub-Himalayan zone. are 1st hill range in front of plains.

(i). lower siwaliks.

(ii) Middle siwaliks

(iii). Upper siwaliks

consists alluvial deposits.

c) The Lesser Himalayan zone.
→ lies between MCT fault in north & MBT fault in south.
→ characterised by medium to low grade metamorphic rocks such as phyllite, schist, quartzite, limestone, dolomite etc.

(i) Midland zone. → south of higher himalayan zone.
altitude - 1000 - 3000 meters.

(ii) Mahabharat Range.
→ metasedimentary rocks such as sandstones limestones.

d) Higher Himalayan zone.
→ includes rocks lying north of MCT & below high fossiliferous Tibetan - Tethys zone.
→ Higher Himalayan zone ranges from 2000 to more than 8000 m.
→ upper parts of these mountains are formed by Tethys sediments, which are underlain by Central Crystalline rocks.
(Araniko Highway) (strong metamorphic rocks.

e) Tibetan - tethys zone
→ northern part of country.
→ begins from top of Higher himalayan zone & extends to north in Tibet
(Mustang, Manang & Dolpa area
(sedimentary rocks

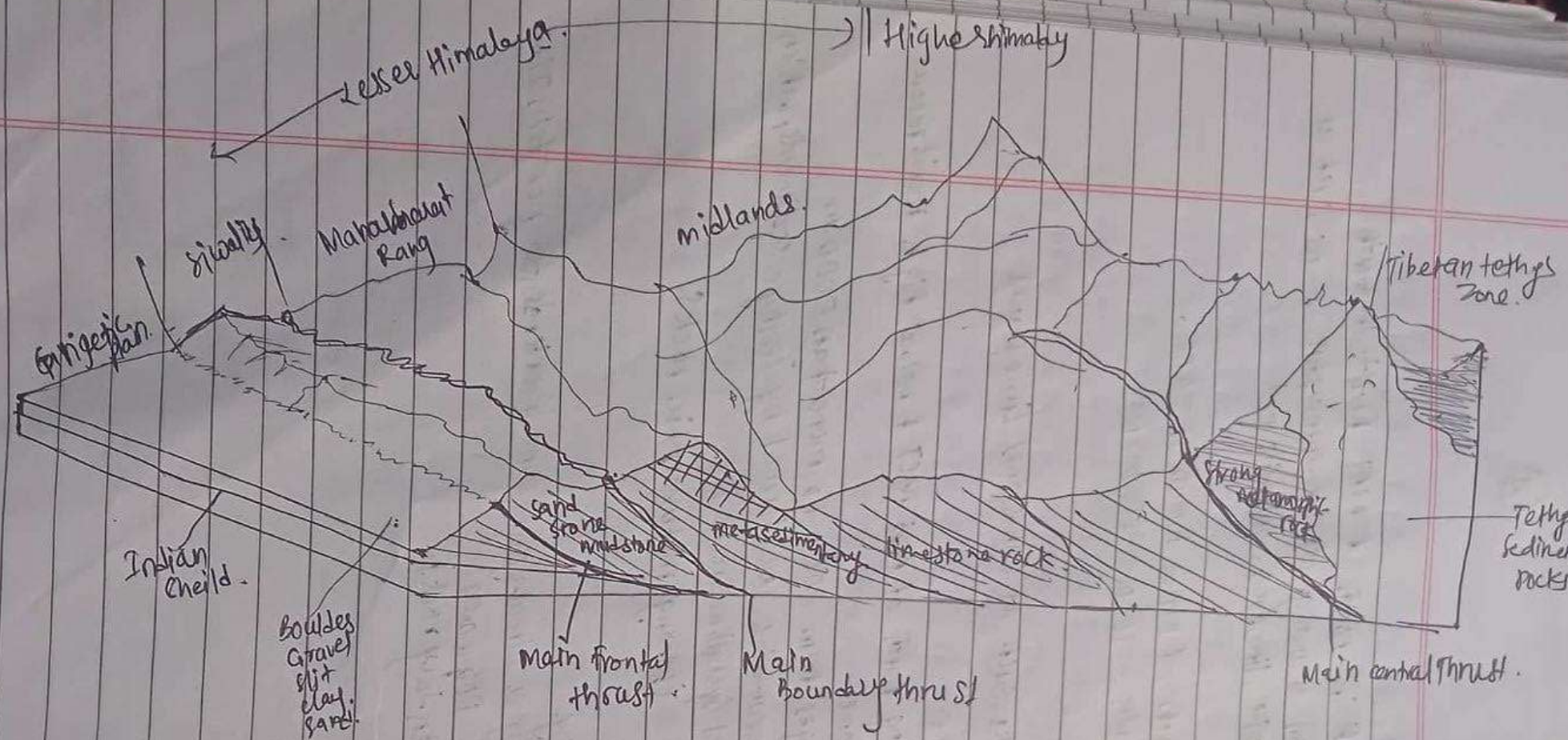


fig. Geological framework of Nepal.

Date:
Page:

5) Engineering function of plants to stabilize the failure of shallow slope.

i) Interception
The ~~veg~~ vegetation canopy intercepts raindrops & reduces their size & mechanical strength which thus protecting the soil from erosion caused by rain splash.

ii) Absorption :- Roots absorbs surface water and underground water thus reducing the saturation level of soil and the concomitant (collateral) risk of slope failure.

iii) Infiltration :- Plants and their residues help to maintain soil porosity and permeability.

iv) ~~Evaporation~~ Evapotranspiration :- vegetation transpires water absorbed through the roots and allows it to evaporate into their ~~at the~~ plant surface.

v) Surface runoff reduction :- Stem and root reduce the velocity of surface runoff by increasing surface runoff.

Date:
Page:

6. Rainfall hazards in relation to slope failures.

i) Erosion. (sheet erosion, hill erosion, gully erosion.)

→ when soil has ~~cto~~ capping, soil cap will prevent infiltrati
or when the rate of ppt. exceeds that of infiltration or soil is saturated & when impermeable rock or soil is at surface, steep slope, water will flow over it causing various erosion.

b) Landslide, debris flow, mudflow;

→ when water percolates soil, all voids are filled by water, hydrostatic pressure, is exerted within the pores.

→ Pressure is transferred to soil grans.

Hydrostatic pressure → sufficiently high take deep translational landslide or circular failure.

c) flood.

Increased rainfall intensity & duration result more water will flow over the surface causing extensive flooding.

Date:
Page:

7) Plant community.

→ established group of plants living more or less in balance with each other & their environment.

→ group can be natural or managed.

→ community is usually dominated by main species of trees, but also contains lower plants such as shurbs, grasses & herbs.

Characteristics are done for purpose of.

→ to record variation within and between communities.

→ for naming & classifying communities.

* Analytical characteristics.

features of community which can be observed or measured directly in every aspect.

→ Involves measurements of various characters in sample ~~pt~~ plots, commonly known as quadrats.

Two sets of characters.

1) Analytical. → directly observed in sample pots.

→ includes no. of species, distribution ~~of ind~~, no. of individuals & ht. of plants etc.

2) Synthetic.

derived from the analytic characters. & utilise data obtained in analysis.

→ Qualitative (non-quantative observation). eg. species composition.

→ Quantitative. (quantitative terms), characters include frequency, diversity, abundance, leaf size, cover, biomass etc. → can be measured

→ frequency. → Density.

→ Biomass. → Abundance.

→ Leaf Area.

→ Cover & Basal Area.

Date:
Page:

Synthetic Characters
→ presence & constance.
→ Fidelity.
→ Dominance

→ Vegetation
→ assemblage of plant species and the ground cover they provide.
→ three dimensional structures.
→ Plan → spatial distribution of individual plants of diff shape & size with some degree of overlap in both above & below ground plants.
→ vertical → usually distinct layer which are characteristics of the type, age status & mgmt. of community.

8) Plant community for stabilization of slope

Characteristic
- Analytical
  - Qualitative
  - Quantitive
    - frequency
    - Diversity
    - Density
    - Biomass
    - leaf area
    - Abundance
    - Cover & Basal area
- Synthetic
  - Fidelity
  - Dominance
  - presence & constance

8) Basic ideal requirements of plants

(i) Air → oxygen for respiration
carbondioxide for photosynthesis
poorly aerated soil gradually weaken plant.

(ii) Water.
→ inadequate amt. of water or too much of water is primary cause of death of newly planted trees.
→ In many landscapes, about 1 inch of water every 7 to 10 days is sufficient to support tree & shrub growth.

(iii) Light. → sunlight for photosynthesis that produce energy.
→ Capture light energy and convert to soluble carbohydrate.

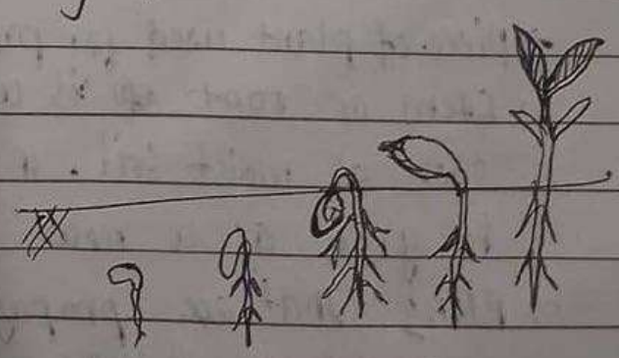
(iv) Plant Nutrient.
Main
- Nitrate → helps leaf growth.
- Phosphate → helps root growth, establish plant.
- Pottassium → keeps plant healthy, involved in production & storage of sugar & starch and drought resistant.

Other secondary
Sulphur, Magnesium, Calcium, Sodium.

micro → iron, Manganese, Boron, Copper, zinc

9) Plant propagation.
→ Creating new plants from a variety of sources.
Three techniques.

(i) Seeding.
→ period of dormacy to break.
→ Germination of seed
→ Establishment of young plant.



Date:
Page:

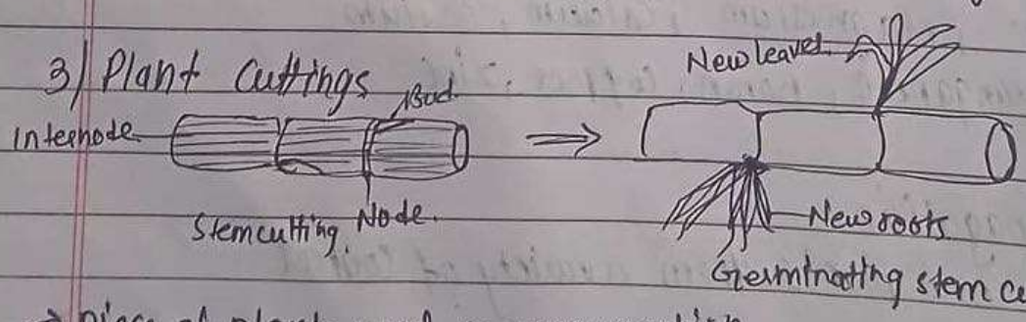
→ small seeded plants are often susceptible to desiccation (dryness) early in establishment.
→ Some trees produce ~~large~~ small quantity of large seed. that may be subjected to ~~degrodtion.~~ degradation.

3 stage:
→ period of dormancy to break → simply involve the seed absorbing sufficient ~~coat to~~ water for metabolism to begin.
→ Germination of seed: where seed coat split and roots starts to emerge & penetrates the soil.
Adequate moisture is essential for good germination.
→ establishment of plant in favourable envt.

2) Planting Nursery Raised plant (Polypot seedling)

→ method of replanting of grown plant.
→ transplanted plant can inevitably suffer disruption of its root system. fibrous roots are easily damaged and quickly dry out when exposed to atmosphere
→ Large fleshy roots are more resistant to desiccation & therefore regenerate more rapidly. younger plant has higher probab to succe

3) Plant Cuttings



→ piece of plant used for propagation.
→ Stem or root is used and placed in suitable medium such as moist soil. If condtns are suitable plans begin to grow as a new independent of the parent plant.
→ Plants that are propagated vegetative (from cutting) usually grow faster & large than those of seed.

71) Check dam.

small dam, either permanent or temporary, constructed across a rills, gullies, drainage ditch or waterway to counteract erosion by reducing water flow velocity & catch debris

- Prevents down cutting of runoff water in gullies
- ease the gradient of gully bed by providing periodic steps
- permits a safe discharge of water via a spillway

base of dam = 600mm + 300 × ht.

Max ht. ≐ 4-5m

- Use dry stone masonary or gabions
- include weep holes
- central spill way or notch to ensure drainage.
- apron to protect scouring & seepage erosion.

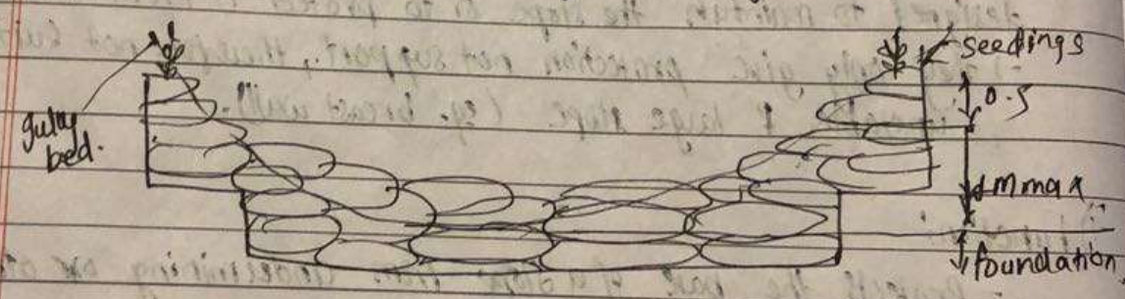


fig check dam.

72. Casacades.

they are surface drains designed to bring water down steep section of slope.

- the principal function of a casade system is to dissipate the kinetic energy gained by flowing water from a sudden drop in elevation.

Date:
Page:

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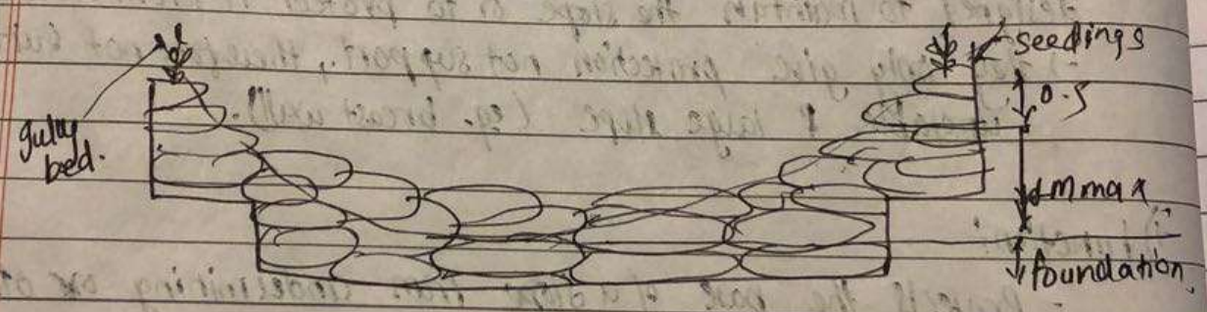

fig check dam.

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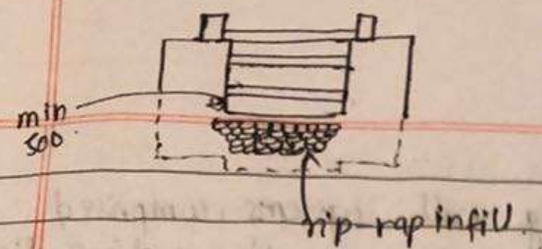
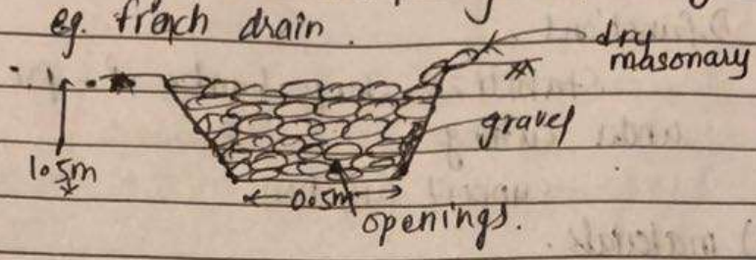


73) Subsurface drains.
- used to remove ground water quickly & efficiently
eg. french drain.



74) stone pitching.-
- used to armour slope.
- gives strong covering
- can withstand considerable velocity of water & helps in drainage

1) Suitability
- any site up to 35°
- sites having seepage problem
- in flood areas where it is difficult to grow vegetation.
- gully floor between check dams & for scour protection by rivers.

75) Wire Bolster cylinder.
→ gabion wire tube having dia 300mm & filled with a stone are called.
→ gabion wire panel are normally of 5m * 1m
1) function.
prevents surface scour.
provide shalow support

76. ~~Crib~~ Crib Walls

they are gravity retaining wall systems, comprised of a series of stacked members creating hollow cells filled with soil & rocks

→ Stacked members may be of either logs or precast structures.

I) functions.

- Stabilize steep banks & protect them against under cutting
- support function

II) materials.

- live branches 1-6cm in ϕ.
- logs, timber or bamboo 1-2 m. long & 30cm ϕ.
- Steel reinforcing bars.
- excavators or digging tools knife measuring tape
- backfill. materials rock & soil

III) Design. :- installed at an angle of 10-15° towards the slope.

IV) construction

- excavate at an area 1-2 m wide up to 1m ~~angle up to 15° towards~~ below the surface & fill with rock.

→ place of series of large logs on the rocks end to end along two lines marking front & back of wall.

→ place smaller logs perpendicular to & towards end of larger logs - allow an overhang of 15cm.

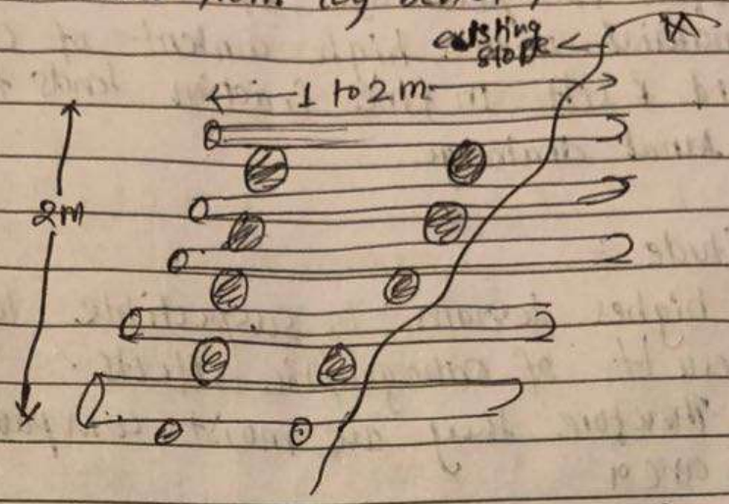
- logs can be fixed together with metal bars or nails.

→ place layers of live cuttings between logs.

→ cover branches with layer of rock & soil & press down to fill the box.

- continue the layers

- each successive course of logs parallel to bank should be set back by 15-20cm from log beneath



85 factors to be considered while selecting species for bio engineering:-

i) method of propagation.
ii) Biological & social consideration.
iii) est. vigor & persistance.
iv) Site ~~sustaine~~ suitability
v) Potential value to local farmers.
vi) Availability.

86) Drought factor.

→ Measure of dryness of site. drought factor is determined based on:-

1) slope angle.
→ slope with less than 30°
- usually needs only mild soil conservation treatment whereas those with steeper than 45° usually demands more attention as they have greater erosion problems.

Date:
Page:

ii) Stoniness.
- refers to percentage of fine in soil.
- material with high content of clay relative to sand & silt in fine fraction tends to have poor internal drainage.

iii) Altitude :-
- higher terrain is suspectible to greater rainfall as a result of orthographic effects.
Therefore they are moist compared to lower altitude area

(iv) Aspect.
→ determines the amt. of direct sunlight that a site recieves, southfacing (warm or dry) & northfacing (cool & damp). Slopes.
→ west facing sites tends to be drier than east facing sites.

v) Rainfall
The level of rainfall across entire site must be considered.
level of moisture depends on amt. of rainfall recieved

Date:
Page:

88) Optimal techniques.

- suitable bio-engineering techniques depends on a range of site conditions.

→ Bio engg. technique are combined with appropriate civil engineering structures where necessary to enhance stability.

- major factors are:-

i) Slope angle:-

- < 30° (mild treatment)
- 30-40° (stabilization properly).
- > 45

ii) slope length

< 15m - > 15m.

iii) Material drainage.

- good or poor.

iv) Site moisture

- wet / moist.
- dry / very dry.

v) Potential problems.

erosion on surface
planar sliding
shear failure
debris flow.
debris collapse.

vi) Function required

(catch, armour, reinforce, anchor, support or drain)

Date:
Page:

eg) Procedure to select optimum bio-engineering techniques.

I) Slope angle >45°
Slope length >15m.

drainage	functions	techniques
→ good		
site moisture: - damp	Ar, Re, drain	diagonal grass line
site moisture: - dry	Ar, Re	- contour grass line
→ Poor		
- damp	Ar, Re, drain	down slope grass line
- dry.	Ar, Re, drain	diagonal grass line.

II) Slope angle >45°.
Slope length <15m.

Drainage	Site moisture	Functn	techniques.
- good	Any	erosion (Ar, Re)	diagonal grass line.
- poor	damp poor	slumping erosion (Ar, Re, Dr)	down slope grass line ~~Jut~~ Jute netting

III) Slope angle 30°-45°
Slope length >15m.

drainage	Site moisture	functn	techniques.
- good	any	Ar, Re, catch	Horizontal bolsters
- Poor.	any	Ar, Re, Drain	Herringbone bolsters.

Date:
Page:

iv) Slope angle 30-45°
slope length < 15m

drainage	site moisture	functn	Technique.
good.	any	Ar, Re, catch	Brush layering
poor.	any	Ar, Re, drain.	diagonal grass lines

v) Slope angle <30°

Slope length	drainage	site Moisture	functn	Techniques.
any	good	any	Ar, catch	Site seeding
	poor	any	Ar, catch, drain	diagonal grass line.
<15m.	any	any	Ar, catch.	Turfing & shurb/tree planting.

→ Base of any slope :- for support, anchor & catch (use large bamboo plantings or large trees)

→ Gullies
<45° :- for armour, reinforce & catch. (Use large bamboo planting or live check dam)

Date:
Page:

→ Rock cycle
basic concept in geology that describes transistions through geologic time among 3 main types of rocks
Igneous
Metamorphic
Sedimentary.

Steps of rock cycle
i) Weathering
ii) erosion & transport
iii) deposition of sediments
iv) burial & compaction
v) Melting
vi) crystallization of magma
vii) uplift
viii) deformation & metamorphism.

→ Runoff generation
→ major component of hydrological cycle & is generated when water from ppt. when ~~water from~~ and glacial melt flows over the land.
- it is water not absorbed by the soil
→ factors affecting
(i) rainfall amt., duration,
(ii) rainfall intensity
(iii) type of ppt.
(iv) direction of storm movement.

→ Engineering function of vegetation
→ reduces runoff by trapping moisture on leaves & branches.

+ Increasing infiltration.
→ slowing flow of water across rough surface.

→ Principle of vegetation mgmt.
i) plant high-quality seedling as soon after harvest as possible
ii) Herbaceous vegetation is a small amt. reduces early stand growth.
iii) good site preparation
iv) target release treatments on tall shrubs & unwanted hardwoods as early as possible.
v) shade tolerant species of trees as much as intolerant species.
vi) good surrounding vegetations

→ Quality control.
process by which entities review the quality of all factors involved in production
- quality control focus on products requirement as per specification

→ Quality assurance.
→ it is any systematic process of checking to see whether process of developing a product or service is meeting specified requirements. It focuses on the process.

Date:
Page:

→ Maintainance of Bio engineering structures:-
a) Routine maintainance
b) preventive Measures.

a) Routine maintainance.
- involves simple protection & care of plants such as
(i) weeding :- removal of unwanted
(ii) mulching :- positioning of inert dead vegetation around seedlings to keep the soil cool & moist.

iii) grass cutting - help growing of new shoots.

(iv) Watering :- helps to grow plants on harsh site during dry season.

b) ~~Preventati~~ Preventive measures:
- carried out at longer intervals.

(i) Pruning & thinning:-
→ pruning is removal of lower branches of tree &
→ thinning is removal of selected shurbs to decrease the density of plants
→ it increases light penetrating through canopy & remove unwanted species.

ii) Repaire of vegetation structures
- Involves repairing of any form of bio-engg treatment such as palisades, fascines, brush layering

iii) Vegetation enrichment:-
means planting more grasses, shurbs or trees

within the site area or in gaps within the existing vegetation.
→ the purpose is to establish more plants in places where there are gaps & to introduce or change species composition on a site.

→ Colluvium & Alluvium.

~~Alluvium~~.

→ rocks breakdown under sub tropical weathering into constituent minerals & begin to move downhill. The mineral particles become ~~the~~ thoroughly mixed & produce a soil that typically consists of fragments of rocks. The resulting mix is colluviums;

- plasticity is low
- very permeable
- susceptible to infiltration & liquefaction during heavy rainfall.

→ When colluviums reaches valley bottoms it is moved along by river. The materials becomes separated and fines moving in suspension & the larger fragments rolling & bouncing along the river bed. & if this deposited material is called alluviums

→ fragments clearly rounded
→ has sandy texture & lacks fines.
→ usually shows signs of horizontal layering due to steady depositions.

Date:
Page:

47) Hydraulic effects.

I) surface roughness & flow velocity

$$v = \frac{1}{n} R^{2/3} S^{1/2}$$

II) Sediment transport capacity.

III) Soil detachment by flow.

IV) transport of splashed material.

V) Sedimentation.

VI) Modification of air flow.

48) Engineering effects of vegetation:-

I) reinforce. - the roots & rhizomes of the vegetation interact with the soil to produce a composit material high tensile strength.
→ increase in soil strength due to binding action & adhesion of soil particles

II) Armour (cover)

vegetation absorbs the energy of falling rain & like a armour, protects the slope against surface erosion from both rain splash effect & runoff.

III) Anchor → anchors the surface material by extending roots through potential failure planes into firmer strata below.

IV) Catch :- loose materials can be stopped from rolling down.

V) Support :- large & mature plants can provide support & prevent movement from lateral earth pressure.

VI Root wedging :-

VII) Surcharging.

VIII) Draining.

50. Stability analysis-

a) Significance.

- to access ~~facth~~ stability of slope.
- to access possibility of land slides.
- → to understand failure mechanisms
- → to enable the redesign of failed slope.
- → Planning & design of preventive & remedial measures.
- → to study the effect of seismic loadings on slopes & embankments.

$$F = \frac{\tau_f}{\tau_m}$$ → shear strength of soil. → mobilized strength of soil

b) Stability analysis of not free soil.

Vertical stress $(\sigma_z) = \gamma z \cos i$.

& $\sigma' = (\gamma_z - \gamma_{wh}) \cos^2 i$

c) Stability analysis of moted soil.

51) factors affecting infiltration

i) texture of soil
ii) groundwater table.
iii) rainfall intensity
iv) Tempr.
v) quality of water
vi) content of soil moisture
vii) agriculture.
viii) soil characteristics.
ix) Precipitation level
x) slope of land
xi) soil saturation
xii) evapotranspiration level.
xiii) Human activities.

Date:
Page:

5.2) Horizontal Grass planting.

i) function

→ Provide a surface cover, reduce the speed of runoff & catch debris.

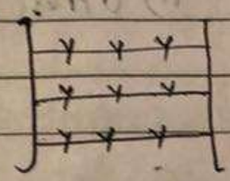
ii) Sites.

- almost any place slope less than 65°.

iii) Materials - grass plants, short planting bars, line string, spirit level, means of transportation.

iv) Design.

- Spacing 100 cm. (5 < 30°)
  50 cm (30° - 45°)
- Plant to Plant 10 cm
- 10 cm above G.L.



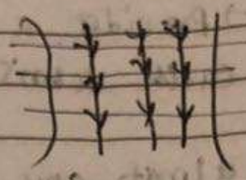
v) Construction steps:

- prepare site in advance of planning
- Start grass planting at the top of slope & work downwards
- mark out lines with strings, using a tape to measure
- with planting bars, make a hole just big enough for the roots. Place the ~~pla~~ grass into the hole.
- → Scatter a few handful manure around grasses.
- consider watering the plants by hand if no rainfall.

Date:
Page:

53) Vertical grass planting.
limitations :- runoff can become damaging, rill erosion may occur.

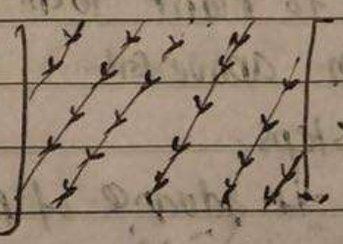
→ Amiriso, babiyo.



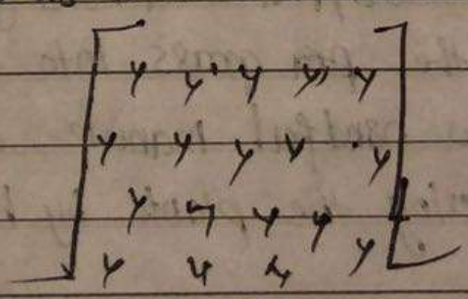
54) Diagonal grass planting
Function → to armour & reinforce with secondary functions to catch & drain.

11) Others same :- but limitations :- on certain very weak materials, small rills can develop down the slope.

(Amiriso, babiyo)



55) Random grass plantation
- Same as horizontal



56) G

Date:
Page:

56) Grass Seeding:-
grass is sown directly to the site.
→ often used in ~~cojo~~ conjunction with mulching & jute netting.

i) Function.
- armour & later to reinforce.

ii) Sites - slopes upto 45°; well drained materials.

iii) Materials - grass seed, tools to scarify the surface to be sown, mulch, 30-45° wide mesh jute netting.

iv) Procedures.
- basics (2 points).
- Sowing @ 25gm /m² from top & then to downwards.
- covers the seeds completely with a layer of mulch wide mesh jute netting.

eg. babiyo.

57) Turfing
- consists of shallow rooting grass & soil grows in it, it is placed on the slope

i) function.
→ put in gentle embankment slopes to armour.

ii) sites - gentle slope less than 30°, well-drained materials with min. risk of slumping.

iii) Materials:- flat shovel, khukuri to cutoff turf to shape, water, wooden rammer, wooden pegs.

iv) eg. dubo.

Date:
Page:

v) Construction.

→ taking out turf..

→ shape, cut 300 x 600 mm

- depth cut 50 mm

- lift them out gently.

→ Placing of turf :-

- Basic steps (2)

- Slope >25°, wooden pegs should be hammered.

- compact the turfs ~~whit~~ with wooden rammel

- water fresh turf thoroughly

limitation

turfing is relatively costly & creates equal base areas at the source of the turf, where erosion can start.

) Shrub & Tree planting

i) function :- to reinforce & later anchor, slope support in long term.

ii) Sites :- Slope 30°-45°

iii) Design :-

Spacing 1x1m, requiring 10,000 plants in a hectare.

iv) Eg:- Bakaino, Pren

v) Construction :- → basic - (3-4 steps).

→ dig pits of 300mm deep & 300mm in diameter

- remove any weeds.

vi) limitations:-

- Seedling takes about 5 years to contribute significantly to slope strengthening.
- care & protection required in first 3 years.

g) Large Bamboo planting

i) function

- reduce movement of material & stabilize slope by reinforcing & supporting slope.

ii) sites. - base of slopes and in gullies, slope angle of $<30°$

iii) Materials:-

- 1 yr old rhizomes & 2-2.5m of culm.
- rooted single - node culm cutting from nursery.
- hessian, means of transport
- tools to dig for mulches & planting

iv) Design

- spacing $\neq$ 2m across slope.
- spacing $\neq$ 5m up & down the slope.

v) Construction steps (traditional).

- remove ~~drains~~ debris.
- Clear site
- cut of culm about 2m above ground level.
- wrap the root ball in damp hessian & transport

dig & put ~~& rooted culm~~ me

rooted culm method:- bring rooted culm from nursery & keep the root ball wrapped in wet hessian.

Limitation

→ 5 years to contribute.
→ not suitable at hot, dry site.

6a) Brush layering.

- woody cuttings are laid in lines across the slope, usually following the contour. In ~~term~~ long term, a small ~~temp~~ terrace will develop.

i) functions :

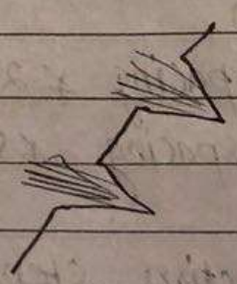
- catch debris & to armour & reinforce the slope.
- Provides very strong & low cost barriers.

ii) Sites :- slopes of 45°, effective on debris sites, avoid ~~usually~~ using in poorly drained soil.

iii) Materials :-

Cuttings made from woody material (20-40 mm in ϕ & 450-600 mm long.)

- hessian & water (keep cutting moist)
- Shovels & pick axes



v) Design.

- critical slope length.

$$L_c = \frac{V_{cr}^{5/2} A^{3/2}}{(R-I)\sin^{3/4} S \cos S}$$

- spacing for slope < 30° is 20m & in between 30°-45° in 1m interval.

→ Spacing between cuttings = 50mm c/c.

- 25% cutting outside ground
→ terrace slope (10°- 20° fall back slope)
- min width 50 cm.

v) Construction procedure :-
→ mark lines to be planted.
- form a small terrace
→ lay 1st layer of cuttings along the terrace with 50 mm interval between cuttings along the terrace, with 50 mm interval between cuttings.
- lay 20 mm layer of soil in between cutting to provide a loose cushion.
- Partly backfill the terrace with excavated earth (> 50 mm thick)

vi) limitations:-
- gives rise to considerable level of disturbance to the slope.

Date:
Page:

01) Palisades.

→ woody cuttings are planted in line across the slope, usually following the contour.

i) function

- to catch debris, to armour & reinforce the slope
- for drainage function.

ii) Sites :- up to 60°, effective on steep landslide debris slope.

iii) Materials :-

- hardwood cuttings (2-5 cm ϕ)
- Hessian & water
- Pointed planting bars or crowbars to make holes.

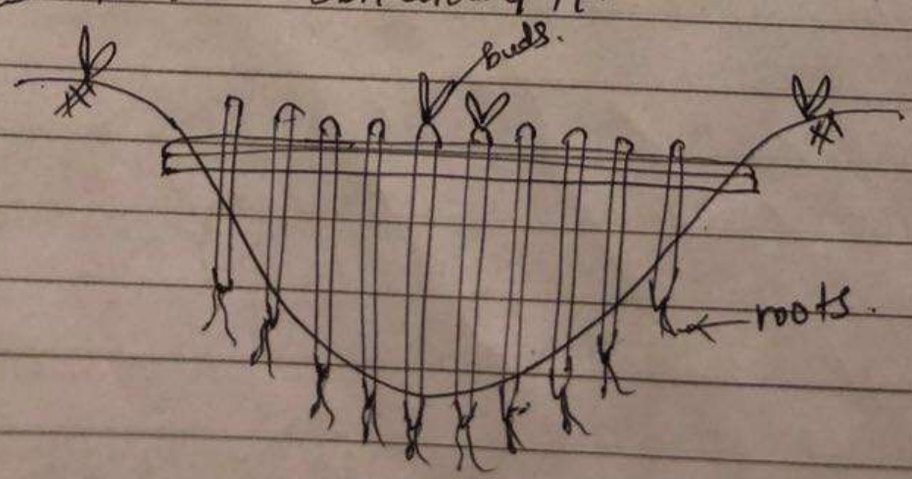
iv) Design :-

- $L_c = \frac{V_{cr}^{5/2}\, n^{3/2}}{(R\, i)\, \sin^{3/4} s \cdot \cos s}$.
- spacing am < 30°
  1m 30°-60°
- 25% cutting outside & 75% buried in ground.

v) construction steps

basics (2/3 steps)

- make hole that must be deep enough to take at least 2/3rd of its length.
- firm the soil around it.



2) Live check dams.

- large woody cuttings are planted across a gully, usually following the contour. These form a strong barrier & trap material moving downwards.

i) functions → to catch debris, to armour & reinforce the slope
→ for drainage function.

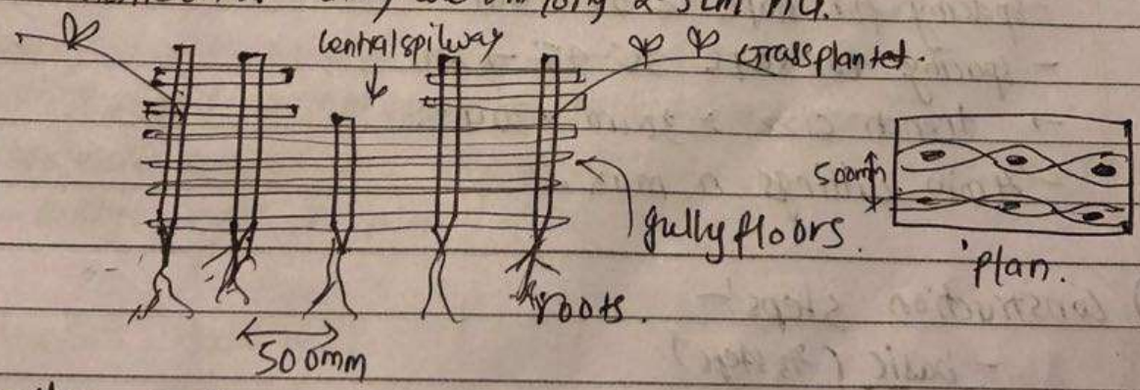
ii) sites :- on wide range of gully sides,
on slopes up to 45°.

iii) Materials :-
- large cuttings (2m long, 20-50mmϕ)
- Truncheon cuttings (2m long, 30-80mmϕ)
- Hessian & water.
- Pointed planting bars or crowbars.

iv) Design.

$$X = \frac{Hg}{K \tan \cos s}$$

- normally at interval of 3-5m.
- within check dams, cutting should be about 30-50mm apart.
- horizontal cutting are 2m long 2-5cm ϕ.



v) construction steps.
→ make hole & insert vertical hardwood cuttings.
→ insert vertical cuttings carefully pushing them into the hole & firming the soil around.
→ Place long hardwood cuttings on the uphill side of vertical stakes
→ key horizontal members into walls of gully
→ Backfill around check dam.

3) Fascines.

→ means: a bunde of sticks. Bundles of live branches are laid in shallow trenches.

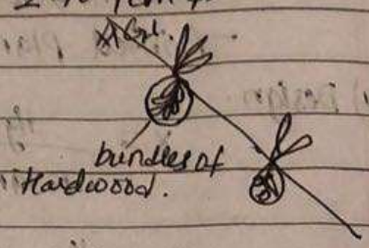
After bustel in trenches they put out roots & shoots, forming a strong line of vegetation.

i) functions :- Catch Debris, armour, reinforce & provide drainage.

ii) sites :- on consolidated debris or soft cut slopes max of 45°

iii) Materials :- - woody cutting (1 m long, 2 to 4 cm ϕ):
- Hessian & water.
- tools to dig trenches.

iv) Eg. Asuro, simali



v) Design. $x = \frac{H_1}{\tan\alpha \cos\alpha}$

- spacing for slope < 30° → 4m
- spacing for slope 30°-45° → 2m
→ trench size :- 30 cm × 30 cm.
- 4 min cuttings or max 8.

vi) Construction steps :-
- basic (2/3 steps)
- dig about 5m of trench at a time
→ lay cuttings together, filling the trench & with their ends overlapping.
- backfill the trench
- slope > 25°, peg fascine.

vi) Limitation:
- donot form a physical barrier immediately but required to period of growth becomes effective.

4) Jute Netting.

→ a locally made geotextile of woven jute is placed on the slope.

I) functions

- Protection of surface, armour, catch small debris.
→ allows seeds to hold & germinate.
→ holds moisture & increase infiltration.
→ as it ~~deeply~~ decays, acts as mulch.

II) Sites : slope angles 45° to 60°
for standard mesh & 30°-45° for wider mesh. Best in well drained materials.

IV.) Materials

- Woven jute nettings. ~~(140x40mm)~~
Standard Mesh (40x40mm)
→ Wide mesh (150x450mm)
→ hardwood cuttings (300-400mm long & 20-50mm ϕ).
- tools for cutting wood & jute iron bar for making holes & a wooden mallet.

IV) Design;

- starting peg at 300mm above the slope to be covered.
- completely covered the affected area by (st wide mesh-size)
- anchor pegs at interval of 500-1000mm.

V) construction. - basic steps.

- hammer hardwood cuttings ~~for~~ pegs through it at intervals of 500 to 1000mm, leaving the cutting protuding about 80mm.
- repeat until whole slope is covered with net.
- & as monsoon rain permits plant grass slips randomly through the netting over the entire area.

VI) Limitation

- Jute netting is only a very temporary aid to vegetation estd.

5) Live wattle fence / Bamboo fencing.

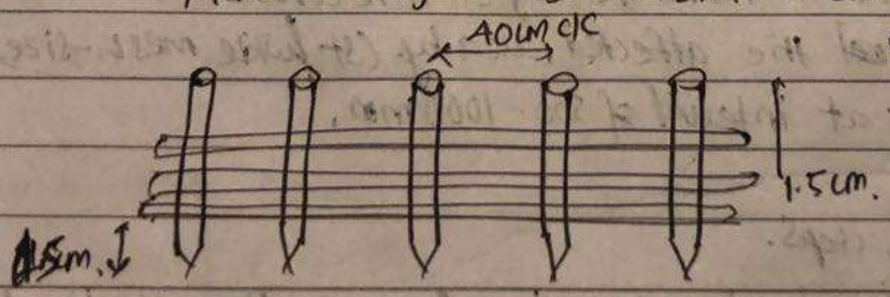
i) function :- debris moving down the slope is trapped behind them. for bamboo fencing, no hard woods are used except bamboo.

ii) site :- slopes min of 30°

iii) Materials :- hardwood cuttings or bamboo cutting at least 1m long & 20 to 40mm in ϕ.
- Hessian & water. (to moisten)
- tools for digging grooves in slope

iv) Design. - spacing - every 4-5m down the slope
- spacing between poles - 40cm c/c.
- Pit 45 - 50cm deep along contour of slope.

v) Construction steps :- ① basic.
- Mark ~~peg~~ & place pegs at intervals about 250mm along the lines.
- dig out a groove (45-50cm deep)
- Place cuttings with their lower ends in the groove.
- Split bamboos in & out between poles to form semi-solid face.
- Plant small grasses and shurbs along upper side of fence.



Limitations.
- too weak to support the volume of debris that is caught.

6) Vegetated earth filled gabions.

- A fill of in-situ earth is placed behind a single layer of dry stone within the gabion basket. Tree seedlings are placed on the gabion.

i) function :- supporting slopes.

ii) Materials :- stones, wire & tools for gabion constn

- Polypot seedlings of tree species are appropriate.

iii) Design :-

~~estimat~~ established at 500mm c/c in random pattern.

iv) construction

→ construct gabion acc. to fill type.

- stone gabions, sow the seeds directly into the ~~gaps~~ below stones (25 seeds per m^3 of gabion)

→ If hardwood cuttings are used a hole must be made right through the gabion into original ground.

- for earth filled gabions, plant 4 ~~pla~~ polypot tree seedling/m^3 at equal spacing at top.

v) limitation :- not well researched in Nepal.

Chap. 09.

1. Nursery.

→ place where plants are propagated & grown to usable size.
→ factory to supply plants,
A good nursery provides.
→ enough plants of the right species,
→ in good, healthy condition.
→ in the form required for planting;
→ at right time and.
→ at a reasonable cost.

2 * Nursery Establishment.

→ it need suitable site selection, calculation of appropriate size of nursery & layout & construction of nursery.

* Site selection.

→ As close as possible to all sites to be planted.
→ established on land owned by DoR or other government's land,
→ should have adequate & reliable supply of water,
→ All weather vehicular access.
→ must have weather & pest proof office cum storage facilities.
→ A const. staff of qualified & experienced people must be provided.
→ Adequate space.
→ Aspect is very important. North facing slopes for nurseries of lower elevations whereas they should be South facing above 1200m.
→ Slope of 2 to 3% is necessary to allow water to drain off without causing erosion.
→ Spacing :- mountain road, 1 nursery per 10 km
Dist. of 25 km between nurseries is adequate.

* Calculating appropriate size of nursery
→ no. of plants to be produced
→ time they will spend in nursery
- density at which they will stand in beds.

→ slope & quality of site influence decision on how much space to allocate.

* Layout & construction of nursery
→ form of factories & need to be laid out with production process in mind.
→ points considered are:
* office /store /chowkidar's hut is normaly placed near gate.
* In hills water tank has to be at highest point of nursery in order to allow gravity feed.
* Place soil & sand store beside the vehicle access & turning area
* Locate the working area beside the soil & sand store.
* Locate the seed beds close to the chowkidar's hut, since these require more attention.
* Orientate the beds to ensure that they receive the max. amt. of light.
* Ensure easy access to all parts of nursery. Do not put the beds too close together.
→ the whole nursery should be well drained.
→ Any remaining corners & rough areas for long term production of grass & hardwood cuttings.

3) Components of Nursery.
1) Main components.
a) General.
b) Office.
c) Storage.
d) Water.
e) Beds.

2) Expendable Materials.
→ Soil & sand
→ seed, grass slips, bamboo cuttings, hardwood cutting & seed.
→ compost fertilizer.
→ fungicide, insecticide.
→ Heavy gauge, polybags for storage.
→ shed material.
→ Wire, nails, string, wire mesh.
→ Seed bed level.
→ Pen, pencil.
→ Poly pots 4"*7"
→ Heavy gauze polythene sheeting
→ Wake proof marker, register, soap

3) Nursery Equipments.
* Pate kuto, chuche kato, Hasiya, shovel, kodalo, chuppi, khukuri Dante, Axe, Hammer, Doko, crowbar, watering can with roses.
* Hose pipe, scissors, padlocks, leather, soil & sand sieves, first aid kit, tape measure.
* Plant carrying trays.
* Seed trays.

4) Nursery staff. (forman, watchman, labors, seed collector.

3) Nursery techniques.

a) Propagation of Grasses.

* Seed. → Plants from seed, either by transplanting as rooted plant, directly on site
* Slip & Rhizome cutting → main method in propagating grass for bio-engineering. root cutting made by splitting ~~or~~ clumps grown in nursery.
→ If grass is rhizomatous the slip consists of section rhizome & some shoots & must include root buds.
* Culm or Stem cutting.
by planting section of stem usually two noded section of culm.
→ carried out either in nurser for transplanting as rooted cutting or directly on site
Eg. Dhonde, napier, nakat

b) Propagation of shurbs & trees.

i) Polypot seedling → Plants grown in polythene container (polypots & move them to site for final transplanting.
→ If seed is reasonably large, it is sown directly into the prepared polypot. If very small, sown in seed bed & later is pricked out to the polypot. Eg. Areci, dhanyero, dhusun, sins, kala, chilaune, gobre sal, sisau, utis, khote salla, khayer.

ii) Hardwood cuttings:
→ a section of woody stem is cut from a parent plant & ~~instead~~ inserted into the soil. From buds on cutting, shoots & roots develop to form a new plant. This is usually done on site later on. Techniques such as brush layering & palisades use hardwood cuttings. Eg. Assuro, banish, kanda phul, namdi phul, saruwa/bihaya, simali etc.

iii) Stump cutting.
→ cutting consisting of sections of plant that include both root & shoot
→ made from seedlings more than one year old raised in soil beds.
Eg. Sisau.

c) Propagation of Bamboo.

-) Large grasses

-) relatively slower growing & harder to establish than the smaller grasses, and tend to grow in damper locations. But once they are established, the big bamboos form huge plants which are useful for catching debris & supporting the slope.

In road sector. two main methods:

* Traditional
* Rooted sing Node clum cuttings.

i) Traditional Methods.

-) a section of rooted rhizome & an entire culm is cut out of an established bamboo clump. It is replanted with the clum cut off about 2 metres above the ground, leaving branches emerging from one or two of the nodes.

ii) Rooted single Node clum cutting.

-) single node of a bamboo clum is planted in wet, well-shaded nursery bed & allowed to root over a period of at least one year. It is then transported for planting on site as a newly rooted plant. Rooted clum cutting are relatively cheap, easy to transport & survive well after planting.

4) Nursery Management.

a) Envt. Mgmt.

i) Shading

making 250 mm ranges, 300 mm seedling

Benefits.

ii) Watering 8-litre watering can / horse pipe

fixed pipe / sprinkler systems.

iii) Cloches.

clear polythene placed over Nursery bed to raise tempr during cooler weather.

Semi circular hoops with bamboo splits every one to two metres along bed.

→ useful in higher altitude nurseries.

b) Restriction of weeds, pests & diseases,

i) weeds. → removal of weeds done frequently.

ii) Insect or mammal pest control.

insecticides → methyl parathion such as Metacid & Paramar.

0.05 % solution of methyl parathion.

Aldrin dust to prevent ants.

Rodents cattle goats ~~removed~~ excluded from nursery

iii) fungal disease control.

→ different fungi

→ Good nursery involves stopping them from killing seedings.

→ no overwatering, removing shade, ensure free air circulation, free of weeds nursery, well drain sandy medium can prevent fungal disease.

c) Preparing plants to leave the nursery.

i) Hardening-off

* removal of shade at an early stage.

* Spacing.

* reduction of watering.

ii) Culling → sorting plants suitable for planting

iii) Preparing & packing grass slips for transport → while packing grass slips, tied grass drums carefully, keeping roots in tact so roots not damaged.

iv) Preparing & packing polypots for transport → thoroughly watering plants in polypots 2 to 3 days before transported.

v) Preparing & packing hardwood plants for transport → wrap in wet jute cloth, tie with string & keep them in cool shady place.

vi) Care of planting stock on site → handle plants, slips, cutting carefully.

d) Use of registers.

* Grass slip hardwood cutting register → keeping track of grass & cutting stocks in a nursery.
* Seedling register → records plants produced from seed in nursery. → progress is checked time of germination onwards.
* Seed identification register → register provides info required to track problems from poor germination.
* Seed collection calendar → serves to remaind staff of seeds that must be collected to provid future plants in the nursery.

e) Making & using compost.
→ breakdown of organic materials by micro-organisms in warm, moist aerated envt.
→ Includes weed, litter, crop residues, animal bedding & dung.

f) Trouble shooting.
→ All nurseries experience difficulties at some stage.
→ most common problem → seeds not germinating, yellow grasses, slow growth, poor growth, wilting leaves,
If cannot resolve a problem call Horticulture wing for specialist advice.

Date.....
Page.....

5) Quality of bio-engineering nurseries.

(i) Grass beds & hard wood cutting beds should be.
* composed of good, fertile & well aerated soil
* kept moist all all times.
* showing even growth.
* kept with porous, uncapped soil surface.

(ii) Grass plants should be.
* a heathy green color.
* growing vigorously, with long new shoots.
* showing no signs of wilting
& attack.

(iii) shurb & tree seed beds should be.
* composed of good fertile, well aerated soil
* keep moist all times
* well weeded
* well shaded
* showing even growth

· Polypot seedling show be.
* showing no signs of wilting
* growing faster with longer new shoots
* well weeded.
* without signs of discoloration on leaves
* undamged.
* no obvious sign of disease.

Whole nurseries should be.
* kept tidy & clean
* weeded throughout
* well maintained.
* protected properly at all times.