6.31

RIPRAP AND PAVED CHANNELS

Definition

Channels with erosion-resistant linings of riprap, paving, or other structural material designed for the conveyance and safe disposal of excess water.

Purpose

To convey concentrated surface runoff without erosion.

Conditions Where Practice Applies

This practice applies where design flow velocity exceeds 2 ft/sec so that a channel lining is required, but conditions are unsuitable for grass-lined channels. Specific conditions include:

- Channels where slopes over 5% predominate; continuous or prolonged flows occur; potential for damage from traffic (people or vehicles) exists; or soils are erodible, and soil properties are not suitable for vegetative protection.
- Design velocity exceeds that allowable for a grass-lined channel.
- Property value justifies the cost to contain the design runoff in a limited space.
- Channel setting warrants the use of special paving materials.

Planning Considerations

Riprap or paving materials are generally employed as channel liners when design flow velocities exceed the tolerance of grass or where grass lining is inappropriate (Practice 6.30, *Grass-lined Channels*).

Flexible liners are preferred to rigid liners, and riprap is the flexible liner of choice. Riprap is preferred primarily on the basis of cost, but it has several additional advantages such as:

- Riprap liners can be designed to withstand most flow velocities by choosing stable stone size.
- Riprap adjusts to unstable foundation conditions without failure.
- Failure of a riprap liner is not as expensive to repair as a rigid liner would be.
- The roughness of riprap reduces outlet velocity, and tends to reduce flow volume by allowing infiltration.

Rigid liners such as concrete or flagstone can carry large volumes of water without eroding. However, they are more expensive to design and construct, are less forgiving of foundation conditions, and introduce high energies that must be controlled and dissipated to avoid damage to channel outlets and receiving streams.

Channels combining grassed side slopes and riprap or paved bottoms may be used where velocities are within allowable limits for grass lining along the channel sides, but long-duration flows, seepage, or a high velocity flow would damage vegetation in the channel bottom.

Paving blocks and gabions have some of the same characteristics as riprap, and are often used instead of riprap to fit certain site conditions.

Channels with smooth liners, such as concrete or flagstone, usually are not limited by velocity, take up less land area, and can be constructed to fit limited site conditions. In addition, they provide a more formal appearance and usually require less maintenance. Exercise care to see that foundation soils are stable, and proper foundation drainage is installed. Appropriate measures are needed to reduce the exit velocity of the paved channel to protect the receiving channel or outlet.

Where urban drainage area exceeds 10 acres it is recommended that riprap and paved channels be designed by an engineer experienced in channel design.

Design Criteria

Capacity—Design channels to contain the peak runoff from the 10-year storm as a minimum. Where flood damage potential is high, expand the capacity to the extent of the value or hazard involved.

Velocity—Compute velocity using Manning's equation with an appropriate *n* value for the selected lining. Values for Manning's *n* are shown in Table 6.31a.

Table 6.31a
Guide for Selecting Manning *n* Values

Lining Material	*n*
Concrete:	
Trowel finish	0.012-0.014
Float finish	0.013-0.017
Gunite	0.016-0.022
Flagstone	0.020-0.025
Paving blocks	0.025
Riprap	Determine from Table 8.05f
Gabion	0.025-0.030

Channel gradient—When the Froude Number is between 0.7 and 1.3, channel flows may become unstable and the designer should consider modifying the channel slope. Reaches designed for supercritical flow should be straight unless special design procedures are used.

$$FR = \frac{\sqrt{Q^2B}}{gA^3}$$

where:

FR = Froude Number, dimensionless
Q = Discharge, ft^3/sec
B = Water surface width, ft
g = 32.2 ft/sec^2
A = Cross-sectional area, ft^2

Cross section—The cross section may be triangular, parabolic, or trapezoidal. Reinforced concrete or gabions may be rectangular (Figure 6.31a).

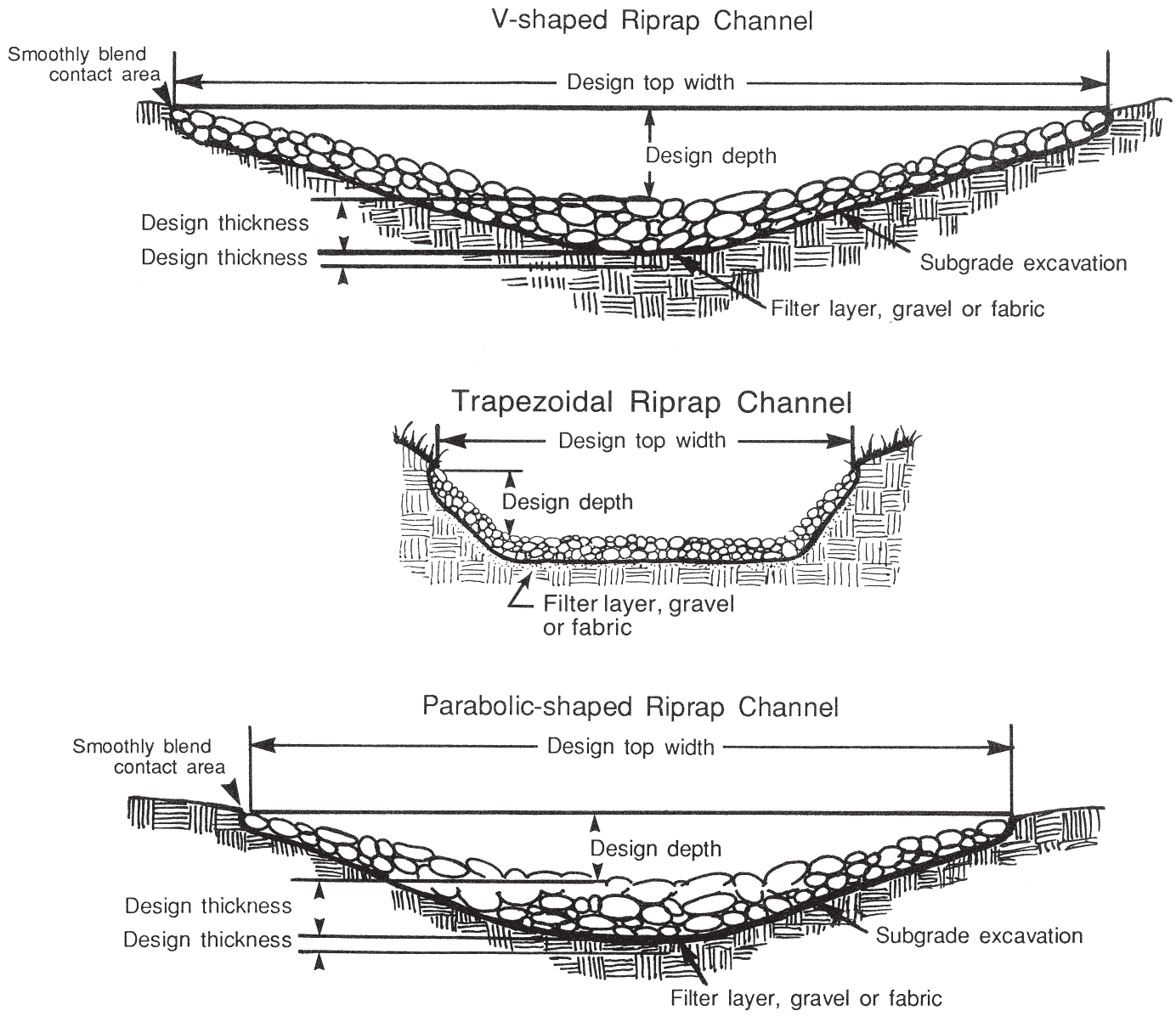

Figure 6.31a Construction detail of riprap channel cross sections.

Side slope—Base side slopes on the materials and placement methods in Table 6.31b.

Hydraulic grade line—Ensure that the design water surface in the channel meets the design flow elevations of tributary channels and diversions. Ensure that it is below safe flood elevations for homes, roads, or other improvements.

Table 6.31b
Guide for Selecting Channel Side Slopes

	Maximum Slope
Nonreinforced Concrete	
Formed Concrete	
Height of lining 1.5 ft or less	vertical
Screeded concrete or flagstone mortared in place	
Height of lining less than 2 ft	1:1
Height of lining more than 2 ft	2:1
Slip form concrete	
Height of lining less than 3 ft	1:1
Riprap and Paving Blocks	2:1

Depth and width—Proportion the channel depth and width to meet the needs of drainage, carrying capacity, foundation limitations, and specific site conditions.

Lining thickness—Minimum lining thickness should be as shown in Table 6.31c.

Filter layer—A sand/gravel filter layer should be used under the channel lining to prevent piping and reduce uplift pressure (*Appendix 8.05*).

Riprap—For the design of riprap channels see *Appendix 8.05*.

Concrete—Concrete for linings should be a dense, durable product sufficiently plastic for thorough consolidation, but stiff enough to stay in place on side slopes. As a minimum, use a mix certified as 3,000 lb/inch^2.

Cutoff—Cutoff walls are needed at the beginning and end of paved or riprapped channel sections to protect against undercutting. Expansion joints and additional cutoff walls may also be needed.

Outlets—Evaluate the capacity and stability of all channel outlets and protect them from erosion by limiting exit velocity (Practices 6.40, *Level Spreader* and 6.41, *Outlet Stabilization Structure*).

Table 6.31c
Channel Lining Thickness

Material	Minimum Thickness
Concrete	4 inches
Rock riprap	1.5 times maximum stone diameter
Flagstone	4 inches including mortar

Construction Specifications

1. Clear the foundation area of trees, stumps, roots, loose rock, and other objectionable material.

2. Excavate the cross section to the lines and grades of the foundation of the liner as shown on the plans. Bring over-excavated areas to grade by increasing the thickness of the liner or by backfilling with moist soil compacted to the density of the surrounding material.

3. Concrete linings:

- Place concrete linings to the thickness shown on the plans and finish them in a workmanlike manner.
- Take adequate precautions to protect freshly placed concrete from extreme temperatures to ensure proper curing.
- Ensure that subgrade is moist when concrete is poured.
- Install foundation drains or weep holes where needed to protect against uplift and piping.
- Provide transverse (contraction) joints to control cracking at approximately 20-feet intervals. These joints may be formed by using a 1/2-inch thick removable template or by sawing to a depth of at least 1 inch.
- Install expansion joints at intervals not to exceed 100 feet.

4. Rock riprap linings: Practice 6.15, *Riprap*.

5. Place filters, beddings, and foundation drains to line and grade in the manner specified. Place filter and bedding materials immediately after slope preparation. For synthetic filter fabrics, overlap the downstream edge by at least 12 inches with the upstream edge which is buried a minimum 12 inches in a trench. See figure 6.14a, page 6.14.6. Space anchor pins every 3 feet along the overlap. Spread granular materials in a uniform layer. When more than one gradation is required, spread the layers so there is minimal mixing. Filter material should consist of at least 3 inches of material on all sides of the drain pipe. The drain pipe conduit should be a minimum of 4 inches in diameter. Acceptable materials include perforated, continuous, closed-joint conduits of clay, concrete, metal, plastic, or other suitable material (Practice 6.81, *Subsurface Drain*).

6. Perform all channel construction to keep erosion and water pollution to a minimum. Immediately upon completion of the channel, vegetate all disturbed areas or otherwise protect them against soil erosion. Where channel construction will take longer than 30 days, stabilize channels by reaches.

Maintenance

Inspect channels at regular intervals as well as after major rains, and make repairs promptly. Give special attention to the outlet and inlet sections and other points where concentrated flow enters. Carefully check stability at road crossings, and look for indications of piping, scour holes, or bank failures. Make repairs immediately. Maintain all vegetation adjacent to the channel in a healthy, vigorous condition to protect the area from erosion and scour during out-of-bank flow.

References

Surface Stabilization
6.11, Permanent Seeding
6.15, Riprap

Runoff Conveyance Measures
6.30, Grass-lined Channels

Outlet Protection
6.41, Outlet Stabilization Structure

Other Related Practices
6.81, Subsurface Drain

Appendices
8.03, Estimating Runoff
8.05, Design of Stable Channels and Diversions