9 Below-ground drainage

Learning objectives

Study of this chapter will enable the reader to:

1. understand the design principles for underground drainage pipework;
2. use discharge units;
3. use a pipe-sizing chart;
4. calculate flow capacity;
5. calculate loads on buried pipelines;
6. identify materials and jointing methods;
7. understand sewage-lifting requirements;
8. know testing procedures;
9. carry out a design assignment;
10. explain the principles of below-ground drain layout;
11. know the location and types of access fitting.

Key terms and concepts

Introduction

Below-ground drainage systems are designed to operate without the input of energy, wherever possible, to be reliable and to require little, if any, maintenance. Their layout has to be such that drains are not subject to undue stress from foundations or traffic and are fully accessible for occasional clearance.

Design calculations can be made on the basis of flow rates, utilizing discharge units, gradients, pipe material and pipe diameter. Stress loads, pipe materials and jointing, sewage lifting and testing are discussed, and a design layout assignment is given.

Design principles

Sanitary discharge services operate by gravity flow and require no energy input. Parts of buildings or sites that are below the sewer invert require a pump to raise the fluid. These operate intermittently to minimize electrical power consumption. Drains are laid to fall at an even gradient, which produces a self-cleaning water velocity so that potential deposits are accelerated and floated downstream. Large drops in drain level are accommodated in a back-drop manhole, rather than a lengthy steep slope, in order to minimize excavation.

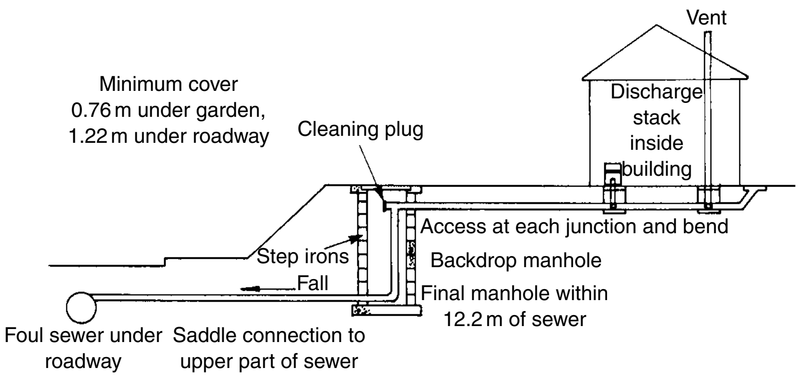
Pipes are laid in a series of straight lines between access points used for inspection, testing and cleaning. Branch connections are made obliquely in the direction of flow. There is a preference against running drains beneath buildings owing to possible settlement and the potential cost of later excavation to make repairs, and because the drain invert is lower than the floor damp-proof membrane and rising drains need a waterproof seal against groundwater.

Selected trench bedding and backfill material is used to provide continuous pipe support, to spread imposed ground loads due to the weight of soil and passing traffic, to protect drains from sharp objects and other services, as well as to divert stresses imposed by building foundations. Temporary boards are used to protect exposed drain trenches during construction work. Figure 9.1 shows a typical foul drain system from a single stack.

Access provision

Blockages may happen, as drain systems are likely to be in place for a hundred years or more and demands upon them continue to increase. Cleanability is an essential feature of good design. Good health depends upon satisfactory drainage. Domestic drains are likely to be located less than 1.5 m below ground level, at a maximum gradient of 1 : 40 and 100 mm in diameter, possibly increasing to 150 mm in diameter at the downstream end of an estate or large building.

Vitrified clay or PVC pipe and fittings are often used, with flexible joints to accommodate ground movement and thermal expansion due to variations in fluid temperature. Brick, concrete,



9.1 Foul drainage installation.

PVC or glass-reinforced plastic (GRP) access chambers are used. All changes in direction are either through 135° or large radius-swept bends.

Access points are provided for removing compacted material and for using rigid rods to clear blockages in the direction of flow, even though flexible water-jetting techniques are currently available and it is possible to clear obstructions from either direction. Air-tight covers are desirable to avoid access points allowing a health hazard or flooding.

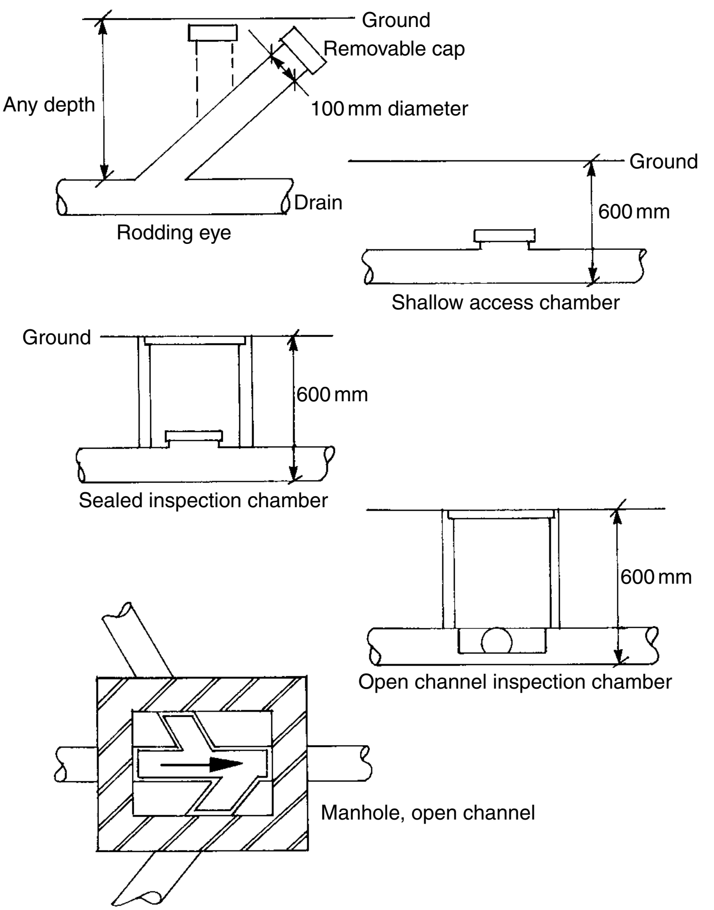
Figure 9.2 shows the types of access.

Rodding eye: a 100 mm diameter drain pipe extended from any depth to ground level to allow rodding in the downstream direction.

Shallow access chamber: a removable threaded cap on a branch fitting to allow access in either direction located such that the distance from ground level to drain invert is less than 600 mm to facilitate reaching into the drain.

Sealed inspection chamber: a 600 mm deep, 500 mm diameter chamber for access to screwed caps on drain junctions.

Open-channel inspection chamber: a 600 mm deep, 500 mm diameter access chamber with benched smooth surfaces for drain junctions.

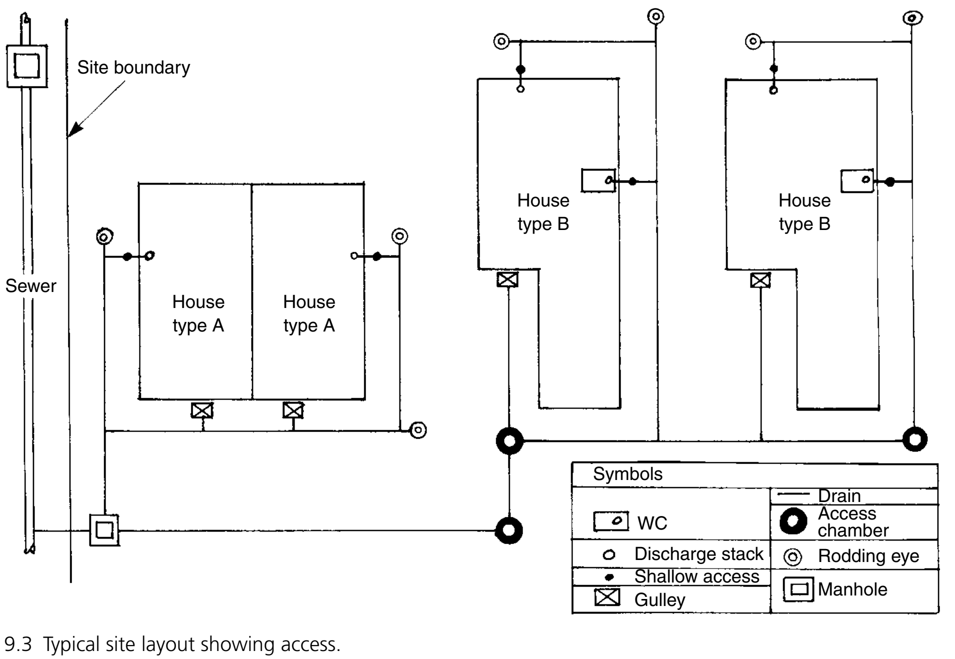


9.2 Types of access to below-ground drainage.

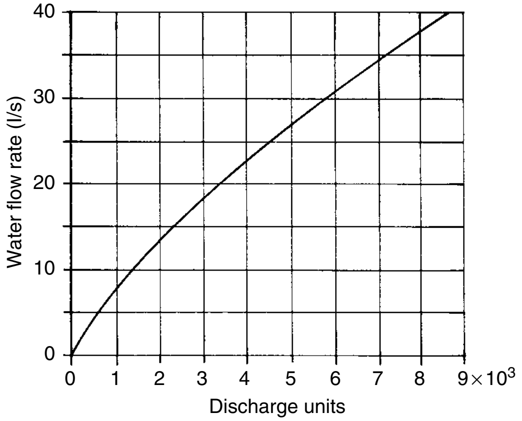
Manhole: the main access point for an operative wearing breathing apparatus to climb down steps to any depth; a 1 m deep manhole is 450 mm^2, and a 1.5 m deep manhole has dimensions of 1200 mm × 750 mm or 1050 mm diameter, and a cover 600 mm^2.
Gulley: ground-level connection point for various waste pipes and the below-ground 100 mm diameter drain providing a water trap against sewer gas and allowing debris removal and rodding access; it may have a sealed lid or open grating.

The first access point close to the building is either a gulley, a removable WC or a shallow access chamber just after the base of the internal drainage stack. It is not necessary to fit access points at every change in drain direction, but pipe junctions are made with access chambers. The maximum spacings between access points are 12 m from the start of the drain to the first access, 22 m from a rodding eye to a shallow access chamber, 45 m from a rodding eye to an access chamber or manhole and 90 m between manholes. Figure 9.3 demonstrates a typical housing estate drain layout. Careful integration with the surface-water drainage system is necessary as falls to the sewers are preconditioned by the sewer inverts, and the two drains may run within the same trenches and cross each other where branch connections are made.

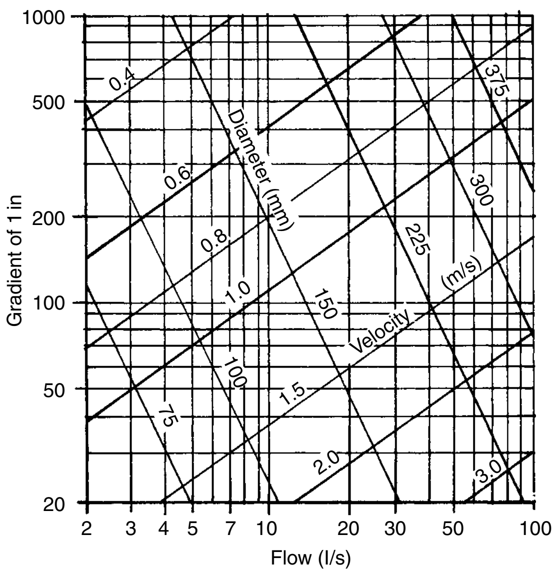
Pipe diameters for surface-water pipework are based on the flow loads discharging from each down pipe. Those for foul drains are found from the discharge units in each stack. Flows in underground drains are found by totalling calculated flow rates along the route of the collecting drain run. Discharge units are converted into flow rate using Fig. 9.4. Pipe sizes and fluid velocities can be read on Fig. 9.5 from the calculated flow rate and desired gradient as appropriate to the maximum allowable fall available on the site.



9.3 Typical site layout showing access.



9.4 Simultaneous flow data for foul- and surface-water drains (reproduced from data in *CIBSE Guide* (CIBSE, 1986) by permission of the Chartered Institution of Building Services Engineers).



9.5 Sizes for two-thirds full spun precast concrete drains (reproduced from *IHVE Guide* [IHVE, 1970], now superseded, by permission of the Chartered Institution of Building Services Engineers [CIBSE, 1986]).

EXAMPLE 9.1

The flow from a 100 mm stack is equivalent to 750 discharge units and is to run underground for 30 m before entering the foul sewer at a depth 375 mm lower than at the building end. Find a suitable diameter for a spun precast concrete drain so that it will not be more than two-thirds full at maximum flow rate.

From Fig. 9.4, note that the horizontal scale is 0–9000, 750 discharge units are equivalent to a flow rate of 7 l/s. The gradient of the drain is given by:

$$\text{Gradient} = \frac{0.375}{30} = 1 \text{ in } 80$$

From Fig. 9.5, a flow rate of 7 l/s at a gradient of 1 in 80 requires a 150 mm diameter drain. The fluid velocity will be 1.05 m/s. Check this result with a simple calculation of carrying capacity. Drains run at a maximum of two-thirds full to provide continuous ventilation throughout their length and avoid creating large suction pressures on water traps in sanitary fittings in buildings. This will only be an approximation to published chart data.

$$\begin{aligned}\text{Pipe flow capacity } Q &= \frac{2}{3} \times Av \\ &= \frac{2}{3} \times \pi \times \frac{0.15^2}{4}\ \text{m}^2 \times 1.05\ \frac{\text{m}}{\text{s}} \times \frac{10^3\ \text{l}}{1\ \text{m}^3} \\ &= 12.3\ \text{l/s, so chart result is confirmed}\end{aligned}$$

It is worth noting that, at this gradient, a 100 mm drain will carry only 5.3 l/s. A 100 mm drain would carry 7 l/s if its gradient was increased to 1 in 48, but this may be impractical. A 150 mm drain is the next available size up from the design point on the chart but it is grossly oversized for the present duty. At 1 in 80 it can carry a flow rate of 15 l/s, which corresponds to 2200 discharge units. This represents a possible future increase in discharge unit capacity of

$$\frac{2200 - 750}{750} \times 100\% = 193\%$$

Where drain use may be increased by additional site or area development, this is a useful advantage.

Materials for drainage pipework

Traditionally, glazed vitrified clay (GVC) pipes have been used because they represent an efficient use of UK national resources. The finished internal surface of GVC pipes offers less frictional resistance to flow than that of concrete pipes and is resistant to chemical attack and abrasion. Rigid joints consist of a socket and spigot cemented together. The brittle nature of such pipe runs has led to the introduction of flexible joints, which can withstand ground movement due to thermal and moisture variations and settlement of buildings. Plastic and rubber sealing ring joints allow up to 5° of bending and longitudinal expansion and contraction. Pipe sizes range from 75 to 750 mm in diameter.

Spun concrete drain pipes of diameter up to 1.83 m with oval cross-sections, which maintain flow velocity at periods of low discharge, are used. Plastic sleeves with rubber sealing rings give joints flexibility and a telescopic action.

Asbestos cement pressure pipes in lengths of up to 4 m have been used because of their lower weight. Flexible sleeve joints with rubber ring seals are used. Diameters from 100 to 600 mm are produced.

Pitch fibre pipes are formed by impregnating wood fibre with pitch. They are lightweight and can be used for some drainage applications. Lengths of 2.5 m are easily handled and can be hand sawn. Push taper joints are made using a hand-operated chamfering tool. Pipelines have flexibility and require well-selected backfill and careful protection during site work. Hot fluid or chemical discharges may lead to the early collapse of the pipe from ground pressure. Plastics are used for bends and other pipe fittings. Diameters are in the range 75–200 mm.

Cast iron drain runs are used for overground sections and where the ground movement might otherwise cause fracture. Pipework beneath buildings can either be cast iron encased in concrete or short lengths with flexible joints. Rigid socket and spigot joints are caulked with tarred yarn and then filled with hot lead or lead wool.

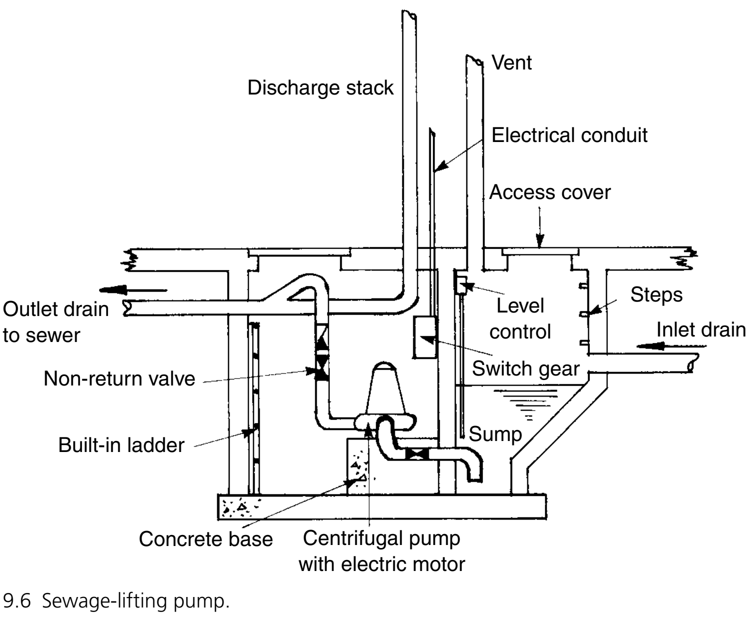
Plastics have increasingly replaced naturally occurring materials owing to their low weight and high degree of prefabrication. Complete systems from the sanitary appliance to the sewer, using one supplier and material, are common. Such materials are derived from crude oil and their higher cost needs to be compensated by reduced site time. Smooth bore drain systems can be assembled with minimum skill and they are highly resistant to corrosion. Thermal expansion is greater, and telescopic joints are used. Short-term discharges from some appliances, for example, some types of washing machine, can be at temperatures of 80°C or higher. Polypropylene and acrylonitrile butadiene styrene, ABS, pipes are suitable for the high-temperature applications.

Sewage-lifting pump

Where sanitary appliances discharge into drain pipework that is below the foul sewer invert, a collecting sump, pump and fluid level controller are used in the manner shown in Fig. 9.6. Either a large clearance centrifugal pump, driven by a 440 V three-phase electric motor, or a pneumatic ejector is used.

The storage chamber is sized to accommodate several hours of normal discharge so that the pump only runs for short periods and total electrical power consumption need not be high. Duplicate pump sets ensure a continuity of service during breakdowns and maintenance.

The pneumatic ejector collects the discharge in a steel tank containing a float. At the upper fluid level, the float operates a change-over valve, which admits air from a compressor and



9.6 Sewage-lifting pump.

storage vessel. The incoming compressed air drives the sewage into the outlet drain at the higher level. Non-return valves are fitted to the inlet and outlet pipes to stop the possibility of reverse flow.

Both types of sewage-lifting equipment have open vent pipes to ensure that back pressures are not imposed upon the soil stack.

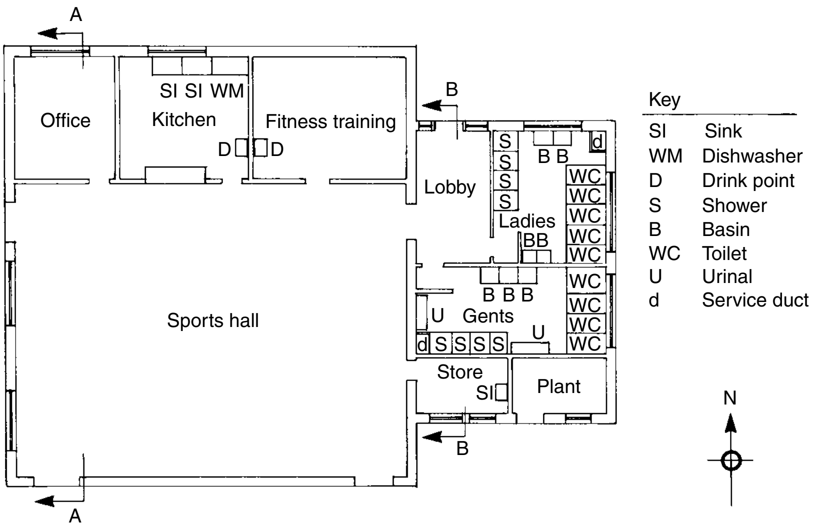
Testing

In addition to the inspection and smoke tests previously described, a water test can be applied to underground drainage pipelines. A test is carried out before, and sometimes after, backfilling. Drain runs are tested between manholes. The lower end is sealed with an expandable plug. A temporary upstand plastic or aluminium pipe is connected at the higher manhole. Water is admitted to produce a static head of 1.4–2.4 m and maintained for an hour or more. Some drainage materials will absorb water, and the initial water level is replenished from a measuring cylinder or jug. The maximum allowable water loss is 1.0 l/h for 10 m of 100 mm diameter pipe or pro rata for other diameters and lengths.

An air test can be conducted in a similar manner: a static pressure of 75 mm water gauge on a U-tube manometer should be maintained for a period of 5 min without further pumping.

Questions

1. List the principal requirements for an underground drainage installation.
2. Explain, with the aid of sketches, the differences between the following types of drain and sewer system: separate, combined and partially separate.
3. A 100 mm discharge stack connects to a drain laid to a 1 in 80 gradient and is expected to carry 500 discharge units. Find a suitable diameter for the drain.
4. A building has four 100 mm discharge stacks, which connect into a common underground drain. The stacks have discharge unit values of 400, 500, 600 and 700. Find the diameters of each part of the collecting drain if it has a gradient of 1 in 100.
5. A 100 mm PVC drain runs for 30 m to connect between a discharge stack and the sewer. If its gradient is 1 in 80 and it commences its route with minimum ground cover under a garden, what will its invert be at the sewer connection if the ground is level?
6. There are 236 houses on a new development. Each has a group of sanitary appliances with a discharge unit value of 14. The common drain is laid at a gradient of 1 in 100. Find the diameter of the common drain and the maximum possible number of houses that it could serve.
7. Sketch and describe the types of bedding used for drains, giving an application for each.
8. Under what circumstances may drains and sewers become damaged during their construction and service periods?
9. Describe, with the aid of sketches, the materials and jointing techniques used for below-ground drain systems.
10. Sketch and describe the operation of a sewage pumping installation. Draw the details of the construction of the below-ground chambers.
11. State the performance criteria for tests on below-ground drain systems.
12. Design a below-ground drainage system for the Pascal Sports Club shown in Fig. 9.7. The foul sewer is at an invert of 2 and 25 m to the right of the east wall of the club. Only one connection is allowed to be made to the 300 mm diameter sewer, and this is to its upper half.



9.7 Pascal Sports Club.

It will be necessary to design the above-ground waste pipework from all sanitary appliances in order to optimize the gulley positions, the 100 mm diameter pipe routes and the location of the one ventilation stack at the high point of the whole system. Minimize the use of underfloor pipework, all of which must be 100 mm in diameter and fully accessible.

Modifications can be made to the building to construct above-ground service ducts to accommodate hot- and cold-water pipes as well as wastes and drains.

A 100 mm diameter rainwater down pipe is located 500 mm from each external corner of the building on the north and south sides. These connect to 100 mm diameter below-ground drains, which run to the surface-water sewer alongside the foul sewer. Ensure that both drain systems are fully integrated and separated by a bedding of at least 100 mm thick shingle or broken stones of maximum size 5–10 mm. Access to the surface-water pipework is of the same standard as that to the foul pipework.

The last access prior to the sewer for both drains should be a manhole. There is no manhole at the junction of the drain and sewer. The shower rooms will have trapped floor gulleys that connect to the foul drain.

No model solution is provided as the design should be discussed with tutor and colleagues, and reference should be made to manufacturers' guides.

13. How are below-ground drains tested?

1. Filling with water and pumping the pressure up to 30 m water gauge for an hour.
2. Sealing ends of completed system, hand pumping air pressure up to 150 mm water gauge for an hour without further pumping.
3. Prior to backfilling trench, subject completed drain system to a static water height of 2.4 m for an hour.
4. Internal camera survey.
5. Watching for leaks prior to backfilling trench.

14. The flow capacity of a two-thirds full below-ground drain at a shallow gradient is approximated from the formula, $Q = (2/3)(\pi d^2/4)\ V$ m^3/s. Which is the flow capacity of a 100 mm diameter drain when the water velocity is 0.9 m/s?

    1. 7.07 l/s.
    2. 9.4 l/s.
    3. 2.35 l/s.
    4. 1.5 l/s.
    5. 4.712 l/s.

15. A 20 m run of below-ground drain falls 175 mm. Which is the correct gradient?

    1. 1.75
    2. 8.75
    3. 0.114
    4. 1 : 175
    5. 1 : 114