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Railway Drainage Systems Manual

Part 2C: Design of Drainage System components

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1 Purpose

The purpose of this Part of the Manual is to provide guidance on the design of the components of a Drainage System.

2 Scope

This Part of the Manual applies to the design of new and remediated Drainage Systems. It provides guidance on the methods to be used to estimate the flow capacity of components in a Drainage System:

3 Drainage components

3.1 Lined Channel Drains

The flow capacity of a Channel Drain should be calculated considering open channel flow and making the following assumptions:

- steady flow - that is, the flow does not vary with time;
- uniform flow - that is, the flow conditions do not vary with distance along the length of the channel, this means that the water surface is parallel to the bed of the channel.

The invert level of a Channel Drain should be below the level to which it is desired to lower the free water surface.

The capacity of Channel Drains can be determined using Manning's equation:

$$Q = \frac{1}{n} A R^{2/3} S^{1/2} \quad \text{Equation 2C.1}$$

where:

Q is the flow;

n is the hydraulic roughness coefficient (see Table 2C.1);

A is the cross-sectional area of the channel below water level (see Table 2C.2);

R is the hydraulic radius (A/P , where P is the wetted perimeter of the channel);

S is the slope of the channel.

The value of n depends upon the nature of the material forming the bed and banks of the channel. It is also affected by changes in the cross-section and alignment of a channel and the presence of vegetation in the channel. The selected value should reflect the realistic condition of the channel in operation rather than its condition immediately following Remediation.

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	Material	Roughness coefficient
Earth uniform section	Clean channel	0.016 – 0.018
	With short grass	0.022 – 0.027
	Gravelly soil	0.022 – 0.025
Earth fairly uniform	No vegetation	0.022 – 0.025
	Grass plus some weeds	0.030 – 0.035
Lined open channels	Concrete lining	0.013 – 0.017
	Gravel bottom concrete sides	0.017 – 0.020
	Gravel bottom rip-rap sides	0.023 – 0.033
	Asphalt rough	0.016
	Asphalt smooth	0.013

Table 2C.1: Roughness coefficients

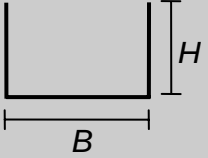
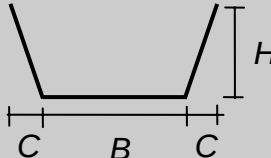
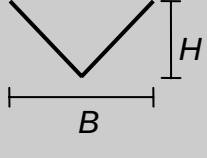
	Rectangular	Trapezoidal	Triangular
			
Area, A	BH	$BH + CH$	$\frac{1}{2}BH$
Wetted perimeter, P	$B + 2H$	$B + 2\sqrt{H^2 + C^2}$	$\sqrt{B^2 + 4H^2}$
Hydraulic Radius, R	$\frac{BH}{B + 2H}$	$\frac{BH + CH}{B + 2\sqrt{H^2 + C^2}}$	$\frac{BH}{2\sqrt{B^2 + 4H^2}}$

Table 2C.2: Geometric parameters

For most common cross-sectional shapes, the geometric parameters, area (A) and hydraulic radius ($R = A/P$, where P is the wetted perimeter of the channel) should be determined using Table 2C.2.

In assessing the capacity of a channel, it is recommended to assume that the water surface is at least 150mm below the top of the channel (this is equivalent to a 150mm freeboard to allow for waves and other disturbances). Hence the value of H to be used in Table 2C.2 should be the actual depth of the channel less, at least, 150mm.

An estimate of the flow capacity of a channel could also be derived using published Wallingford tables (*Tables for the hydraulic design of pipes, sewers and channels*) or software such as the EA'S Conveyance Estimation System (CES) which is freely available from <http://www.river-conveyance.net>.

When selecting the geometric parameters of the Channel Drain the following should be taken into account:

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1. Gradients of railway Drainage Systems should be 1 in 500 or less but, where practicable, Channels Drains should not be installed at slopes less than 1 in 200 because the flow velocity will be low and allow material to be deposited in the channel.
2. If the flow velocity exceeds the maximum permissible flow velocity for the material forming the bed or banks of the Channel Drain (see Table 2C.3) the design should be modified or the Channel Drain lined to eliminate the risk of erosion of the channel.

Material	Maximum velocity (m/s)
Fine sand	0.45
Silt loam	0.60
Fine gravel	0.75
Stiff clay	0.90
Coarse gravel	1.20
Shale, hardpan	1.50
Vegetation	0.75 - 2
Concrete	6

Table 2C.3: Suggested maximum permissible flow velocities

It is difficult to assess the maximum flow velocity for vegetated channels because the velocity is strongly dependent on the type and growth of vegetation.

3.2 Stepped Channel Drains on Earthwork slopes

Velocities in stepped Channels Drains on Earthwork slopes can be supercritical. Air entrainment occurs at high velocities and produces a bulking effect that increases the depth of flow. Air entrainment also reduces channel friction and thereby increases the velocity of the flow.

To allow for the bulking effect, the required depth of a Channel Drain has to be greater than that computed using Table 2C.3. The effect might be offset by using a Drain with a higher roughness coefficient.

Recommendations for the design of stepped Channel Drains can be found in:

- FHWA: *Design of roadside channels. HDS 4*
<http://www.fhwa.dot.gov/engineering/hydraulics/pubs/hds4.pdf>;
- USACE: *Engineering and Design – Drainage and erosion control mobilization construction* (1984). Publication No. EM 1110-3-136.
<http://140.194.76.129/publications/eng-manuals/em1110-3-136>

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To allow for wave action in chute channels, and the greater damage that can be caused by high-velocity water, the freeboard allowance for an open stepped Channel Drain should be greater than used for Channels on flatter slopes. Freeboard allowances vary according to the amount of wave action and turbulence expected, but the minimum freeboard should be about 0.3m.

Changes in channel alignment and/or cross section have to be smooth to avoid violent wave action and the resulting overtopping of the channel sides.

The inlet of stepped Channel Drains should be designed to prevent water bypassing the channel and eroding the slope, and energy dissipaters or other types of erosion protection should be provided at the outlet.

3.3 Pipes

3.3.1 Capacity

The flow capacity of a pipe depends upon the pipe diameter, the hydraulic roughness of the pipe material, and the hydraulic gradient (upstream head minus downstream head divided by the length of pipe).

The discharge capacity of a full pipe can be determined using the Darcy-Weisbach and Colebrook and White equation:

$$Q = \frac{\pi D^2}{4} \left[-2\sqrt{2gDS} \log \left(\frac{k}{3.7D} + \frac{2.51\nu}{D\sqrt{2gDS}} \right) \right] \quad \text{Equation 2C.2}$$

where

Q is the discharge capacity;

D is the internal diameter of the pipe;

S is the hydraulic gradient;

k is the hydraulic roughness;

g is the gravitational acceleration (9.81 m/s²);

ν is the kinematic viscosity of water (1.141x10⁻⁶ m²/s at 15°C).

The capacity of perforated pipes should be based on the water level corresponding to the position of the lowest perforations. Calculations are also required to determine the flow velocities and discharges for particular depths of flow within the pipe.

Such flows can be determined by multiplying the pipe-full discharge of the pipe determined using Equation 2C.2 by the appropriate coefficient from Table 2C.4.