Rock Sizing for Slope Drain Outlets

STORMWATER MANAGEMENT PRACTICES

Photo 1 – Slope drain with rock-lined outlet structure

Photo 2 – Flexible-pipe slope drain with rock-lined outlet structure

1. Introduction

A 'slope drain' is a prefabricated solid-wall or lay-flat pipe anchored to the side of an embankment to provide temporary stormwater drainage. They are normally used to provide drainage during the revegetation of an embankment or as part of a flow diversion system.

An 'outlet structure' is the rock pad placed at the outlet of a slope drain to control soil scour and to dissipate flow energy.

The primary performance objectives of an outlet structure are to minimising the risk of soil erosion at the outlet, spread the released flow, and to dissipate flow energy. The critical design parameters are the mean rock size (d_{50}) and length of rock protection (L).

2. Rock sizing for slope drain outlet structures

The following information is appropriate for the design of loose rock outlet structures for small slope drains up to 375 mm diameter.

Tables 2 and 3 provide the recommended mean (d_{50}) rock sizes and length (L) of rock protection for slope drain outlets for smooth and rough internal sidewall pipes respectively. These design tables are based on the acceptance that some degree of rock movement and minor soil erosion will occur following the initial storm events.

The thickness of the rock pad should be based on at least two layers of rock. This typically results in a minimum thickness as presented in Table 1.

The typical layout of a rock pad for a slope drain is shown in Figure 1. The rock pad should be straight and align with the direction of the pipe outlet.

If the width of the rock pad is governed by the width of the receiving channel, then the rock protection should ideally extend up the banks of the channel to a height no less than the central elevation of the pipe outlet, but no more than the expected depth of flow.

Slope drain outlet structures should be constructed at a level grade, or a gradient equal to that of the receiving channel.

The surface level of the downstream end of the rock pad should be level with the invert of the receiving channel, i.e. the rocks should be recessed into the outlet channel to minimise the risk of erosion around the outer edges of the rock pad.

The placement of filter cloth under the rock pad is generally considered optional for temporary outlet structures placed at the end of slope drains.

Table 1 – Minimum thickness (T) of rock pad

Min. Thickness (T)	Size distribution (d_{50}/d_{90})	Description
1.4 d_{50}	1.0	Highly uniform rock size
1.6 d_{50}	0.8	Typical upper limit of quarry rock
1.8 d_{50}	0.67	Recommended lower limit of distribution
2.1 d_{50}	0.5	Typical lower limit of quarry rock

[1] d_{50} = nominal rock size (diameter) of which 50% of the rocks are smaller (i.e. the mean rock size).

Table 2 – Mean rock size (mm) and length (m) of rock pad outlet structure for smooth internal sidewall slope drain

Pipe diameter: 300 and 375mm						Smooth internal sidewall: Manning's n = 0.01							
Pipe slope (X:1)	Pipe discharge (L/s)												
	30	40	50	60	70	80	100	120	140	160	180	200	220
10	150	150	150	150	150	150	200	200	200	200	200	300	300
8	150	150	150	150	150	150	200	200	200	200	300	300	300
7	150	150	150	150	150	150	200	200	200	300	300	300	300
6	150	150	150	150	150	200	200	200	300	300	300	300	300
5	150	150	150	150	200	200	200	200	300	300	300	300	300
4	150	150	150	200	200	200	200	300	300	300	300	300	300
3	150	150	200	200	200	200	300	300	300	300	300	300	300
2	150	200	200	200	200	300	300	300	300	300	400	400	400
1	200	200	300	300	300	300	300	400	400	400	400	400	400
L [1]	**1.1**	**1.2**	**1.5**	**1.5**	**1.5**	**1.5**	**1.7**	**2.0**	**2.0**	**2.0**	**2.1**	**2.1**	**2.5**

[1] Recommended minimum length (m) of rock pad outlet structure.

Table 3 – Mean rock size (mm) and length (m) of rock pad outlet structure for rough internal sidewall slope drain

Pipe diameter: 300 and 375mm						Rough internal sidewall: Manning's n = 0.03							
Pipe slope (X:1)	Pipe discharge (L/s)												
	30	40	50	60	70	80	100	120	140	160	180	200	220
10	150	150	150	150	150	150	150	150	150	150	150	150	150
8	150	150	150	150	150	150	150	150	150	150	150	150	150
7	150	150	150	150	150	150	150	150	150	150	150	150	150
6	150	150	150	150	150	150	150	150	150	150	150	150	150
5	150	150	150	150	150	150	150	150	150	150	150	150	150
4	150	150	150	150	150	150	150	150	150	150	150	150	200
3	150	150	150	150	150	150	150	150	150	150	200	200	200
2	150	150	150	150	150	150	150	150	200	200	200	200	200
1	150	150	150	150	150	150	200	200	200	200	300	300	300
L [1]	**1.6**	**1.8**	**1.9**	**2.1**	**2.2**	**2.3**	**2.5**	**2.6**	**2.8**	**2.9**	**3.1**	**3.2**	**3.3**

[1] Recommended minimum length (m) of rock pad outlet structure.

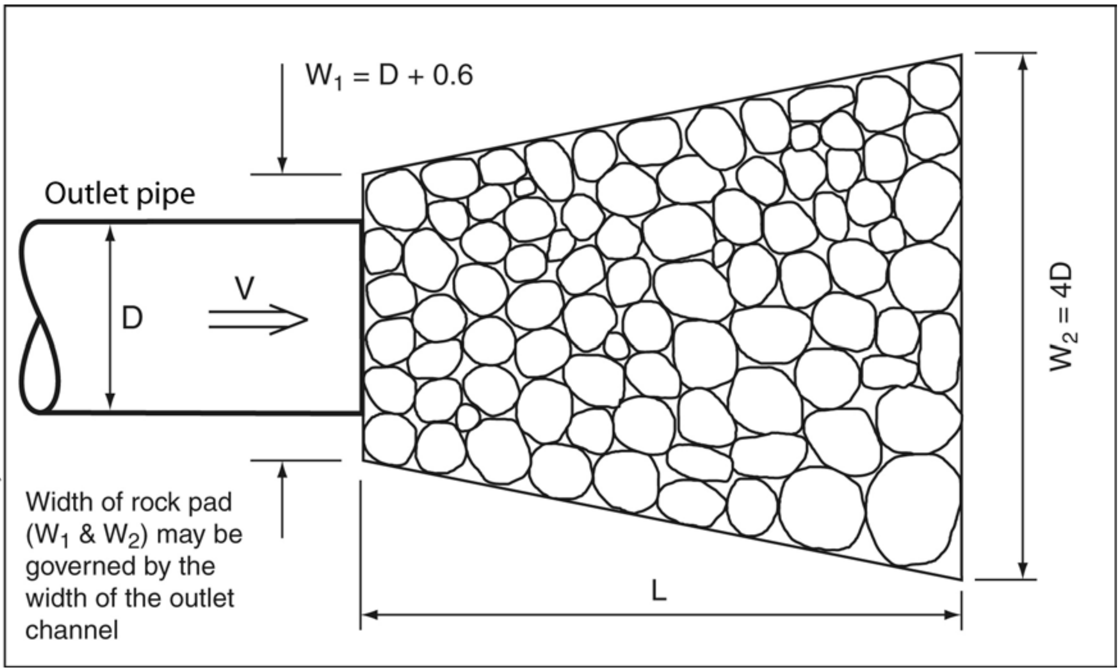

Figure 1 – Typical layout of a rock pad for a slope drain outlet (plan view)

3. Background to rock sizing tables

Many of the rock sizing charts traditionally presented for the design outlet structures can attribute their origins to Bohan (1970). This research work was based on low gradient flow conditions where the pipe is flowing full just upstream of the outlet, and during low tailwater conditions, the flow passes through critical depth at or near the outlet of the pipe. Such flow conditions are not consistent with the high-velocity, partial-full flow expected at the base of a slope drain.

The rock sizes and pad lengths presented in Tables 2 and 3 have been determined by firstly determining the partial-full, supercritical flow velocity expected at the base of a slope drain for a given discharge, internal pipe roughness, and slope gradient. Secondly an equivalent pipe diameter was determined that would have a full-pipe discharge and velocity equivalent to that determined above. Using this equivalent pipe diameter and actual discharge velocity, the design charts presented by Bohan for low tailwater conditions were used to determine the required mean rock size and length of rock protection. The rock sizes where then rounded up to the nearest 100 mm rock size, with a minimum rock size set as 150 mm.

4. Reference

Bohan, J.P. 1970, *Erosion and riprap requirements at culvert and storm-drain outlets*. Research Report H-70-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, USA.