8 Surface-water drainage

Learning objectives

Study of this chapter will enable the reader to:

1. calculate rainfall run-off into surface-water drains;
2. calculate gutter water flow capacity;
3. choose appropriate gutter and rainwater down pipe combinations to create an economical design;
4. calculate and find gutter sizes;
5. assess methods for the disposal of surface-water;
6. calculate soakaway pit design.

Key terms and concepts

Introduction

Design calculations for roofs, gutters and ground drainage are presented along with practical exercises in suitable arrangements. It is important for the designer to maintain the closest contact with the architect during this process because of the required integration.

Flow load

In the UK, ground surface-water systems are designed on the basis of a rainfall intensity of 50 and 75 mm/h for roofs. The quantity of water entering a drain depends on the amount of evaporation into the atmosphere and natural drainage into the ground. The drain flow load is represented by the impermeability factor, and typical figures are shown in Table 8.1.

Table 8.1 Ground impermeability factors.

Nature of surface	*Impermeability factor*
Road or pavement	0.90
Roof	0.95
Path	0.75
Parks or gardens	0.25
Woodland	0.20

The drain water flow rate Q is given by:

$$Q = \text{area drained m}^2 \times \text{rainfall intensity } \frac{\text{mm}}{\text{h}} \times \text{impermeability factor}$$

EXAMPLE 8.1

Footpaths, roadways and gardens on a commercial estate cover an area of 75 000 m^2, of which 20% is garden and grassed areas. Estimate the surface-water drain flow load in litres per second. How many 15 l/s surface-water drain gulleys are needed?

From Table 8.1, impermeability factors are 0.9 for the roads and paths and 0.25 for gardens and grass. Therefore:

$$\text{Average impermeability} = 0.2 \times 0.25 + 0.8 \times 0.9$$
$$= 0.77$$

Hence,

$$Q = 75\,000 \text{ m}^2 \times 50 \frac{\text{mm}}{\text{h}} \times \frac{1 \text{ h}}{3600 \text{ s}} \times \frac{1 \text{ m}}{10^3 \text{ mm}} \times 0.77 \times \frac{10^3 \text{ l}}{1 \text{ m}^3}$$
$$= 802.1 \text{ l/s}$$

Number of drain gulleys needed

$$= 802.1 \frac{\text{l}}{\text{s}} \times \frac{\text{gulley s}}{15 \text{ l}}$$
$$= 54 \text{ gulleys}$$

Roof drainage

A rainfall intensity of 75 mm/h occurs for about 5 min once in 4 years. An intensity of 150 mm/h may occur for 3 min once in 50 years, and where overflow cannot be tolerated this value is used for design. The flow load Q for a roof is calculated from:

$$Q = A_r \text{ m}^2 \times 75 \frac{\text{mm}}{\text{h}} \times \frac{1 \text{ h}}{3600 \text{ s}} \times \frac{1 \text{ m}}{10^3 \text{ mm}} \times \frac{10^3 \text{ l}}{1 \text{ m}^3}$$
$$= A_r \text{ m}^2 \times 0.021 \text{ l/s}$$

where A_r is the surface area of a sloping roof of pitch up to 50° and no evaporation takes place, which is characteristic of a cold saturated atmosphere.

For a roof pitch of greater than 50°:

$$Q = 0.021 \times (1 + 0.462 \tan\theta) \times A_r \text{ l/s}$$

where θ is the roof pitch in degrees.

The flow capacity of a level half-round gutter is given by:

$$Q = 2.67 \times 10^{-5} \times A_g^{1.25} \text{ l/s}$$

where A_g is the cross-sectional area of the gutter in mm^2. For level gutters other than half-round the flow capacity can be found from:

$$Q = \frac{9.67}{10^5} \times \sqrt{\left(\frac{A_o^3}{W}\right)} \text{ l/s}$$

where A_o is the area of flow at the outlet, mm^2, and W is the width of the water surface, mm. The depth of flow in a level gutter discharging freely increases from the outlet up to a maximum at the still end. It can be assumed that the depth of flow at the outlet is about half that at the still end. Thus the depth at the outlet is half the gutter depth. A_o is found from the gutter cross-sectional area at half its depth. W will normally be the width across the top of the gutter.

A fall of 1 in 600 increases flow capacity by 40%. The frictional resistance of a sloping gutter may reduce water flow by 10%, and each bend can reduce this further by 25%. Water flow in down pipes is much faster than in the gutter and they will never flow full. Their diameter is usually taken as being 66% of the gutter width. Some typical gutter flow capacities are given in Table 8.2.

For calculation purposes, a roof is divided into areas served by a gutter with an end-outlet rainwater down pipe. If the whole roof is drained into a gutter with an outlet at one end, then the gutter carries water from the entire roof area. However, when a centre outlet is used, a smaller gutter size might be possible as it only carries half the flow load. The number and disposition of the down pipes is considered in relation to the gutter size, architectural appearance, cost and complexity of the underground drainage system.

Table 8.2 Typical flow capacities for a PVC half-round gutter at a 1 in 600 fall.

Nominal gutter width (mm)	*Q (l/s)*	
	End outlet	*Centre outlet*
75	0.46	0.76
100	1.07	2.10
125	1.58	2.95
150	3.32	6.64

Source: Reproduced from *1HVE Guide* (CIBSE, 1986 [IHVE, 1970]) by permission of the Chartered Institution of Building Services Engineers.

Rectangular gutter sizes can be found from:

$$A_o = \frac{WD}{2}$$

where D is the gutter depth (mm).

EXAMPLE 8.2

A sports centre roof of dimensions 15 m × 8 m is laid to fall to a PVC half-round gutter along each long side. Find an appropriate gutter size when the gutter is to slope at 1 in 600. Each gutter can have a centre or end outlet.

The flow load is:

$$\begin{aligned} Q &= 0.021 A_r \text{ l/s} \\ &= 0.021 \times 15 \times 8 \text{ l/s} \\ &= 2.52 \text{ l/s} \end{aligned}$$

Each gutter will carry half of Q, that is, 1.26 l/s. For one gutter, the fall will increase the carrying capacity by 40% and friction will reduce it by 10%. The required gutter area can then be found from:

$$Q = 1.40 \times 0.9 \times 2.67 \times 10^{-5} \times A_g^{1.25} \text{ l/s}$$

Hence,

$$\begin{aligned} A_g^{1.25} &= \frac{10^5 \times Q}{2.67 \times 1.4 \times 0.9} \\ &= \frac{10^5 \times 1.26}{3.3642} \\ &= 0.375 \times 10^5 \end{aligned}$$

Therefore,

$$\begin{aligned} A_g &= (0.375 \times 10^5)^{1/1.25} \text{ mm}^2 \\ &= (0.375 \times 10^5)^{0.8} \text{ mm}^2 \\ &= 4563 \text{ mm}^2 \end{aligned}$$

For a half-round gutter:

$$A_g = \frac{\pi W^2}{8}$$

and hence,

$$W = \sqrt{\frac{8A_g}{\pi}}$$
$$= \sqrt{\left(\frac{8 \times 4563}{\pi}\right)} \text{ mm}$$
$$= 108 \text{ mm}$$

Thus a 125 mm half-round gutter with an end outlet would be used along each side. This can be checked with the data in Table 8.2. A smaller 100 mm gutter would be possible if a centre outlet was appropriate to the appearance of the building and the underground drain layout.

EXAMPLE 8.3

A roof sloping at 42° has a level box gutter 125 mm wide and 50 mm deep. The roof is 15 m long and 5 m up the slope. Calculate whether the gutter will adequately convey rainwater when the rainfall intensity is 75 mm/h. Recommend the outlet location.

The flow load is given by:

$$Q = 0.021 \times (1 + 0.462 \times \tan 42°) \times 15 \times 5 \text{ l/s}$$
$$= 3.24 \text{ l/s}$$

If an end outlet is used, the water depth at the outlet will be half the gutter depth, that is, 25 mm. Thus,

$$A_o = 125 \times 25 \text{ mm}^2$$
$$= 3125 \text{ mm}^2$$

The gutter flow capacity is expected to be:

$$Q = \frac{9.67}{10^5} \times \sqrt{\frac{3125^3}{125}} \text{ l/s}$$
$$= 1.69 \text{ l/s}$$

This is less than the imposed flow load and would produce overflow from the gutter. A centre outlet would have the effect of halving the flow load on the gutter. For a centre outlet,

$$\text{Flow load } Q = 0.50 \times 3.24 \text{ l/s}$$
$$= 1.62 \text{ l/s}$$
$$A_o = 3125 \text{ mm}^2 \text{ as previously calculated}$$
$$\text{Gutter capacity } Q = 1.69 \text{ l/s}$$

The solution is to use the centre outlet so the gutter capacity exceeds the calculated flow load from the roof.

Cast iron covers over drainage gulleys in roadways pass 20 l/s or more, depending upon surface-water speed, degree of flooding and blockage from debris.

Disposal of surface-water

Surface-water can be removed from a site by one or more of the following methods.

Sewer

Where the local authority agrees that there is adequate capacity, surface-water is drained into either a combined sewer or a separate surface-water sewer. Surface-water from garage forecourts and car parks is run in open gullies to an interceptor chamber. Ventilation of explosive and poisonous petrol vapour is essential, as a concentration of 2.4% in air is fatal. It is illegal to discharge petrol, oil or explosive vapour into public sewers. The interceptor chamber is an underground storage tank of concrete and engineering bricks, which allows separation of the clean water from the oily scum remaining on its surface. It is intermittently pumped out and cleaned. The discharge drain to the sewer is turned downwards to near the bottom of the interceptor and three separate chambers are used in series.

Soakaway

Ground permeability is established using borehole tests to measure the rate of natural drainage within a curtilage. If running underground water is found, a simple rock-filled pit can be used. Slow absorption is overcome by constructing a perforated precast concrete, dry stone or brick pit, which stores the rainfall quantity. The stored volume is found from an assumed steady rainfall of 15 mm/h over a period of 2 h. This is exceeded around once in 10 years, so there may be occasional flooding for short periods. A soakaway pit is circular with its depth equal to its diameter.

Storage

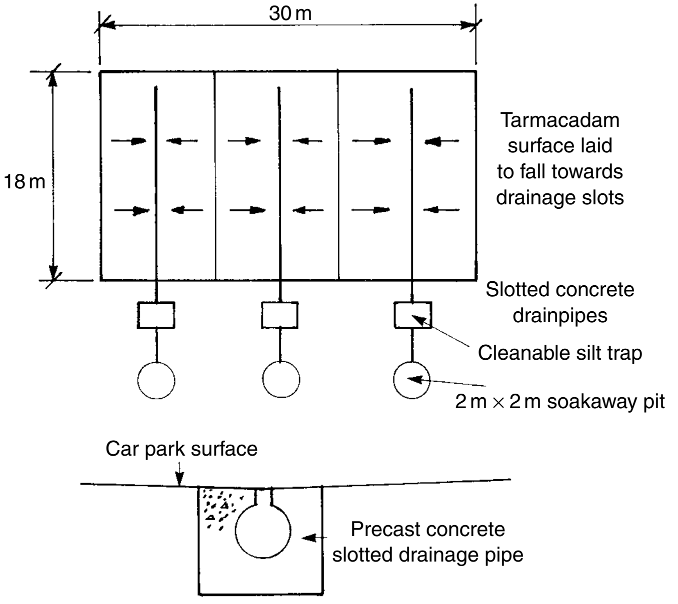
An artificial pond or lake, or even an underground storage tank, will be necessary if the expected run-off from a curtilage is at a greater rate than could be accommodated by a sewer or watercourse.

Watercourse

The relevant local authorities may allow the disposal of surface-water into watercourses. Expected flow rates at both normal and flood water levels must be established.

EXAMPLE 8.4

Storage soakaway pits 2.25 m deep are to be employed for a tarmac-covered car park of dimensions 100 m × 30 m. Determine the number and size of the pits needed. Draw a suitable drainage layout for the car park.



8.1 Surface-water drainage for the car park in Example 8.4.

$$\text{Volume to be stored} = 15\ \frac{\text{mm}}{\text{h}} \times 2\ \text{h} \times \frac{1\ \text{m}}{10^3\ \text{mm}} \times 100\ \text{m} \times 30\ \text{m} \times 0.9$$

$$= 81\ \text{m}^3$$

Pits 2.25 m deep will have diameters of 2 m. Therefore:

$$\text{Pit volume} = \frac{\pi \times 2^2}{4} \times 2.25\ \text{m}^3 = 7.07\ \text{m}^3$$

and hence,

$$\text{number of pits} = \frac{81}{7.07} = 12$$

Figure 8.1 shows a suitable arrangement of precast concrete slot drainage channels and soakaway pits.

Questions

1. Explain how the rainwater flow load is calculated for roof and groundwater drainage system design.
2. A housing estate has footpaths and roads covering an area of 4000 m^2. Calculate the rainwater flow load and the number of drain gullies required.
3. Find the flow load for a flat roof of dimensions 20 m × 12 m.
4. Find the flow load for a roof of dimensions 10 m × 4 m with a pitch of 52°.
5. Calculate the flow capacity of a level half-round gutter 125 mm wide. Ignore friction.
6. Calculate the flow capacity of a level box gutter 200 mm wide and 150 mm deep when running full. Ignore friction.

7. A PVC half-round gutter 150 mm wide slopes at 1 in 600 and has an end outlet to a rainwater pipe. The water depth at the outlet is half the gutter depth. Assume that A_o is half the gutter cross-sectional area. Take W as the gutter width. Calculate the gutter flow capacity.
8. A house has two sloping roofs, each side of a ridge, of dimensions 15 m × 8 m. Calculate the flow load and determine the gutter and rainwater pipe design from Table 8.2.
9. The flat roof of a school is to be of dimensions 30 m × 20 m with a rectangular gutter on each long side and sloping at 1 in 600 to an outlet at each end. Calculate suitable dimensions for the gutter.
10. A pitched roof of dimensions 20 m × 5 m drains into a level box gutter 120 mm wide and 80 mm deep on one long side. The gutter has one end outlet. Calculate whether this is a satisfactory arrangement.
11. Describe the actions taken during the design and construction of a surface-water disposal system, stating what options are investigated.
12. Storage soakaway pits 2 m deep are to be used to dispose of rainwater from a roof of dimensions 10 m × 8 m. Determine a suitable size and number of pits.
13. List the techniques used for subsoil drainage systems.
14. Describe the features and maintenance requirements of surface-water drainage systems for car parking, garage forecourts and large paved areas in shopping centres.