D-2 RIPRAP SLOPE STABILIZATION

PURPOSE & APPLICATIONS

Riprap is a permanent, erosion-resistant ground cover constructed of large, loose, angular or sub-angular (rounded) stone. Riprap may be used, as appropriate, at storm drain outlets, on channel banks and/or bottoms, roadside ditches, drop structures, at the toe of slopes, or to stabilized streams. Its purpose is:

- To protect the soil surface from the erosive forces of concentrated runoff.
- To slow the velocity of concentrated runoff while enhancing the potential for infiltration.
- To stabilize slopes with seepage problems and/or fine textured non-cohesive soils.

This practice is applicable at soil-water interfaces where the soil conditions, water turbulence and velocity, expected vegetative cover, etc., are such that the soil may erode under the design flow conditions.

CONSIDERATIONS

Riprap along streambanks can lead to thermal pollution as the sun heats the stone to high temperatures. As the rain falls on the stone, it warms up and raises the stream temperature. Several fish species are very sensitive to small increases in temperature and whenever riprap is used along streams, it should be used in combination with vegetation to shade the stone.

Use vegetation whenever possible as it provides habitat for wildlife species and a buffer capable of taking up pollutants and nutrients from runoff. If riprap is unavoidable, then use a combination of riprap and plantings to provide some vegetative cover.

Since riprap is used where erosion potential is high, construction must be sequenced so that the riprap is put in place with the minimum delay. Disturbance of areas where riprap is to be placed should be undertaken only when final preparation and placement of the riprap can follow immediately behind the initial disturbance. Where riprap is used for outlet protection, the riprap should be placed before or in conjunction with the construction of the pipe or channel so that it is in place when the pipe or channel begins to operate.

No riprap can be installed or repaired along the rivers, ponds, lakes, or the ocean without permission from the DEP and Army Corps of Engineers and all requirements of state laws and permit requirements of local, state and federal agencies must be met.

SPECIFICATIONS

Riprap is composed of three sections:

- The typical **armor layer** is composed of rough, angular rock.
- The **underlying filter layer** supports the stone against settlement, allows groundwater to drain through the structure, and prevents the soil beneath from being washed through the armor layer by waves or groundwater seepage.
- The **toe protection** prevents downward movement of the riprap layer. It is usually constructed by trenching in the riprap at the toe of the slope.

Design Criteria

Types of Riprap: Refer to MDOT specifications for information about standard types of riprap.

Gradation: Since graded riprap consists of a variety of stone sizes, a method is needed to specify the size range of the mixture of stone. The average size of stone in a mixture is described as the D50. In other words, it is specifying a diameter of stone in the mixture for which 50 percent, by weight, will be smaller and 50 percent will be larger.

A mixture composed primarily of the larger stone size but with a sufficient mixture of other sizes filling the progressively smaller voids between the stones is described as a well-graded mixture. The diameter of the largest stone size in such a mixture should be 1.5 times the D50 size.

The designer, after determining the riprap size that will be stable under the flow conditions, shall consider that size to be minimum size and then, based on riprap gradations actually available in the area, select the size or sizes that equal or exceed the minimum size.

Thickness: The minimum thickness of the riprap layer shall be 2.2 times the maximum stone diameter (for a D_{50} of 12" or smaller), but not less than 6 inches. For D_{50} specified greater than 12 inches, the riprap layer thickness shall be 2 times the D_{50}.

Quality of Stone: Stone for riprap shall consist of sub-angular field stone or rough unhewn quarry stone of approximately rectangular shape. The stone shall be hard and of such quality that it will not disintegrate on exposure to water or weathering, be chemically stable and it shall be suitable in all other respects for the purpose intended. The bulk specific gravity (saturated surface-dry basis) of the individual stones shall be at least 2.5. Rubble concrete may be used, if locally allowable and provided it has a density of at least 150 pounds per cubic foot, and otherwise meets the requirements.

Filter Blankets: A filter blanket is a layer of material placed between the riprap and the underlying soil surface to prevent soil movement into or through the riprap. The need for a filter blanket is determined by comparing the particle sizes of the overlying material and the base material:

- **Gravel filter blanket**: The filter material should be a minimum of 6 inches thick. The material shall be a DOT Type C underdrain and shall be free from organic matter. It may be crushed, uncrushed or a washed gravel with the following specifications:

	% By Weight Passing Mesh Sieves
1 inch	100 %
3/4 inch	90 – 100 %
3/8 inch	0 – 75 %
No. 4	0 – 25 %
No. 10	0 – 5.0 %

- **Geotextile filter**: Geotextile filter cloth may be used in place of or in conjunction with gravel filters. Filter blankets should always be provided where seepage from underground sources threatens the stability of the riprap.

Installation Requirements

Subgrade Preparation: The subgrade for the riprap or filter shall be prepared to the required lines and grades. Any fill required in the subgrade shall be compacted to a density approximating that of the surrounding undisturbed material. If placed on fill, fill shall be 95% compacted as determined by Standard Proctor Density. Brush, trees, stumps and other objectionable material (i.e., organic matter) shall be removed.

Filter Blanket: Placement of the filter blanket should be done immediately after slope preparation. For granular filters the stone should be spread in a uniform layer to the specified depth. Where more than one layer of filter material is used, the layers should be spread so that there is minimal mixing of layers.

For geotextile filter cloths, the cloth should be placed directly on the prepared slope. The edges of the sheets should overlap by at least 12 inches. Anchor according to the manufacturer's recommendations and with the pins suggested by the manufacturer. The upper end of the cloth should be buried a minimum of 12 inches deep. The lower end should be toed in. Care should be taken not to damage the cloth when placing the riprap. If damage occurs, that sheet should be removed and replaced or repaired. For large stone, 12 inches or greater, a 4-inch layer of gravel shall be used to prevent damage to the cloth, protection from ultraviolet rays and to provide interfacial contact.

Stone Placement: Placement of riprap should follow immediately after placement of the filter. The riprap should be placed so that it produces a dense well-graded mass of stone with a minimum of voids. The desired distribution of stones throughout the mass may be obtained by selective loading at the quarry, controlled clumping of successive loads during final placing, or by combination of these methods. The riprap should be placed to its full thickness in one operation.

The riprap should not be placed in layers nor dumped as it segregates the various stone sizes. Care should be taken to not dislodge the underlying material when placing the stones.
The finished slope should be free of pockets of small stone or clusters of large stones. Hand placing may be necessary to achieve the required grades and a good distribution of stone sizes. Final thickness of the riprap blanket should be within plus or minus 1/4 of the specified thickness.

Shoreline Riprap Slope Stabilization

In shoreline situations, riprap is generally only used to stabilize areas eroding due to wave scouring and wave impact but it cannot be relied on alone to stabilize slopes failing due to seepage or soil instability. In these cases, stabilization may require the installation of groundwater drains, soil reinforcements, or retaining walls.
Strength: Shore protection structures must be strong, and this can only be achieved by using massive and heavy components that cannot be dislodged by waves.
Flexibility is also desired because it allows the structures to compensate for settlement, consolidation and toe scour.
Wave Height: Wind action or, less critically, moving vessels generate waves and the design water level and wave's height are the defining criteria for appropriately sizing the stones in a riprap embankment. The height of wind-driven waves depends upon the wind speed, direction, duration, fetch length and depth. The U.S. Army Corps of Engineers should be consulted to properly identify the fetch, wind direction and wave height for the site.
Stone Selection: Stone revetment is a proven method of shoreline protection as it is durable. When the height of waves is greater than 5 feet, quarried stones should be used. If the waves are less than 5 feet, than riprap may be sufficient. The stones should be clean, hard, dense, durable, and free of cracks and cleavages
Filter Layer: A filter layer of either special filter cloth or a 6-inch layer of well-graded stone should be provided to prevent the loss of slope material through voids in the armor. Once the fabric is in place, put a layer of ¾-inch washed stone about 3 inches deep on top of the fabric to help distribute the riprap load and prevent rupture of the filter cloth. If using a stone filter layer, get a clean, well-graded mix containing stone sizes ranging from ¾ of an inch to 3 inches.
Stone Size for the Armor Layer: To assure that a riprap shoreline will remain stable, you must specify the size of the stone to be used for the armor layer. The thickness of the riprap layer should be at least 2 times the D50. Be sure that you get a mixture, which includes smaller stone sizes so that small voids in the rock mix can be filled.

INSTALLATION

Install the riprap when the water level is the lowest. Ideally, machinery should be parked on a flat area at the top of the slope, reaching out over the slope. Unstable slopes, however, may have to be worked from the side or toe to avoid possible slope failure due to the weight of the machinery.

- Prior to placing the riprap, the existing ground should be graded to an appropriate slope, preferably no steeper than 1.5 horizontal feet to 1 vertical foot (1.5:1). Clean, well-graded fill material should be added as needed to achieve a uniform grade. The fill should be free of large stones (larger than 6 inches) and firmly compacted before construction proceeds.
- Dig a trench at the toe of the slope to key in the riprap. The key should be at least three feet deep.
- Install the filter layer using proper construction methods for the material. Key-in the filter fabric at the top of the riprap edge and extend the fabric into the toe trench. A stone filter should extend into the toe trench and, if possible, be compacted against the native soil prior to placing the riprap.
- Stone placement should start at the toe trench and work upwards; making sure the armor layer is at least two stones thick and completely covers the fabric or stone filter. An excavator bucket may be used to compact the stone into a solid, interlocking mass. In addition, it may be necessary to place smaller stones by hand in order to get a uniform surface.

MAINTENANCE

Despite its strength, riprap is not maintenance free. Inspect the slope in the spring, in the fall, and after severe storms for slumping, sliding, or seepage problems. Correct any problems immediately. Severe slumping or sliding may indicate that the slope is failing due to forces other than wave impact. Make a careful inspection of the land to the side of the riprap area. Near the riprap edge, erosion may be accelerated. If this is the case, additional measures may be necessary to halt the erosion.