Chapter 5
BANK STABILIZATION

Description

Bank stabilization is the process of establishing and implementing resistive measures against erosion and failure of roadway cut slopes or fill embankments. Stabilization may be achieved by either mechanical(structural) means, vegetative, or both.

Erosion can be directly caused by direct rainfall, runoff, wind, freezing, gravity, or a combination of these. The magnitude of these parameters can be effected by changes in upland land use, fire, tree harvest, etc. Indirect causes include flow-line scour within a road ditch, diverted or impeded flow by obstacles within drainage ways and culverts, wave action, seepage, over-bank drainage, off-road vehicles, maintenance machinery, etc.

Bank or slope failure occurs when a section of the bank slides. There are many potential causes. One cause is too steep of a slope gradient for the strength of the soil. High shrink/swell soils (usually fine clays) tend to have the weakest slope stability. These soils crack during dry weather opening fissures which allow rainfall to enter, and thus saturate the soil causing high ranges of swelling. The swelling reduces the soil density, which never recovers when the soil dries out, thus causing further, more extensive cracking. Subsequent rainfall during this cycle will eventually deliver a load and lubrication which the weakened soil cannot resist, resulting in "slip-plane" failure. Other soils, including some sands and sand-clays, are just too weak to "stand" at the steep grades impose on them.

Other causes of slope failure have to do with improper soil compaction, slope toe erosion, groundwater pressure, and excessive artificial loads placed on the slope, such as building construction, automobile parking, etc.

Importance to Maintenance & Water Quality

Proper long term stabilization of banks along roadways and drainage ways will significantly reduce if not prevent costly maintenance, and will contribute significantly to the reduction and prevention of considerable amounts of sediment delivery into streams and waterways. Stable road banks also decrease public disenchantment, improves motorist safety, improves traffic flow, and protects adjacent land.

Implementation

Construction and Grading/Re-Grading

Bank construction and maintenance procedures in relation to compaction (for fills), slope gradient, and surface grading is critical to establishing a long term, stable slope.

Fill slopes should be compacted to a density commonly stable for the soil material used. Loose fill should be placed on a relatively level, scarified surface (roughened one inch) in lifts not to exceed 12 inches, and thoroughly compacted before more material is added. Compaction equipment must cover the entire surface, preferably in a cris-cross pattern, sufficient enough times to achieve the desired compaction. Tests may be required to determine the level of compaction (density). With familiar soils, established, common, and proven methods may be routinely used for expediency and economy. Most fill slopes should be 3 feet horizontal to 1 foot vertical (3:1) or flatter for stability, however, some soils can be placed at steeper slopes to accommodate limited space. Evaluation of the soil material should be made by a professional engineer to determine whether slopes flatter or steeper than 3:1 should be used.

Smooth, and even grading of the slope surface will enhance aesthetics and will also improve the ability to establish a good vegetative cover and maintain it. Slope grades should be straight and true without humps, bellies, dips or ridges. This will reduce concentration of runoff on slopes and promote sheet flow which is less erosive and enhances infiltration of water needed for plant growth. Vertical tracking (up & down slope) with a dozer will also enhance infiltration.

Bank-Grading Techniques

Terracing

The construction of benches on long and/or excessively steep slopes to provide breaks and near level "troughed" areas in the slope which will intercept runoff. These troughs are back-sloped from the slope face to catch runoff and channel it to either end of the embankment. (See figure 5-1).

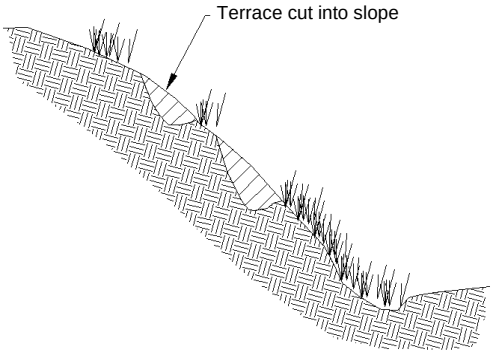


Figure 5-1. Slope Terracing

Cutting and/or Filling

The removal and/or addition of soil to the bank to create the desired slope. May result in flattening the slope to a stable gradient, or involve replacing less stable soils with more stable soil material in the process of regrading the slope. Maximum slope grade should be 3:1 for fill slopes, and 2:1 for cut slopes. (See figure 5-2).

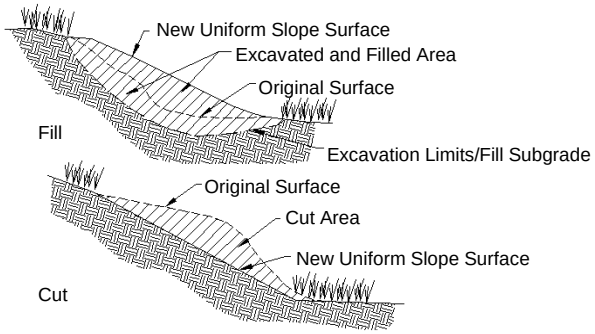


Figure 5-2. Slope Shaping by Cutting and/or Filling

Keying

The cutting of a trench or bench into a slope surface prior to placing fill on it in order to prevent slippage or creep of the added fill. This method is often used when replacing slide material back onto the slope from which it came. (See figure 5-3).

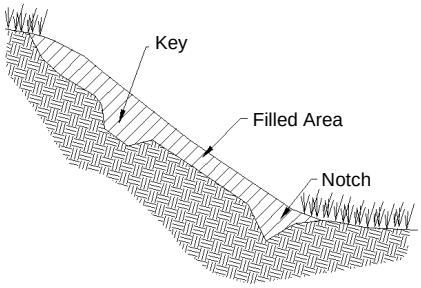


Figure 5-3. Slope Keying for Fill Placement

Counter-weighting

The placing of material (soil, rock, etc.) at the toe of a slope to prevent or halt sliding. The mass weight of the counter-weighting material must exceed the mass weight of the sliding material above it. (See figure 5-4).

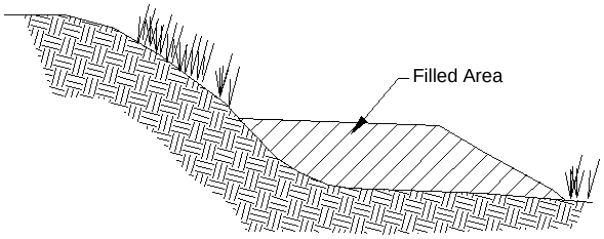


Figure 5-4. Counter-weighting Toe of Slope

Vegetation by Grass Seeding

Grass seeding is the most efficient and cost effective method of stabilizing banks and slopes. This method should always be considered first and use wherever possible. Grass will slow water movement and allow more infiltration. It will effectively hold soil particles in place, reducing sedimentation. The following should be followed when establishing vegetation by seeding.

a. Slopes to be seeded should be no steeper than 2 horizontal to 1 vertical (2:1) and should be covered with a minimum of 2 inches of topsoil. Finish grading should always follow top soil placement.

b. Where soils are unstable, use sod or erosion control blanket and place immediately. Consider mulching graded and finished areas before a rain event if seeding can not be performed.

c. Seed bare areas as soon as possible after disturbance, preferably as soon as a significant area is graded and finished and before the next rain event.

d. Fertilize and lime the area as needed based on soil condition and disk or rake it into the soil surface to a depth of 2 to 4 inches.

e. Use temporary seeding when outside the seeding dates for permanent vegetation.

f. Apply a seed mixture which is appropriate for the climate, soil, and drainage conditions of the site.

g. Seeding can be done by hand or machine broadcasting, or by hydro-seeding. **Do not mix seeds of different sizes** when broadcasting as this will yield an uneven disbursement of seeds. Hydro-seed areas where it is unlikely to get an even disbursement of seeds or a satisfactory germination.

h. Mulch the surface immediately at a rate of 1-1/2 tons per acre and anchor with a disk harrow, mulch anchoring tool, or by tracking. Tracking the mulch in with a dozer is acceptable where soil conditions and moisture are ample to avoid sticking, and the mulch can be adequately creased into the earth. Tracking must be done walking the dozer up and down the slope, making the track creases as near perpendicular to the slope grade as possible.

i. Seeding can sometimes be use in combination with other type vegetation such as trees, shrubs, willow spikes, etc. planted after seeding is complete.

Proper seedbed prep, and straw or mattress mulching, including crimping or pinning. . .

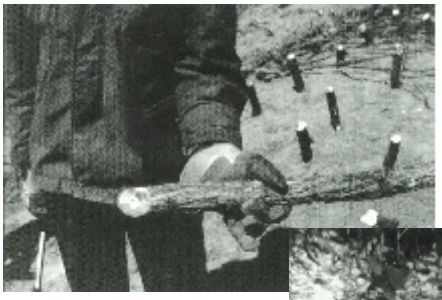
. . . along with other pre-establishment site protection will yield well vegetated, stable, and more easily maintainable . . .

roadway shoulders . . .

roadway ditches . . .

soil storage areas, . . . culvert inlets & outlets, . . . and sediment control.

Exhibit 5.1 - Vegetation by Grass Seeding



Live Stake

Live Stake Planting

Two Year Growth

Live Fascine Installation

Live Fascine Fabrication

Bank Trenching for
Fascine Installation

Second Growing Season

Brush Mattress Installation

Two Month Growth

Two Year Growth

Exhibit 5.2 - Vegetation By Trees & Shrubs

Vegetation by Trees & Shrubs

Trees and shrubs can be used to create a good vegetative filter strip and stabilize steep or wet slopes, stream banks, and/or other areas where stronger and/or larger vegetation than grass is needed for stabilization. Deep rooted species of trees and shrubs provide greater protection against soil slippage problems.

Use native plants of the area to ensure adaptability and reduce costs. Identify plants in the area which are proven to provide the protection and stabilization desired. Some plants common to the CPYRWMA area which are often used for stabilization are willows, alders, and dogwoods. Use the most effective, appropriate technique in planting and establishing trees and shrubs for bank stabilization.

Live stakes

Cuttings of live branches neatly pruned of limbs, usually 1/2 to 1-1/2 inches in diameter, and 2 to 3 feet long. This technique is inexpensive and can be used when time and/or resources are very limited and the site is not complicated. See figure 5-5 below.

1. The basal end should be cut at an angle to facilitate insertion into the ground.
2. Stakes are driven into the ground perpendicular to the slope, basal end first (buds oriented upward), until only 2" to 3" of the stake protrudes above the ground.
3. Stakes are planted in rows on the contour. Stakes in each successive row are staggered yielding an alternating grid pattern with two to four stakes per square yard.
4. Stakes should be cut during dormant seasons and installed the same day as cut, or temporarily stored (a few days) in a very moist, cool environment until use.

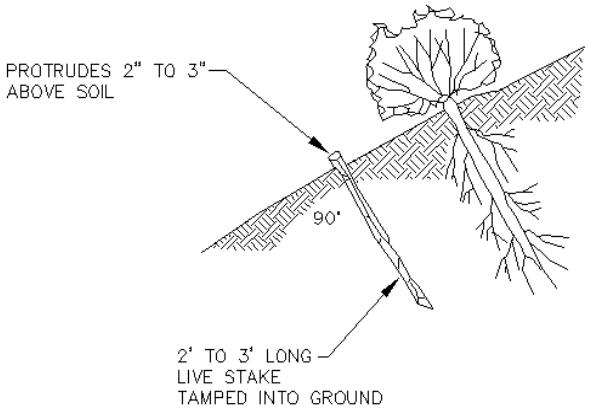


Figure 5-5. Live Stake Planting

Live fascines/wattle/bundles

Long bundles, 5 to 30 feet in length and 6 to 8 inches in diameter, of live branches tied together with growing tips oriented the same direction and tops evenly distributed throughout the length of the bundle. See figure 5-6 below.

1. Can be used on slopes as steep as 1' horizontal to 1' vertical.

2. Bundles are placed in a 12 to 18 inch deep trench dug along the contour of the slope.

3. Bundles should be secured with live stakes placed 33° to 45° off horizontal, basal end down, and strong dead stakes placed vertically through the bundle. All stakes should be 2 to 3 feet long and protrude 2" to 3" above the soil.

4. Bundles are covered with a moist, compacted soil backfill.

5. Bundles should be cut during dormant seasons and installed the same day as cut, or temporarily stored (a few days) in a very moist, cool environment until use.

6. Installation of this practice begins at the toe of the slope and progresses up-slope.

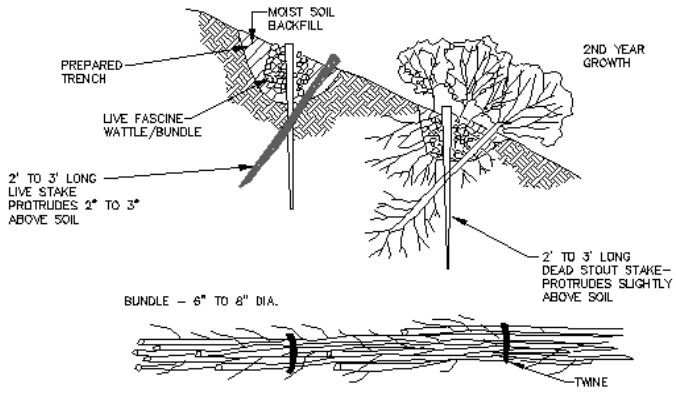


Figure 5-6. Live Fascines/Wattles/Bundles

Brush Layering

Layer of live branches, 1/2 to 2 inches in diameter and 3 to 4 feet long, laid in a benched trench on the contour, and used to break long slopes into smaller slope lengths. See figure 5-7 below.

1. Branches are placed in a slightly inward sloping, benched trench, extending 2 to 3 feet (horizontal distance) into the slope face. Branches are placed with growing tips (buds) outward.

2. Branches are placed in the benches in a slight cris-cross or overlapping pattern.

3. Layers are covered with a moist, compacted soil backfill.

4. Branches should be cut during dormant seasons and installed the same day as cut, or temporarily stored (a few days) in a very moist, cool environment until use.

5. Installation of this practice begins at the toe of the slope and progresses up-slope.

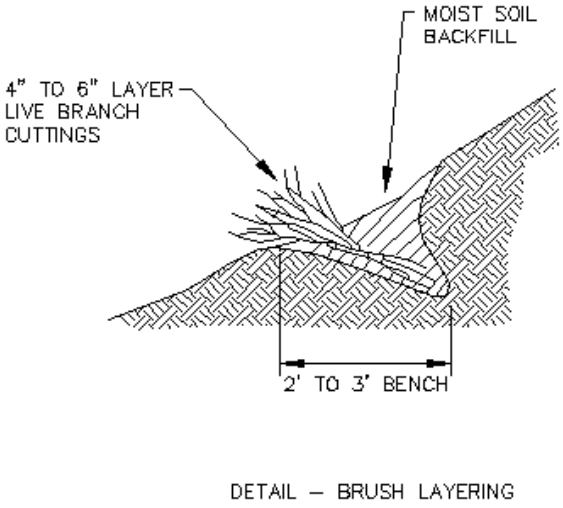


Figure 5-7. Brush Layering Details

Sprigs/plugs

Individual plant stems with roots or rooted cuttings. Often used on filled slopes in conjunction with soil reinforcement materials. See figure 5-8 below.

1. Place sprig/plug in a hole dug at least twice the root ball diameter. Tamp fill soil firmly around root ball leaving no air pockets. Initial saturation around each plant will help ensure consolidation of soil around the root ball and help eliminate air pockets which will dry out the root ball.

2. Plant sprigs/plugs in rows on the contour with sprigs/plugs 1/2 to 1 yard apart. Sprigs/plugs in each successive row are staggered yielding an alternating grid pattern.

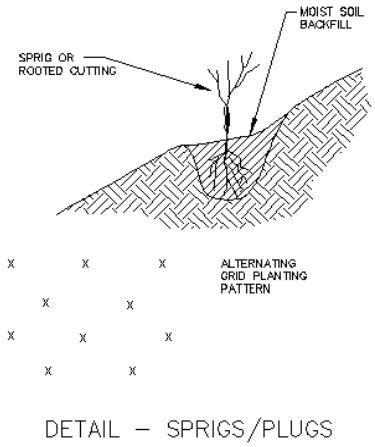


Figure 5-8. Sprig/Plug Planting

Structures

In many cases, permanent or semi-permanent structures must be constructed to support, reinforce, or establish a stable condition or environment to protect road and ditch banks.

Gabion Retaining Wall

Rectangular wire mesh boxes filled with stone, stacked and assembled as a near vertical or stepped wall (figure 5-9) to support the earth material behind it. This structure provides a slope face which can be used where there is limited or no room for a stable inclined earth slope. Gabions can also provide a non-erosive surface for road ditch back-slopes, and can increase infiltration by absorbing some runoff into its porous mass where it is held.

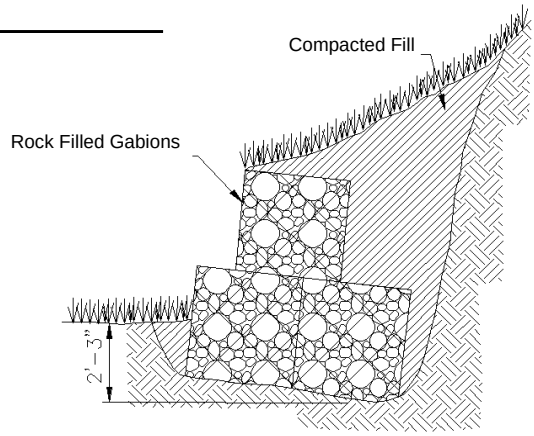


Figure 5-9. Gabion Retaining Wall

Vegetated Gabion Retaining Wall

Rectangular wire mesh boxes filled with stone, stacked and assembled as a near vertical or stepped wall and combined with live branches (as used in brush layering, figure 5-7) to support the earth material behind it in a more permanent, aesthetically pleasing manner. Roots, stems, and associated plant growth will eventually intertwine itself with the stone in the gabions and take the place of the wire mesh when it has deteriorated away (figure 5-10).

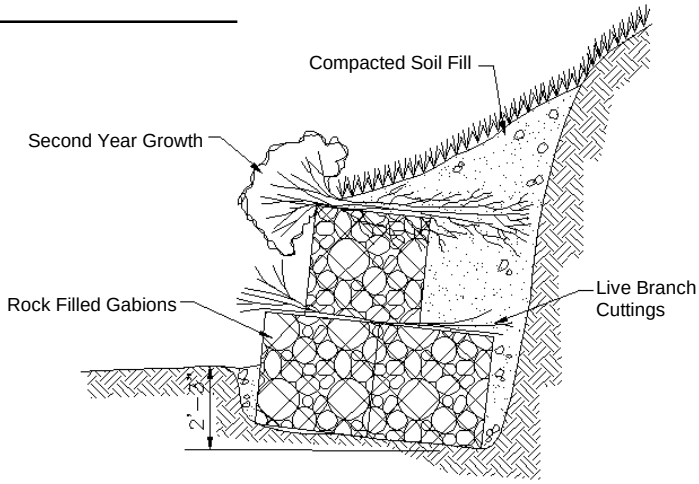
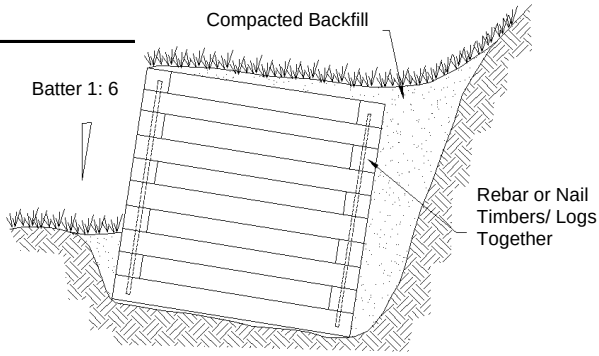


Figure 5-10. Vegetated Gabion Retaining Wall

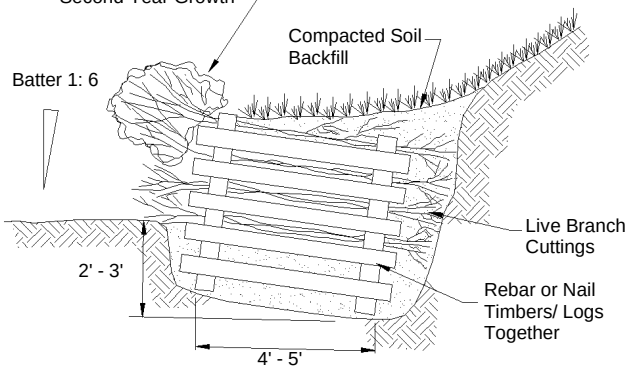
Log or Timber Crib Retaining Wall

Rectangular box made of alternately placed logs or treated timber in a log cabin style construction, filled with soil, rock, or other fill material to provide a stable and supported road or ditch bank. As shown in figure 5-11a, this structure provides a near vertical slope face which can be used where there is limited or no room for a stable inclined earth slope.

Also, as shown in figure 5-11b, the structure can be made more permanent, stable, and aesthetically pleasing by adding live branches (as used in brush layering, figure 5-7). Roots, stems, and associated plant growth will eventually intertwine itself with the wood structure and backfill, thus establishing natural stability. These Structure may be step-constructed to provide planting areas.

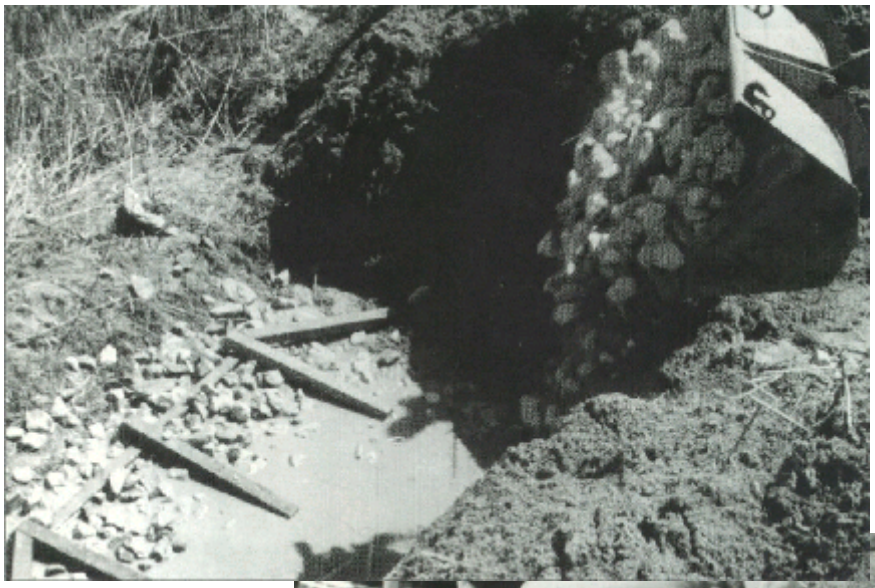


(a)



(b)

Figure 5-11. Log or Timber Crib Retaining Wall



Preparing Foundation of Structure. Rock Fill (Optional) Placed in the Foundation of Structure to the Level of Inundation. Soil Fill May be Used When Inundation or Perennial Flow Will Not be Encountered.

Brush and Wood Member Placement

Frontal View of Completed Live Cribwall

Exhibit 5.3 - Live Crib Wall

Vegetated Riprap Revetment by Design

Two Years Growth

Mechanical Riprap Basin Revetments
Vegetated Naturally with Willows
(Growth Age is a Beaver-Pruned Four Years)

Mechanical Riprap Basin Revetment

Exhibit 5.4 - Vegetative and Mechanical Riprap Revetments

As fill is placed in the crib, lay mats of branches in a cris-cross pattern on top of each fill layer which coincides with an opening between the timbers at the face of the structure. Branch cuttings must be long enough for the basal ends to reach the undisturbed soil at the back of the crib while the growing tips (buds) extend outward approximately 12 inches from the face of the wall.

Each layer of brances shall be covered by at least 2 inches of compacted soil. Fill shall be subsequently placed up to the next brush layer level.

Mechanical Riprap Revetment

A lining of rock riprap covering the surface of a slope or embankment to protect it from erosive forces. Usually used when vegetation is not adequate to protect the slope such as on very steep slopes, sharp directional changes in stream flow, sharp turns in the stream or channel itself, where streams are constricted by bridges or culverts, etc.

Rock size is dependent upon the application. Larger stone will be required for stability where flow volumes and velocities against the riprap are high. Riprap layer thicknesses should be based on maximum rock diameter used and the application. A professional engineer should be consulted where stream flows will be encountered. Riprap armor against flow must always be underlain with a filter such as graded aggregate or geo-fabric.

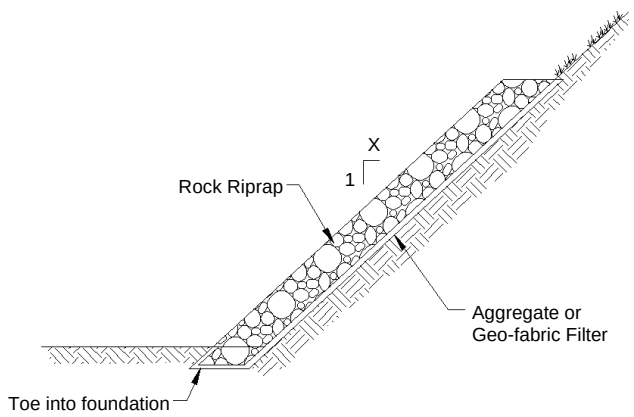


Figure 5-12. Mechanical Riprap Revetment

Vegetated Riprap Revetment

A lining of rock riprap covering the surface of a slope or embankment with live stakes driven through the voids in the riprap and into the subgrade (figure 5-13) to provide enhanced stability and protection from erosive forces. This type of structure can be a near permanent solution to problems recurring when flows and velocities reach extremes, and can also be used in design to reduce the thicknesses and height required in mechanical riprap revetments.

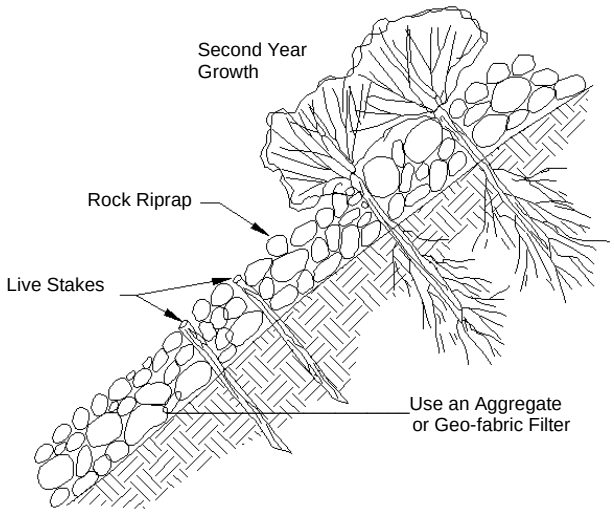


Figure 5-13. Vegetated Riprap Revetment

Mats and Blankets

These products and materials are used to prevent erosion on a temporary basis on steep slopes, in ditches with high flow velocities, and other areas prone to erosive force. They usually deteriorate giving way to vegetation to hold the soil. Some of these products may be spaced longitudinally with the flow in channel flow situations, or laterally across the flow in sheet flow situations such as on slopes.

Examples are: *Jute Matting* - an undyed yarn, woven into an open mesh (usually 1 inch square openings). It is lain over seeded & mulched areas to hold in place and may be used to cover an entire area or spaced on the contour to break concentrated flow and check erosion; *Mulch Blanket (Temporary)* - mulch materials (straw, wood fibers, coconut, etc.) sandwiched between photo-degradable plastic. This product provides the mulching and is lain over seeded areas. It may be used to cover an entire area, but is mostly used in strips on the contour, in specific areas where mulch anchoring is difficult, or where a more intense strength mulching is necessary. *Mulch Blanket (Permanent/Semi-Permanent)* - mulch materials (straw, wood fibers, coconut, plastic coils, etc.) and non-woven geo-fabric sandwiched between photo-degradable plastic. This product is used for resisting surface slippage problems and to provide a stronger resistance to erosive forces. It is often buried and usually requires special engineering and design.

Below are installation recommendations for proper and effective use of these products.

[] bury up-slope ends or edges in a check slot, backfill, and tamp securely in place.

[] Unless otherwise recommended or specified by manufacturer, overlap ends 12 inches and pin securely. Up-slope section lies over down-slope section where applicable.

[] Unless otherwise recommended or specified by manufacturer, overlap edges 4 inches and pin securely. Up-slope section lies over down-slope section where applicable.

[] In accordance with manufacturers recommendations, securely anchor mats with backfilled check slots spaced along the length, and anchor each mat to the earth surface with stakes, pins, and/or staples.

[] make sure all areas prone to up-lift, due to tension in the material, are thoroughly and securely pinned to the ground. Examples are: crease points where the slope changes abruptly (where a flat ditch bottom and its side slopes intersect), swales, or concave slopes.

Geotextiles

Permeable synthetic materials manufactured for use in protecting and filtering soils and/or increasing the strength of the soil profile.

Filter - woven or non-woven fabric. Often used in lieu of an aggregate filter under riprap, gabions, and other structures requiring filtering to inhibit migration of finer soil and fill particles.

Reinforcement Fabric - webbed fabric which can be placed at or below the soil surface to provide improved strength and erosion resistance to the soil surface or profile. Usually requires specialized engineering and design. Often installed horizontally between soil layers of a slope or embankment to increase soil strength and protect against slides. Available in various shapes, sizes, strengths, and configurations.

Reinforcement Grids - pocketed, webbed material forming cells which can be placed at or below the soil surface, filled with soil or other fill material, to provide improved strength and erosion resistance to the soil surface or profile. Usually requires specialized engineering and design. Often installed at the surface. Cells are filled with soil and/or aggregate with a layer of topsoil added, then vegetated with seed or sod, or, filled with aggregate without vegetation to provide a non-erosive surface conducive to traffic or simply for reduced maintenance and/or aesthetics. Available in various shapes, sizes, strengths, and configurations.