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Riprap

Description

Riprap is a layer of large stones used to protect soil from erosion in areas of concentrated runoff. Riprap can also be used on slopes that are unstable because of seepage problems.

Riprap consists of crushed rock placed on filter fabric on a prepared surface. The individual stones are typically angular in shape and well graded so that they will interlock. This interlocking property combines with the weight of the stone to form a solid mass that will resist erosion.

Selection Criteria

Use riprap to stabilize slopes from construction (cut-and-fill), channel side slopes and bottoms, BMP inlets and outlets, check dams, slope drains, and storm drains. Riprap is an integral part of a number of BMPs (See also 4.1 Check Dam (CD), 4.4 Construction Exit (CE), 4.6 Inlet Protection (IP), 4.7 Outlet Protection (OP), 4.10 Sediment Trap (ST), 7.1 Dry Detention Basin (DDB), 7.3 Wet Detention Basin (WDB) and others in this Manual).

Design Considerations

Riprap can be unstable on very steep slopes, especially when rounded rock is used. For slopes steeper than 2:1, consider using materials such as geotextile matting (See Geotextile Matting (MA) other than Riprap for erosion protection.

Consider the following design recommendations for Riprap installation (Smolen et al., 1988):

- *Gradation. Use a well-graded mixture of rock sizes instead of one uniform size.*
- *Quality of stone. Use Riprap material that is durable so that freeze and thaw cycles do not decompose it in a short time; most igneous stones, such as granite, have suitable durability.*
- *Riprap depth. Make the Riprap layer at least two times as thick as the maximum stone diameter.*
- *Filter material. Apply a filter material--usually a synthetic cloth or a layer of gravel--before applying the Riprap. This prevents the underlying soil from moving through the Riprap.*
- *Riprap Limits. Place Riprap so it extends to the maximum flow depth, or to a point where vegetation will be satisfactory to control erosion.*
- *Curves*. Ensure that Riprap extends to five times the bottom width upstream and downstream of the beginning and ending of the curve and the entire curved section. *Riprap Size*. The size of the rip rap material depends on the shear stress of the flows the Riprap will be subject to, but it ranges from an average size of 2 inches to 24 inches in diameter (Idaho Department of Environmental Quality, no date).

- *Wire Riprap Enclosures (Gabions)*. Consider using chain link fencing or wire mesh to secure Riprap installations, especially on steep slopes or in high flow areas.

Riprap Lined Ditch Design Example
(See also Channel Linings with Basic Flow Calculations BMP)
As an example of design considerations, the following discusses use of Riprap as a ditch lining. Similar design considerations will be needed for other applications such as a Riprap aprons. This example is taken from TDOT's Drainage Design Manual and refers to it as a reference for more specific design examples.

Due to environmental concerns, the use of Riprap as a ditch lining should be minimized. Permanent turf reinforcement mats are often an effective substitute. In general, Riprap should be used where perennial flows or frequent ponding would drown a vegetated lining or where the shear stress on an unvegetated permanent turf reinforcement mat during the 2-year storm event exceeds the shear strength of the lining. The selection of Riprap class is based on the computed velocity in the ditch. However, if the slope of the proposed ditch is 10 percent or greater, special criteria apply. Where this is the case, the selection of Riprap should be based on the criteria provided below in the section 'Riprap Linings on Steep Slopes'.

Detailed design for use of Riprap lined ditches should generally be needed only in areas were the ditch slope exceeds 1 percent or the drainage area is greater than 5 acres. To insure an adequate ditch design, the capacity and lining of the ditches for a project should be spot-checked at the following points:

- Points just upstream and just downstream of any grade break in the ditch profile.
- At the approximate midpoint of any curved portion of the alignment where the ratio of the radius of curvature, Rc, to the bottom width of the ditch, B, is 3 or less.
- Just downstream of any point where a significant amount of flow is added to the ditch, such as culvert or other drainage structure outlets (but usually not including underdrain outlets).
- Just upstream of any culvert inlet or any other structure that would receive flows from the ditch
- Just upstream of any ditch outlet.

Specific examples of ditch designs can be found at:
http://www.tdot.state.tn.us/Chief_Engineer/assistant_engineer_design/design/DrainManpdf/Chapter%205.pdf

Riprap Linings on Steep Slopes
In general, Riprap stability on a ditch side slope depends on the forces acting on the individual stones in the Riprap layer. These forces include the weight of a stone, the lift, and drag forces induced on it by the ditch flow. On a steep slope, the weight of a stone has a significant component in the direction of flow. Because of this, a stone within the Riprap will tend to be moved by the flow more easily than the same stone on a mild gradient. Hence, for a given discharge, ditches on steep slopes require larger stones to compensate for the greater shear forces in the flow direction.

Stone size is less critical for wire enclosed Riprap (gabions) on steep slopes because the stones are bound by a wire mesh which allows the material to act as a single unit. However, the stability of wire enclosed Riprap depends on the integrity of the wire mesh. In ditches carrying high concentrations of sediment or rocks, the wire mesh may be abraded and could potentially fail. Thus, the use of these structures should be avoided where such conditions exist.

The actual vector analysis of riprap stability on steep slopes can be very complex and involves a number of assumptions. Tables 1 through 4 are provided below as a guide for selecting Riprap for ditches on steep gradients. For a given ditch slope and cross section, these tables specify the greatest design discharge allowed for different classes of Riprap linings. It should be noted that the tables are based on a safety factor of 1.5. A detailed procedure for the use of these tables is presented TDOT's Drainage Manual at:
http://www.tdot.state.tn.us/Chief_Engineer/assistant_engineer_design/design/DrainManpdf/Chapte%205.pdf

To the extent possible, steep ditches should be on straight alignments. Freeboard should be equal to the average depth of flow, since the wave heights in the flow may reach approximately twice the mean depth. In addition, an energy dissipation structure such as a Riprap basin may be required where the steep ditch transitions to a mild gradient ditch. More information on the use and design of these structures may be obtained in Chapter 9 of the TDOT Drainage Manual at: http://www.tdot.state.tn.us/Chief_Engineer/assistant_engineer_design/design/DrainManpdf/Chapte%205.pdf.

Standardized Riprap Size Definitions

The classes of machined Riprap which are generally used for channel linings are described below. It should be noted that the D50 values listed below are approximate and intended only to aid the designer in evaluating the hydraulic performance of the various classes of machined Riprap.

Machined Riprap (Class A-1) may be used for flow velocities up to 5 feet per second. The median stone size (D50) for this class of Riprap is approximately 9 inches and it is placed to a minimum depth of 18 inches. Machined Riprap Class A-2 consists of the same basic material as Class A-1 Riprap; however, it is hand-placed to a depth of 12 inches. Because of the difficulty in ensuring the integrity of hand placement, machined Riprap Class A-2 is not recommended for ditch linings. Class A-3 is also not recommended due to the small size of the stone.

Machined Riprap (Class B) may be used for flow velocities greater than 5 feet per second, up to 10 feet per second. The D50 of this material is approximately 15 inches.

Machined Riprap (Class C) may be used for flow velocities greater than 10 feet per second, up to12 feet per second. The D50 of this material is approximately 20 inches.

If Riprap is to be placed on a ditch side slope steeper then 3H:1V, more attention to design is needed. See Chapter 4 of the FHWA publication HEC-15 to insure that the Riprap on the side slopes will be stable.

Limitations

The steepness of the slope limits the applicability of Riprap, because slopes greater than 2:1 can cause Riprap loss due to erosion and sliding. If used improperly, Riprap can actually increase erosion. In addition, Riprap can be more expensive than other stabilization options.

Maintenance

Inspect Riprap areas annually and after major storms. If Riprap has been damaged, repair it promptly to prevent a progressive failure. If repairs are needed repeatedly at a location, evaluate the site to determine if the original design conditions have changed. Also, you might need to control weed and brush growth in some locations.

Photos 1 - 4
Riprap in Various Applications

Photos 5 - 8
Riprap in Various Applications

References:

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