British Standard

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BRITISH STANDARD

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Code of practice for

Building drainage —

(Formerly CP 301)

UDC 628.6:696.12/.13:628.2

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Building Services Standards Committee (SEB/-) to Technical Committee SEB/12, upon which the following bodies were represented:

Association of District Councils
British Board of Agrément
British Ceramic Research Association
British Foundry Association
British Plastics Federation
British Precast Concrete Federation Ltd.
British Steel Industry
Building Employer's Confederation
Cement and Concrete Association
Chartered Institute of Building
Clay Pipe Development Association Limited
Concrete Pipe Association
Department of the Environment (Building Research Establishment)
Department of the Environment for Northern Ireland
Department of the Environment (Housing and Construction Industries)
Department of the Environment (Property Services Agency)
Ductile Iron Producers' Association
Fibre Cement Manufacturers' Association Limited
Health and Safety Executive
Incorporated Association of Architects and Surveyors
Institute of Clerks of Works of Great Britain Inc.
Institute of Environmental Health Officers
Institute of Plumbing
Institution of Building Control Officers
Institution of Municipal Engineers
Institution of Public Health Engineers
Institution of Structural Engineers
Institution of Water Engineers and Scientists
London Boroughs Association
National Coal Board
Royal Institute of British Architects
Scottish Development Department
Union of Construction — allied Trades and Technicians
Water Authorities Association

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Contents

Foreword

This code, prepared under the direction of the Building Services Standards Committee, is a complete revision of CP 301 and supersedes the 1971 edition which is withdrawn.

The revision takes into account developments since 1971 in materials used in drainage together with recent advances in drain clearing methods affecting access to pipelines.

It emphasizes the need for pipeline flexibility for the avoidance of failure from ground movement and has adopted a computed load method for structural design.

The code does not define in legal terms any hard and fast boundary between the drainage systems covered by this code and the sewerage systems covered by CP 2005. It is mainly concerned with pipelines comprising DN 100 and DN 150 pipes but includes recommendations appropriate for pipes up to about DN 300 which are used in building development. For larger pipework CP 2005 should be consulted and efforts have been made to ensure, where the two codes overlap, that inconsistencies do not occur.

The terminology used in describing drainage has developed over a long period, during which important changes in design, materials and installation techniques have taken place. These have made possible a more rational approach to design, and encouraged simplicity and economy in presentation.

Although materials referred to in this code are mainly traditional and covered by British Standards, the use of new materials and new applications of established materials are not precluded where it can be demonstrated that they are satisfactory for their purpose.

As regards the testing of inspection chambers and manholes for watertightness, and the recommendation of performance criteria for these units, the committee has felt the need for further data and research. These topics will therefore be the subject of continuing work on the committee and appropriate amendments to the text will be made as soon as possible.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 70, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

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Section 1. General

1 Scope

This code sets out recommendations for the design, layout, construction, testing and maintenance of foul, surface water and groundwater drainage systems constructed in the ground under and around buildings, and their connection to sewers, treatment works, cesspools, soakaways or watercourses.

The structural design criteria are limited to drains not generally exceeding DN 300, although the other criteria are of general application.

NOTE The titles of the BSI publications referred to in this standard are listed on the inside back cover. References in the text to other publications are identified in the text by numbers in square brackets, and are listed in Appendix A.

2 Definitions

For the purposes of this code the definitions of drainage terms given in BS 892, BS 4118, BS 5572 and BS 6100 apply. Some of these are repeated here for convenience. Other definitions not given in the above standards are included and these also apply.

2.1
blinding

material that will fill the interstices and irregularities in the exposed trench bottom and, when adequately compacted will create a firm uniform formation on which to place the pipe bedding material

NOTE Hoggin, sand, gravel, all-in aggregate or lean concrete are commonly used.

2.2
branch drain

a line of pipes installed to discharge into a junction on another line or at a point of access, i.e. an access junction, inspection chamber or manhole

2.3
branch vent

a ventilating pipe connected to one or more branch drains

2.4
discharge unit

a unit of flow calculated for a drainage appliance so that the relative load-producing effect of its discharge can be expressed as a multiple of that unit

NOTE The discharge unit load of an appliance depends on its rate and duration of discharge, the interval between discharges and the chosen criterion of satisfactory service (see **7.4.3.2**). It is not a simple multiple of a rate of flow (see BS 5572).

2.5
drop-pipe connection

a vertical connection to or near the invert level of a manhole from a sewer or drain at a higher level

2.6
foul water

any water contaminated by soil, waste or trade effluent

2.7
junction

a fitting on a pipeline designated to receive discharges from a branch drain(s)

2.8
inspection chamber

a covered chamber constructed on a drain or sewer so as to provide access thereto, for inspecting, testing or the clearance and removal of obstructions, and usually situated in areas subjected to light loading only

2.9
manhole

a working chamber with cover constructed on a drain or sewer within which a person may inspect, test or clear and remove obstructions in safety

2.10
nominal size (DN)

a numerical designation of the size of a pipe, bend or branch fitting, which is a convenient round number approximately equal to a manufactured dimension

NOTE "Nominal bore" is the approximate internal diameter of a unit as declared by the manufacturer. This quantity is quoted with units (mm) whereas nominal size (DN) is quoted without units.

2.11
storm water

rainwater discharged from a catchment area as a result of a storm

3 Exchange of information

3.1 General

The full exchange of information between all the parties concerned is essential before drainage work is begun. Close liaison should be maintained with all appropriate authorities. In general, the information in **3.2** to **3.10** should be provided. Recommendations on the preparation of plans are given in Appendix B.

3.2 From owner or user to designer

a) A plan of the site showing existing and proposed levels preferably related to Ordnance Datum, indicating the position and floor levels of the proposed building and the ground levels and contours of the site, including any proposed regrading.

b) Details of the positions and types of all appliances requiring drainage, the location and extent of all paved areas and the position of all existing sanitary pipework, rainwater pipes and gullies.

c) The nature of the discharges and the nature and volume of any trade effluents involved.

d) The number of occupants and the periods of occupation.

3.3 From sources of technical information to designer

3.3.1 ***From the local authority and/or water authority***

a) Building regulations and other requirements of legislation (see clause **4**).

b) Whether adequate sewerage is available to receive the proposed discharge(s).

c) The conditions under which any trade effluents may be accepted.

d) The position, size and level of the public sewer(s) and manhole(s).

e) The system of sewerage, i.e. separate, partially separate or combined.

f) The materials of construction and the condition of the sewer(s).

g) Relevant water table levels, flood water levels and their seasonal and other variations.

h) Whether interceptors are required.

i) The positions and levels at which connections may be made, taking account of surcharge conditions.

j) Any relevant local byelaws or further design requirements.

k) By whom the connections will be made: if by the authority, the estimated cost; if by the developer or contractor, the requirements of the authority.

l) The limits of responsibility for installation and maintenance.

m) Where sewerage is not available a separate system should be designed. The authority should be consulted on their requirements for the storage or treatment of sewage and disposal of effluent; whether to natural watercourse, ditch or land drainage; also for the disposal of surface water to soakaway, ditch or natural watercourse.

n) The physical and chemical nature of the ground to be excavated, particularly as regards the presence of sulphates. The client is responsible for making his own soil survey but the local authority should pass on any relevant local knowledge.

3.3.2 ***From other authorities***

a) *Highway authority and the police.* Requirements as regards drains underpassing roads and reinstatements thereafter. Requirements regarding control and/or diversion of vehicles and pedestrians where drains cross roads or footpaths.

b) *Local mining authority.* Information on subsidence.

c) *Electricity, gas and water supply authorities.* Location of all present and relevant future services. Owners of such services should be given notice of the intention to excavate. Some will possess statutory powers to exact an indemnity against damage to their buried services and to prescribe special precautions against damage during excavation.

d) *Building owner.* Details of any wayleaves negotiated where a drain crosses land in other ownership. The exact location of manholes should be shown on wayleave plans particularly where drains are laid in fields or other open ground. The right of access to manholes and the right to maintain or renew the drain should be specifically included in any wayleave arrangements made with the owner of the land. Certain provisions relating to drains laid in the land of other owners appear in Section 16 of the Water Act 1973 and may present an alternative to wayleaves.

Details of any prior damage to buildings and structures near where trenches have to be excavated. Inspection, preferably with the owners of the property, should be made before starting the work, to establish whether any visible defects exist and a survey and records of the condition of buildings lkely to be affected should be made. Dated tell-tales may be placed across any cracks and kept under observation. Photographic evidence may prove useful.

e) *BSI.* See references herein to appropriate codes and specifications.

3.4 From designer to drainage authority

a) Proposal to connect to the public sewerage system.

b) Information and plans in the prescribed form. Normally the drainage plans form part of the general building drawings submitted (see Appendix B).

c) Estimated dry weather flow, peak rates of flow and character of sewage with particulars of any trade effluent.

d) At the conclusion of the work, plans should be lodged with the authority recording details of the work as installed (see Appendix B).

3.5 From designer to contractor

a) Adequate detailed drawings with the specification for the work.

b) Full details of any special requirements of the authorities and in respect of wayleaves or other matters.

3.6 From designer to owner

a) Full detailed drawings for the record of the work as installed.

3.7 From contractor to building control authority

a) Submission of plans for warrant approval (Scotland).

b) Prior notice of intention to commence work.

c) Notice prior to haunching in concrete or covering in any way. Notice of readiness for first testing (Scotland).

d) Notice after backfilling. Notice for readiness for final testing (Scotland).

e) Notice of completion of work.

3.8 From contractor to drainage authority

a) Notice of intention to connect to a sewer or other means of disposal.

3.9 From contractor to designer

a) Details of any deviations from working drawings.

b) Notification of start and finish of work and interim progress reports.

c) Details of any unforeseen difficulties.

3.10 From contractor to highway authority

a) Full details in respect of highway opening notices.

4 Enactments and official recommendations

4.1 General

There are a great number of Acts and Regulations affecting the powers or duties of local authorities, water undertakings and, in Northern Ireland, the Department of the Environment, in connection with drains and sewers; the following list includes the most important but is not intended to be complete:

England and Wales

Building Regulations

Public Health Act 1936

Public Health (Drainage of Trade Premises) Act 1937

Highways Act 1980

Public Health Act 1961

London Government Act 1963

Local Government Act 1972

Water Act 1973

Control of Pollution Act 1974

Scotland

Building (Scotland) Acts 1958 and 1970 as amended

The Building Standards [Scotland] Regulations 1981

Sewerage (Scotland) Act 1968

Control of Pollution Act 1974

Northern Ireland

Water Act (NI) 1972

The Building Regulations (NI) Order 1972

(The Building Regulations (NI) 1977)

Water and Sewerage Services (NI) Order 1973

4.2 Safety

The Health and Safety at Work etc. Act 1974 and the relevant regulations made thereunder apply to execution of the works on site. The recommendations of the booklet “Safe working in sewers and at sewage works” published by the National Joint Health & Safety committee for the Water Service, should be observed [1].

Section 2. Materials and components

5 Materials and components

5.1 Selection of materials

The materials for pipes, pipe joints, bedding, associated building works and the type of cement and mix to be employed should be selected to ensure satisfactory service for the life of the drainage system. Factors to be taken into account include:

a) the type of usage likely to occur and the nature of the liquids to be conveyed;

b) the nature of the ground and the possibility of chemical attack therefrom;

c) the physical and chemical characteristics of the drainage materials themselves;

d) the possibility of erosion by solids in the flow or of chemical attack;

e) the quality of workmanship that may be expected;

f) the degree of supervision to be provided.

Recommendations for the most commonly used drainage materials are given in the following paragraphs. Reference should be made to BS 5493 and to PD 6484 for advice on corrosion problems.

5.2 Cement

Cement used for building drainage work should comply with the requirements of BS 12, BS 146, BS 915, BS 4027 or BS 4248 (see **5.4.1**). The most commonly used are ordinary and rapid hardening Portland cements. The "deemed to satisfy" provisions in the Building Regulations 1976 do not include the use of high alumina cement to BS 915 for structural work.

5.3 Aggregates

5.3.1 *Aggregates for concrete.* Aggregates for concrete should comply with the requirements of BS 882 or BS 1047. The nominal size of coarse aggregate should be as large as practicable within the limits specified in the appropriate British Standard, provided that the concrete can be satisfactorily placed and compacted. Where tests are required they should be carried out in accordance with BS 812.

5.3.2 *Aggregates for mortar.* The fine aggregate for mortar for brickwork or blockwork should comply with the requirements of BS 1200. Sands for rendering should comply with the requirements of BS 1199. Sands for jointing of pipelines or precast concrete manholes should generally comply with one of these standards or alternatively may be fine concreting sands complying with BS 882 from which the excess coarse material has been removed.

5.4 Concrete

5.4.1 *General.* The recommended mixes for in situ concrete used in building drainage work are given in Table 1. In the case of the prescribed mixes given in Table 1 the grade is in terms of a number which will normally (but not contractually) be its 28 day characteristic strength (N/mm^2). Where compliance is to be by strength a designed mix should be specified. In addition to strength it will also be necessary to specify cement content and water cement ratio to ensure adequate durability. Reference should be made to BS 8110[1)] and BS 5328.

Aqueous solutions of sulphates, as may be present in some soils and groundwater, can cause expansion and disruption of concrete. Concrete containing ordinary Portland cement should not, unless combined with appropriate proportions of pulverized-fuel ash (p.f.a.) or slag, be used in contact with soils above class 2 classification. Unprotected concrete containing sulphate-resisting cement may be used in soils up to class 4 classification. Above this classification an adequate protective coating should be provided.

Recommendations for the type of cement, maximum free water content and minimum cement content required for different sulphate concentrations may be found in BS 8110[1)] and BRE Digest 250 [2]. These recommendations should be followed for any main structural work but for the majority of applications covered by this code it will be acceptable to select a mix from Table 1.

Concrete made with Portland cements is not recommended in acidic conditions. Sulphate-resisting Portland cement does not differ significantly from ordinary Portland cement in its acid resistance but where sulphates are present in a low acidic solution its use may give improved durability.

In conditions where the pH is less than 6 or in situations such as industrial sites, where conditions may be very aggressive to any concrete, special advice should be obtained.

Fresh sewage is not normally aggressive to Portland cement concrete and mortar, but attack may occur as a result of an aggressive groundwater, discharge from hospitals, from trade or industrial processes or septic sewage conditions which give rise to hydrogen sulphide resulting in the formation of sulphuric acid. In such circumstances the nature and quantities of such discharges should be ascertained and expert advice should be obtained and followed. Hot liquids may be more aggressive than those at normal ambient temperatures.

[1)] In preparation. Revision of CP 110.

5.4.2 *Admixtures.* The use of admixtures for promoting workability, for improving strength, for entraining air or for any other purpose should be permitted only with prior agreement of the designer.

Calcium chloride as an admixture should not be used in reinforced concrete, prestressed concrete or any concrete made from sulphate-resisting Portland cement. For guidance reference should be made to BS 8110[1)]-1.

5.5 Cement mortar

Selection of the correct cement for use in mortars should take account of the considerations set out in **5.1** to **5.3**. A mortar mix having a 1 : 3 cement/sand ratio is suitable for the following purposes:

a) rigid joints for clay or concrete pipes;

b) rendering of inverts and benchings;

c) jointing concrete manhole sections.

A mix of 1 : $^{1}/_{4}$: 3 cement/lime/sand is recommended for brickwork mortar.

5.6 Pipes, joints and fittings

5.6.1 *Factors affecting choice of materials and systems.* Whatever selection is made, pipes should have adequate strength to meet loading requirements, be sufficiently robust to withstand site handling and be sufficiently durable to remain watertight for the anticipated life of the system. Pipes and joints should remain sufficiently watertight to prevent ingress of ground water and egress of effluent when subjected to ground movement and settlement. Pipe sizes available in various materials are given in Table 2.

In addition to those factors listed in **5.1**, consideration should also be given to the diameters and lengths of pipes available, ease of cutting, simplicity of the jointing system, the range of fittings available, ease of unloading and positioning in the trench without damage to the pipe or to any coating.

The coatings most commonly applied to metal pipes do not necessarily provide adequate protection against all types of corrosion. Specially designed coatings may be required for protection against concentrations of acids, alkalis, sulphates and other aggressive chemicals likely to be encountered in the ground and in liquids carried. An indication of the resistance to chemical attack of available pipe and jointing materials for various liquids and groundwater, is given in Table 3.

Flexible joints are generally available for the range of materials used for drainage and they can accommodate angular deflection, axial displacement and draw within the joint. They are designed to resist shear loads without loss of watertightness. Where rigid joints are required they can be made by caulking metal or compound or by working a cement mortar into the joint, by bolted flanges or by welding the pipes together. Care should be taken on such jointing operations not to disturb the gradient of the line or the continuity of the bore.

Brief information on available pipes is given below. For further information, reference should be made to the appropriate British Standard.

Table 1 — Recommended mixes for buried concrete

Use of concrete	Soil conditions			
	Sulphate classification (see note 2)			
	Class 1 or less	Class 2	Class 3	Class 4
Concrete for backfilling of trenches	C 10 P (see note 3)	C 20 P	C 25 P	C 30 P
Structural protection of buried pipelines	C 20 P	C 20 P	C 25 P	C 30 P
Structural plain concrete, e.g. foundations to manholes	C 20 P	C 25 P	C 25 P	C 30 P
Reinforced concrete	C 25 P	C 25 P	C 25 P	C 30 P
Cement type	OPC	SRPC		

NOTE 1 The above grades of concrete are those described in BS 5328 as ordinary prescribed mixes. The grade is in terms of a number which will normally (but not contractually) be its 28 day strength.

Where designed mixes are used for other work on the same site, consideration should be given to their use for underground drainage work.

NOTE 2 These mixes are only suitable in near-neutral ground conditions pH 6 to pH 9 (see **5.4.1** and BRE Digest 250 [2] for definition of soil classifications).

NOTE 3 Lean mix concrete may be used where sulphates are not present (see **5.7.6.3**).

5.6.2 ***Rigid pipes***

5.6.2.1 *General.* The materials for these pipes show linear, brittle stress-strain behaviour. The pipes do not deform appreciably under their design load. Thus the ability of a rigid pipe to support the total load transmitted to it is established by reference to actual crushing tests.

5.6.2.2 *Asbestos-cement.* Asbestos-cement pipes and fittings for gravity drainage are manufactured to BS 3656 in diameters from 100 mm, in lengths 3 m, 4 m and 5 m and to the strength classifications given in that standard. Half and quarter length pipes are also available. Pressure pipes are manufactured to BS 486 in diameters from 50 mm and in lengths 3 m and 4 m. Cast iron fittings for use with these pipes are also available.

Both of these standards include requirements for flexible joints.

5.6.2.3 *Vitrified clay.* Vitrified clay pipes and fittings in preferred nominal diameters from 100 mm are manufactured to BS 65 in lengths of 0.3 m to 2.5 m in three strength classifications as given in that standard. The standard also includes requirements for flexible joints, perforated pipes and extra chemically resistant pipes.

5.6.2.4 *Concrete.* Plain and reinforced concrete pipes and fittings are manufactured to BS 5911 in diameters from 150 mm in lengths of 0.9 m to 2.5 m and to the strength classifications given in those standards, which include requirements for flexible joints.

5.6.2.5 *Grey iron.* Pipes and fittings to BS 437 are manufactured in grey iron in diameters from 50 mm, Standard pipe lengths are 1.83 m, 2.74 m, 3.66 m and 5.5 m (except that those of 50 mm diameter are in 1.83 m lengths only). These pipes or fittings have run or caulked lead joints. BS 437 permits the use of flexible joints and proprietary flexible couplings are available. BS 6087 specifies flexible joints for use with these pipes.

Grey iron pressure pipes are manufactured to BS 4622 in diameters from 80 mm. They are available with caulked lead, flanged or flexible joints. Standard pipe lengths are 5.5 m for pipes with caulked lead or flexible joints, 4.0 m for pipes with screwed-on flanges and 0.75 m or 1.0 m for pipes with cast-on flanges.

5.6.3 ***Flexible pipes***

5.6.3.1 *General.* The materials for these pipes show ductile stress-strain characteristics. Flexible pipes deform under load and the extent of this deformation depends upon the stiffness of the pipe and the compaction of the immediate surrounding fill. Some plastic pipe materials may display cold flow or regression of strength characteristics. When GRP, pitch fibre and uPVC pitch fibre pipes are installed with bedding materials, properly compacted in accordance with this code they will not generally be deformed by more than 5 % of their original diameter, which is considered acceptable.

5.6.3.2 *Ductile iron.* Ductile iron pressure pipes and fittings are manufactured to BS 4772 in diameters from 80 mm and to BS 437 in diameters from 50 mm. They are available with flexible or flanged joints. Standard lengths are 5.5 m or 4.0 m for pipes with the two types of joint respectively.

5.6.3.3 *Glass fibre reinforced plastics (GRP).* GRP pipes and fittings manufactured to BS 5480 are available with diameters from 25 mm and in lengths of 3 m, 5 m, 6 m, 10 m and 12 m. Experience of their use in building drainage in the UK is limited. It is known that their life may be adversely affected by continuous conveyance of hot liquids and, since the term GRP covers a wide range of materials, they may have differing characteristics. It is essential that the manufacturer be consulted regarding their use.

5.6.3.4 *Text deleted*

5.6.3.5 *Steel.* Steel pipes and joints are manufactured to BS 534 with outside diameters from 60.3 mm. Protection against corrosion by the liquid carried and by groundwater and by anaerobic attack is necessary.

5.6.3.6 *Unplasticized PVC (uPVC).* uPVC pipes and fittings for gravity drainage with flexible or rigid (solvent welded) joints are manufactured to BS 4660 in outside diameters of 110 mm and 160 mm, and to BS 5481 in outside diameters of 200 mm upwards. Pipes are generally available in lengths of 3 m, 6 m and 9 m.

For pressure drainage systems uPVC pressure pipes are manufactured to BS 3506 in nominal size from 3 (DN 75). Fittings for uPVC pressure pipes are manufactured to BS 4346.

If it is proposed to use these pipes and fittings with untreated trade waste or with prolonged discharges at temperatures greater than 60 °C reference should be made to BS 5955 and/or to the manufacturer.

Table 2 — Pipe size as defined in BS 8301 and individual pipe standards

	Rigid pipes						Flexible pipes						
	Asbestos		Clay	Concrete	Grey iron		Ductile iron	GRP	Pitch fibre	Steel	Unplasticised PVC		
	BS 3656	BS 486	BS 65	BS 5911	BS 437	BS 4622	BS 4772	BS 5480	BS 2760	BS 534	BS 4660	BS 5481	BS 3506
Nominal size	**Nominal bore**	**Nominal bore**	**Nominal bore**	**Nominal bore**	**Nominal bore**	**Nominal bore**	**Nominal bore**	**Nominal bore**	**Nominal bore**	**Outside diameter**	**Outside diameter**	**Outside diameter**	**Min. outside diameter**
DN	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
75	—	75	[a] 75	—	75	80	80	80	75	76.1 88.9	—	—	88.7
100	100	100	100	—	100	100	100	100	100	114.3	110	—	114.1
125	125	—	—	—	—	—	—	125	125	139.7	—	—	140.0
150	150	150	150	150	150	150	150	150	150	168.3	160	—	168.0
175	175	—	—	—	—	—	—	—	—	193.7	—	—	193.5
200	200	200	[a]200	—	—	200	200	200	200	219.1	—	200	218.8
225	225	225	225	225	225	—	—	—	225	244.5	—	—	244.1
250	250	250	[a]250	—	—	250	250	250	—	273.0	—	250	272.6
300[b]	300	300	300	300	—	300	300	300	—	323.9	—	315	323.4

[a] Non preferred sizes.

[b] Although not covered in this code, pipes in many of these materials are available in diameters greater than 300 mm. These are dealt with in CP 2005.

Table 3 — Chemical resistance of materials (for general guidance)

Group	BS no.	Material and applications	Normal domestic sewage	Trade effluent: At normal temperature		Organic solvents	Containing oils and fats		At sustained high temperature		Soil environment containing	
				Acids	Alkalis		Vegetable	Mineral	Acids	Alkalis	Sulphates	Acids
Ceramics	65, 1196 3921	Clayware pipes and fittings	A	S	S	S	S	S	A	A	S	S
		Bricks and blocks of fired brick-earth, clay or shale	A	S	S	S	S	S	A	A	S	S
Concrete	5911	Concrete: ordinary Portland cement	A	E	A	A	E	A	E	A	E	E
		sulphate-resisting Portland cement	A	E	A	A	E	A	E	A	A	E
Asbestos cement	486	Asbestos cement pressure pipes and joints										
	3656	Asbestos cement pipes, joints and fittings (gravity) for sewerage and drainage	A	E	A	A	E	A	E	A	A	E
Metals	534	Steel pipes and fittings	A	E	A	A	A	A	E	E	E	E
	437	Grey iron pipes and fittings (gravity)	A	E	A	A	A	A	E	E	E	E
	4622	Grey iron pipes and fittings (pressure)										
	4772	Ductile iron pipes and fittings										
Plastics	4660 5481	uPVC gravity drain and sewer	A	S	S	E	A	A	E	E	S	S
	3506 5480	GRP pressure	A	A	A	E	A	A	E	E	A	A
Jointing materials [other than Portland cement and iron and steel components (see under pipes)]	2494	Rubber:										
		natural (NR)	A	A	A	E	E	E	E	A	A	A
		chloroprene (CR)	A	S	A	E	A	A	A	A	S	S
		BUTYL (IIR)	A	S	S	A	A	A	A	A	S	S
		styrene-butadiene (SBR)	A	A	A	E	E	E	E	A	A	A
		nitrile-butadiene (NBR)	A	A	A	E	A	A	E	A	A	A
		ethylene-propylene terpolymer (EPDM)	A	A	A	E	A	E	A	A	A	A
		ethylene-propylene copolymer (EPM)	A	A	A	E	A	E	A	A	A	A
		[a] Bituminous compositions	A	A	A	E	E	E	E	E	A	A
		[a] Polyester resin	A	S	A	E	A	A	E	E	S	S
		Polyethylene:	A	A	A	A	S	A	A	A	S	S
		(Type 32) cold water services										
	1972	(Type 32) general purposes including chemical and food										
		(Type 50) cold water services										
	3284	(Type 50) general purposes including chemical and food										
		[a] Polyurethane	A	S	S	A	S	A	A	A	S	S
	6437	[a] Polypropylene	A	S	S	A	S	A	A	A	S	S
		[a] Epoxy	A	A	S	E	E	A	E	S	S	A

A = normally suitable.
E = need expert advice, each case to be considered on its own merits.
S = specially suitable.

NOTE It is important to take account of **quantities and concentrations** of all types of chemical likely to be encountered.

[a] There are no relevant British Standards for these jointing materials. The classification given to them in the table assumes that the formulations and methods of curing employed are those appropriate for pipe jointing.

The impact strength of uPVC pipes is reduced in cold weather during which extra care in handling should be exercised. Further guidance on handling, support, transport and installation is given in BS 5955-6.

5.6.3.7 *Polyethylene.* Polyethylene pressure pipes are manufactured to BS 1972, BS 1973, BS 3284 and BS 6437. Jointing can be effected either by fusion jointing or by means of compression fittings.

5.6.4 *Pipes for field drains.* Open-jointed pipes or porous or perforated pipes of the following types may be used for field drains:

a) clayware field drain pipes to BS 1196 and vitrified clay pipes to BS 65 (surface water quality pipes or perforated pipes);

b) concrete pipes to BS 5911;

c) plastics pipes to BS 4660, BS 4962 and BS 5481;

d) porous concrete pipes to BS 1194.

Concrete pipes may be unsuitable where subsoil water carries sulphates or is acidic owing to the presence of peat.

5.7 Miscellaneous materials and components

5.7.1 *Manholes*

5.7.1.1 *Inspection covers, manhole covers and frames.* Cast grey and ductile iron and cast steel inspection covers, manhole covers and frames should comply with BS 497-1.

5.7.1.2 *Pre-cast concrete inspection chamber and manhole sections.* Concrete inspection chamber and manhole sections and pre-cast cover slabs should comply with BS 5911-1 and BS 5911-2.

5.7.1.3 *Step irons.* Step irons should comply with BS 1247.

5.7.1.4 *Steel ladders.* Steel ladders for permanent access should comply with BS 4211.

5.7.2 *Gullies and gratings*

5.7.2.1 *General.* A gully usually incorporates a trap, or a sump, or both, to retain detritus. The top should be fitted with either a grating or a sealed cover. Connections should be made below the grating or cover. Gullies may be specially designed to suit selected locations and the volume and nature of the flow. They can also incorporate means of access for rodding the branch drain beyond the trap. Gullies and gratings are available in various materials as detailed in **5.7.2.2** to **5.7.2.6**.

5.7.2.2 *Cast iron.* Cast iron gullies and assemblies should comply with BS 437.

5.7.2.3 *Clayware.* Clayware waste, rainwater, yard, garage and road gullies should comply with BS 65 which specifies general performance requirements.

5.7.2.4 *Concrete.* Pre-cast concrete gullies for drainage of roads and paved areas should comply with BS 5911-2.

5.7.2.5 *Plastics.* Plastics gullies are manufactured in glass reinforced plastics, polyethylene, polypropylene and uPVC. Where hot liquids or chemicals may be discharged or where they may be subjected to vehicular wheel loadings, the manufacturer's advice should be obtained.

5.7.2.6 *Gully gratings.* Gratings and, where provided, frames should be suitable for the gullies with which they are to be used and should be capable of supporting the loadings likely to be encountered in use without excessive deformation or failure. Cast grey and ductile iron and steel road gully gratings and frames should comply with BS 497-1.

5.7.3 *Bricks.* Bricks should be at least class B engineering bricks complying with BS 3921 and should additionally be subject to the limitation of twist and bow to ± 2 mm when measured by the methods applied to clay blocks in clauses **17** and **18** of BS 3921:1974. The bricks should be of sufficient compressive strength to withstand any super-imposed loads likely to be experienced in use.

Frogless bricks are to be preferred but, if frogged, frogs should face upwards. If double frogged bricks are used they should be placed with the deeper frog uppermost.

Concrete bricks to BS 6073 should have a crushing strength of not less than 20 N/mm^2 for surface water drainage. Special purpose concrete bricks having a minimum strength of 40 N/mm^2 and a minimum cement content of 350 kg/m^3 should be used for foul drainage and for situations where improved durability is required.

5.7.4 *Blocks.* Concrete blocks for surface water drainage should comply with BS 6073 and have a density of not less than 1 500 kg/m^3. Manufacturers' advice should be obtained for the suitability of other blocks.

5.7.5 *Granular material for bedding.* Granular material for use for bedding pipes should comply with one of the requirements set out below. The greater the proportion of fines in the material the greater is the care needed in compaction.

a) Nominal single sized aggregate to Table 4 of BS 882:1983 as follows:

DN 100	10 mm size;
DN 150	10 mm or 14 mm size;
DN 200 and above	10 mm, 14 mm or 20 mm size.

b) Graded aggregate to Table 4 of BS 882:1983 as follows:

DN 150 pipes	graded 14 mm to 5 mm;
DN 200 pipes and above	graded 20 mm to 5 mm; or graded 14 mm to 5 mm.

c) Granular material having a compaction fraction value not greater than 0.3 when tested in accordance with Appendix D. Particle size should not exceed 20 mm.

5.7.6 *Backfill material*

5.7.6.1 *Selected material.* Selected material from a trench can be used as side fill for rigid pipes above the bedding, or for the layer directly above the pipes for rigid and flexible pipes, provided that it is readily compactible. It should exclude stones retained on a 40 mm sieve, hard lumps of clay retained on a 100 mm sieve, timber, frozen material and vegetable and foreign matter. Cohesive soil that has dried out on a spoil heap may not be readily compactible and is not suitable.

5.7.6.2 *General backfill.* Normally the excavated material from the trench will be suitable for backfill above the selected material. Boulders, lumps of concrete, timber and vegetable matter should be excluded.

5.7.6.3 *Lean mix concrete.* If the use of lean mix concrete for backfill is contemplated the following factors should be considered.

a) The concrete mix should be no richer than 1 in 18. Solid, high strength concrete could transmit the full traffic impact load directly to a pipe, irrespective of the depth of the pipe.

b) The sides of the trench will tend to consolidate more readily than the concrete, and this could result in a "hump" in the road surface.

c) Any other services crossing the trench will be affected by the differential settlement of the fill and the sides of the trench.

d) Any subsequent excavation involving removal of concrete would be more difficult than would that of selected backfill.

5.7.6.4 *Fill for ductile iron pipes.* For ductile iron pipes it is usual to use tamped excavated natural material for the side fill. In bad ground, or where the fill contains large stones or lumps of cohesive material a suitable bedding material should be imported. The excavated or imported material should pass through a 75 mm sieve and should be free from vegetable matter, builders' rubbish, domestic refuse, metal, timber, etc.

5.7.7 *Sealing rings.* Sealing rings should be made from natural or synthetic rubber complying with BS 2494.

5.7.8 *Solvent cements.* Solvent cements should comply with either BS 6209 for non pressure pipework or BS 4346-3 for pressure pipework.

Precautions in the use of solvent cements for jointing uPVC drainage pipes can vary for each type of solvent or solvent mixture used in the manufacture of the solvent cement. Some solvents are flammable, whilst others are toxic. For the safe use of solvent cements the manufacturer's data safety sheet should be consulted and relevant precautions taken before the product is used. Where these solvent cements are used in confined spaces the associated handling risks are increased and more specific instructions may have to be obtained from the manufacturer before use. Further advice on this latter aspect can be obtained from HM Inspectors of Factories situated in Area Offices or from HSE Guidance Note GS5 [3] purchaseable from HMSO or through booksellers.

Section 3. Design

6 General design considerations

6.1 Introduction

A drainage system should be designed, installed and maintained so as to convey and discharge its contents without causing a nuisance or danger to health, arising from leakage, blockage or surcharge.

It is essential that early consultation should take place between architect and designer(s) of the engineering services. This should commence at site acquisition stage and continue thereafter to achieve whole-life economy of operation.

There may be technical and economic advantages in providing a drainage system to serve more than one property but such an arrangement may cause difficulties in conveyancing or appointment of maintenance costs. Designers should consider this when preparing drainage layouts.

6.2 Layout

Access should be provided at all bends and junctions. Where a bend external to an inspection chamber or manhole is unavoidable, it should be adjacent and should provide a deviation of not more than 45°. A bend receiving a drop-pipe, a discharge stack or the outfall from a drainage appliance may deviate up to 90°.

Bends, particularly in the smaller diameter pipes, should have a long rather than a short radius and in any case this should be sufficiently long to enable access for cleaning by the usual methods.

Inspection chambers and manholes should be sited so as to avoid the need for acute changes in direction of flow from branch drains (see **7.6**).

The routes selected should make full use of the natural slopes of ground or any adjustments thereto, so as to achieve design gradients with minimum excavation.

Common trenches for foul and surface water drains may prove economical in excavation. However, care is needed to ensure the stability of the shallower pipes and the spacing of pipelines should be adequate for the connections, including those which may be needed in the future. When deciding on trench arrangements the primary consideration, as in every aspect of the design process, should be the hydraulic effectiveness of the system.

The layout will be influenced by other factors such as:

a) site conditions, retained features and existing services;

b) availability of suitable sewers or outfalls;

c) layout of building(s); disposition of discharge stacks and rainwater pipes; appliances located on levels necessitating direct connections to drains;

d) user-pattern of building(s) served;

e) planning and coordination of services;

f) practical aspects of excavation for building foundations, working space and adequate protection and support of drainage;

g) stability of the building during and following construction of the drainage;

h) density of site development;

i) provision for future development;

j) connections to or from existing services which are to be retained;

k) provision for phased construction and occupation;

l) feasibility of avoiding areas where the ground contains or is likely to contain tree roots.

6.3 Pipe sizes

A foul drain should be of nominal size not less than DN 100 (see clause **7**). A surface water drain should be of nominal size not less than DN 75 (see clause **8**). In certain cases a connection to a drain may be of smaller nominal size to suit the nature and volume of flow from a single appliance.

There may be situations where, for hydraulic reasons, a discharge pipe, designed in accordance with BS 5572, may need to be continued below ground without increase in bore to a position in a drainage system where the flow will prevent undesirable deposition of solids. Such a pipe should be laid direct to an inspection chamber or manhole without change of line or gradient.

6.4 Pipe gradients

The choice of gradient should be such as to maintain self-cleansing velocity under normal discharge conditions (see **7.4.4.4**).

6.5 Drains laid outside buildings

For housing and small structures it is preferable for drains to be laid outside where provision can be made for ready detection of blockages and their removal. Pipework laid under the buildings should then be limited to short branches.

A drain trench should not impair the stability of a building. When drains are laid parallel to the foundation, care should be taken that the foundations are not undermined (see Figure 9).

Where the horizontal distance between the drain trench and the foundation is less than the depth from the underside of the foundation to the invert of the trench, the sides of the trench should be shored with members of sufficient strength to resist any horizontal or vertical movement of the foundation. This shoring is additional to the statutory requirements for the sides to be supported where persons are required to work in trenches with a depth greater than 1.2 m. Careful consideration should be given before removing this shoring where it is set below the underside of the foundation and the merit of leaving it permanently in place to minimize ground relaxation should be recognized.

Trenches adjacent to load bearing walls within 1 m of the foundation of the wall should be filled with concrete to at least the level of the underside of the foundation. For distances greater than 1 m the concrete fill should be to a level below the underside of the foundation equal to the distance from it to the nearside of the trench, less 150 mm.

6.6 Pipelines under and through structures

Drains should be laid outside buildings wherever practicable. Branch drains from stacks fixed internally and from appliances make some pipework under building unavoidable.

A building designed with central core services and/or strict site limitations may require most, if not all of the drainage to be within or below the building.

Where the routing of drains below or through a building or structure is contemplated it is essential to consider the effects of differential settlement between the building or structure and the drain.

Frequently the only feasible arrangement for large buildings is for the drains to be laid in the ground under the lowest floor or in the underfloor ducts[2]. Perforation of slabs and retaining walls in contact with the ground should be kept to the minimum so as to reduce the risk of subsoil water seeping into the building around the pipes.

It may be difficult to provide external overflow points, such as open gullies, at suitable levels to give warning of blockage. Surcharge may then cause flooding within the building and suitable and sufficient access is, therefore, essential to enable maintenance to be carried out speedily without causing nuisance or risk of injury to health. Surcharge-warning devices can be provided in appropriate locations where surcharge might result in flooding of critical areas within a building.

6.7 Differential movement

Differential movement in a drain will occur when there is a change in either loading conditions or in the mode of support between successive pipes. Inspection chambers, manholes and other structures generally will be subject to settlement different from that of the pipes associated with them.

Differential settlement can be accommodated by means of flexible joints, The risk of shear fracture is considerably reduced by the provision of a flexible joint located as close as practicable to the face of the structure. The length of the next (“rocker”) pipe should not exceed 0.6 m. Where considerable differential settlement is anticipated several “rocker” pipes should be laid, and the gradient should if necessary be increased locally to reduce the likelihood of a back fall developing.

Where it is not necessary for a pipe to be built into a structure, the effects of differential movement may be overcome by the provision of a lintel, relieving arch or sleeve leaving a gap of not less than 50 mm around the pipe. Effective means should be adopted to prevent the entry of gravel, rodents or gas. The designer should take due note of the proximity of underground gas services (see Department of Energy report on gas explosions [4]).

6.8 Ventilation of drains

A free passage of air should be maintained through the system. The achievement of this may affect the layout (see **7.10**, **8.13** and **9.9**).

6.9 Disused drains

Existing drains which are or will be disused when superseded by new installations should be traced, grubbed up and removed. Where this is impracticable they should be filled with suitable material, e.g. weak concrete, cement grout or similar material to prevent their collapse or, in appropriate circumstances, effectively sealed against ingress of water and vermin, e.g. by sealing all open ends with slates set in cement mortar or by plugs of concrete.

Any drain which, although apparently disused, shows signs of flow should be investigated to establish its origin and authenticity. Arrangements should be made for its diversion or connection to the new system as appropriate.

[2] Pipework suspended in basements or similar situations is not covered by this code and reference should be made to BS 5572.

7 Foul drainage

7.1 Drainage to a sewerage system

The outfall of a foul water drainage system should discharge into a foul water or combined sewer, but where such a sewer is not conveniently available and cannot economically be extended to a site other methods of foul water disposal will be necessary, either to treatment or to cesspool. The drainage in these cases should be designed on the separate system.

7.2 Treatment

Where it is necessary to provide sewage treatment facilities the recommendations of BS 6297 should be followed in consultation with the water authority.

7.3 Cesspools

Where an appropriate sewer is not available and sewage treatment is impracticable, provision for storage in a cesspool may be necessary. It should be located where satisfactory arrangements can be made for emptying. Technical advice and guidance on the design of cesspools is given in BS 6297.

Cesspools are not permitted in Scotland.

7.4 Hydraulic design of foul drains

7.4.1 *General.* In an area sewered on the separate system, all rain and surface water should be excluded from the foul drains. In an area sewered on the partially separate system, where this system is to be used for building drainage, the discharge of rain and surface water into the foul drains should not exceed the proportional quantity allowed for in the overall design of the foul sewers, unless agreed with the drainage authority.

If the area is sewered on the combined system, and all new buildings are to be similarly served, the drains should provide capacity for foul and surface water flows.

7.4.2 *Basic principles.* Flow in foul drains is intermittent even when serving large numbers of appliances. The discharge flow in a branch drain is normally of a wave form, close to the point of connection of a discharge stack, or an appliance, especially a WC. As the wave travels along the drain its velocity and depth decrease, the attenuation depending on the volume of flow, the gradient, bore, hydraulic roughness of the drain and the presence of fittings. It may also be affected by simultaneous discharges from other appliances connected to the system.

The method given in this code for determining drain size and gradient has been found in practice to result in a reliable and economical system, although it does not exactly reflect the above flow conditions. Probability theory is used to estimate the maximum peak flow rate from appliances, and flow through the drain is assumed to be steady, without attenuation. This ensures that the pipe sizes are adequate at positions of maximum flow depth. Some oversizing downstream of connections in systems with long pipe runs may result, but is usually acceptable in that it provides a factor of safety and may enable future connections to be made without causing surcharge.

7.4.3 ***Determination of flow***

7.4.3.1 *General.* When assessing probability of use factors and consequential peak flow rates in a foul drain the following should be considered:

a) the number and type of appliances to be connected;

b) the rate of discharge from each appliance (L/s);

c) the average duration of discharge from each appliance (t in s);

d) the likely use interval of each appliance (T in s);

e) an acceptable criterion of satisfactory service (see Appendix C).

Table 4 shows typical data for commonly used appliances. The same values are used in BS 5572.

7.4.3.2 *Calculation for groups of similar appliances.* One simple method of estimating peak flows for drains serving only one type of appliance is based on the probability method referred to in Appendix C. From items c) and d) in **7.4.3.1** a probability of discharge factor $P\left(P = \frac{t}{T}\right)$ can be found. The probability of discharge graph given in Figure 1 indicates the probable number of appliances in simultaneous use within a group.

Example: Given a group of 20 WCs in congested use ($P = 0.017$ from Table 4) the graph given in Figure 1 shows that three could be discharged simultaneously, giving a maximum flow rate of 3 × 2.3 L/s = 6.9 L/s.

This method should not be used for groups of mixed appliances because it can lead to unacceptable oversizing of pipes.

7.4.3.3 *Calculation for groups of mixed appliances.* The probability theory referred to in **7.4.3.2** is also used in the discharge unit method, for the calculations of flow in drains serving mixed appliances. Discharge units are so chosen that the relative load-producing effect of appliances can be expressed as multiples of the units. The discharge unit rating of an appliance depends on its rate and duration of discharge, on the interval between discharges and on the chosen "criterion of satisfactory service"[3]. It is not a simple multiple of a rate of flow.

Discharge unit values for sanitary appliances in common use are given in Table 4. For other appliances the discharge unit value for each should be deduced from the data given in Table 4 for an appliance with the same trap diameter, and duration and rate of discharge.

Table 4 — Flow rates, probability of discharge factors and discharge unit ratings

Appliances	Capacity	Discharge data		Recurrence use interval (frequency of use), T	Probability of discharge, P $P = \frac{t}{T}$	Discharge units
		Flow rate	Duration, t			
	L	L/s	s	s[a]		
WC (9 L, high level cistern)	9	2.3	5	1 200 600 300	0.004 0.008 0.017	7[b] 14 28
Washbasin (32 mm branch discharge pipe)	6	0.6	10	1 200 600 300	0.008 0.017 0.033	1[b] 3 6
Sink (40 mm branch discharge pipe)	23	0.9	25	1 200 600 300	0.021 0.042 0.083	6[c] 14 27
Bath (40 mm branch discharge pipe)	80	1.1	75	4 500 (domestic) 1 800	0.017 0.042	7[c] 18
Automatic washing machine	180	0.7	300	15 000	0.020	4
Shower	—	0.1	—	—	—	Use flow rate
Spray tap	—	0.06	—	—	—	Use flow rate
Urinal (per stall, automatic flushing)	4.5	0.15	30	1 200 900	0.025 0.033	0.3

[a] A use interval or recurrent interval (frequency of use) of 1 200 s corresponds to domestic use; 600 s to commercial use; 300 s to congested use such as in public toilets, schools and factories.
[b] In domestic installations, the highest loading occurs during the morning peak period and is made up of the discharges from WCs, basins, and sinks. For this reason, a dwelling is usually allotted a fixed number of discharge units for a group consisting of one each of these appliances. In this code, 14 discharge units per dwelling is assumed (see BS 5572).
[c] Some proportion of the total number of appliances may be assumed to be in simultaneous operation if considered appropriate.

[3] The "criterion of satisfactory service" referred to in this code is 99.5 % and is defined as the percentage of time that the design discharge flow loading will not be exceeded. A graph, based on this figure, showing the number of appliances likely to be in simultaneous use for a given total is shown in Figure 1, for different values of appliance probability of discharge (P) figures.

The discharge unit values of all the appliances contributing to flow in the drain should be added, and the equivalent peak rate in L/s for this total obtained from Figure 2. When the drain carries continuous flows from other sources, their rates can be added to the value obtained from Figure 2.

7.4.4 ***Determination of pipe size and gradient***

7.4.4.1 *General.* Figure 3 shows the discharge capacities of drains, from 75 mm to 300 mm diameter, when flowing full, and at 0.75 and 0.67 proportional depth. Using Figure 3 and the likely peak flow rate, the designer should select a pipe diameter and gradient taking account of the factors in **7.4.4.2** to **7.4.4.3**.

The design curves in Figure 3 are based on a hydraulic roughness of 0.6 mm as defined for the Colebrook-White equation. This roughness should be suitable for intermittently used drains of all pipe materials. However, drains subject to continuous flow, sometimes full, should be designed using a roughness of 1.5 mm (see Figure 4)[4)].

7.4.4.2 *Design for minimum blockage.* Blockages may occur because of misuse but the risk of recurring blockages during normal use can be minimized by ensuring a high standard of drain and manhole construction throughout the system and that pipes are not unacceptably oversized.

7.4.4.3 *Choice of pipe size and depth of flow.* Foul drains should be of minimum size DN 100, but where waste water only is conveyed DN 75 is considered acceptable[5)].

For foul drains, the size of the pipe and the gradient (see **7.4.4.4**) at which it is to be laid should be so chosen that at peak flow the risk of induced trap siphonage is minimized by ensuring adequate air movement in the drain. This is usually achieved by not exceeding a proportional depth of 0.75 (see also **7.10**).

7.4.4.4 *Choice of gradients.* Choice of gradients should be such as to maintain self-cleansing velocity under normal discharge conditions.

To achieve a satisfactory installation, diameter and gradient should be adequate for the maximum flow and competent supervision should be provided to ensure a high standard of pipe quality, laying, jointing and workmanship. This is particularly important when pipes are laid to flat gradients.

The following guidelines on gradients should be observed.

a) For flows of less than 1 L/s, pipes not exceeding 100 mm nominal bore at gradients not flatter than 1 : 40 have proved satisfactory.

b) Where the peak flow is more than 1 L/s, a 100 mm nominal bore pipe may be laid at a gradient not flatter than 1 : 80, provided that at least one WC is connected.

c) 150 mm nominal bore pipe may be laid at a gradient not flatter than 1 : 150, provided that at least five WCs are connected.

d) Experience has shown that for gradients flatter than those given in items a) to c), a high standard of design and workmanship is necessary if blockages are to be minimized. Where this has been achieved, gradients of 1 : 130 for 100 mm nominal bore pipes and 1 : 200 for 150 mm nominal bore pipes have been used successfully.

Where the available fall is less than that necessary to achieve the recommended gradient, increasing the pipe diameter particularly at low flows is not a satisfactory solution. It will lead to a reduction in velocity and depth of flow and an increase in the tendency for deposits to accumulate in the pipes.

Where it is expected that a drain may be affected by settlement, the selected gradient should be such as to ensure that a satisfactory fall will be maintained.

Recent research has shown that high velocities of sewage flow arising from steep gradients do not cause increased erosion of pipes or deposition of solids. In such situations drains should be laid at gradients which are the most economical in excavation and cost. High velocities can, however, cause excessive turbulence at bends and manholes and lead to fouling. Where this occurs it can be mitigated, for example by reducing the arc in which fouling can occur by providing an access cover at pipe level.

[4)] See "Tables for the hydraulic design of pipes" (metric edition) (Hydraulics Research Station HMSO 1982) [5]. For further information on on-going research, reference should be made to Water Research Centre.

[5)] There may be special bore requirements, e.g. for hospitals and some industrial discharges.

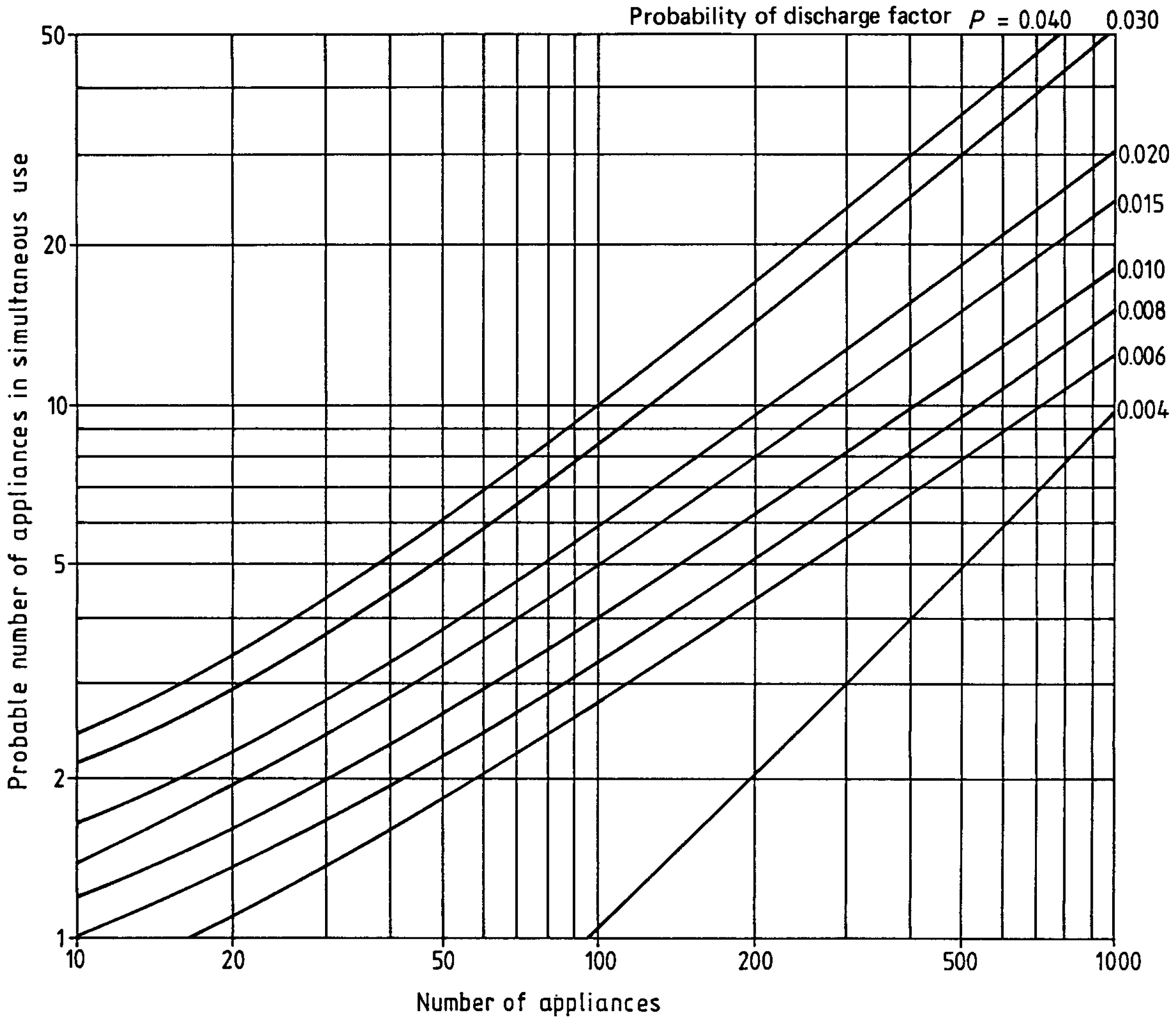


Figure 1 — Probability graph for number of appliances discharging simultaneously
(see **7.4.3.2**)

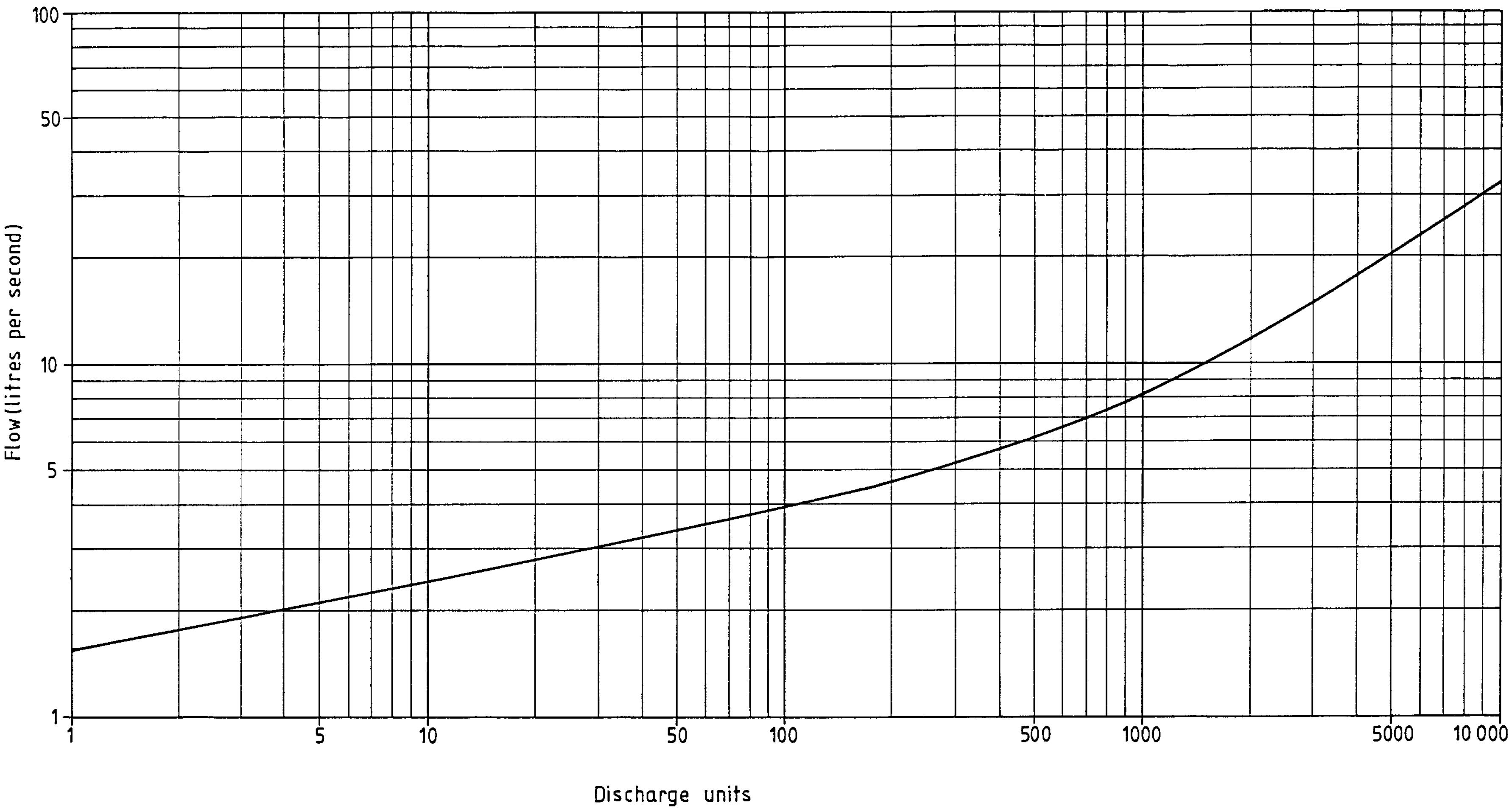


Figure 2 — Design flows for foul drains: conversion of discharge units to flow rates (see **7.4.3.3**)

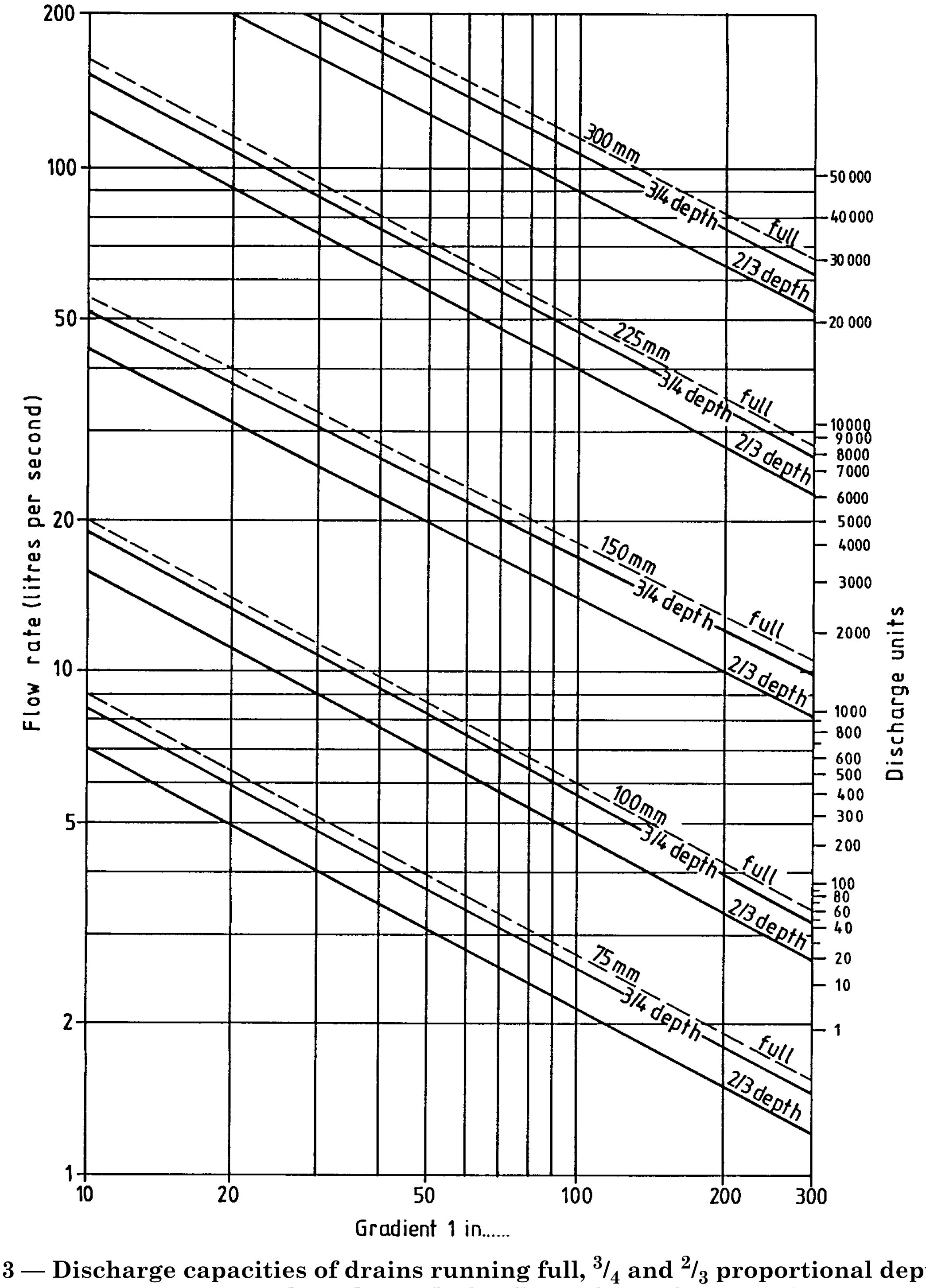


Figure 3 — Discharge capacities of drains running full, $^3/_4$ and $^2/_3$ proportional depth: used pipes in good condition (hydraulic roughness, k = 0.6 mm)

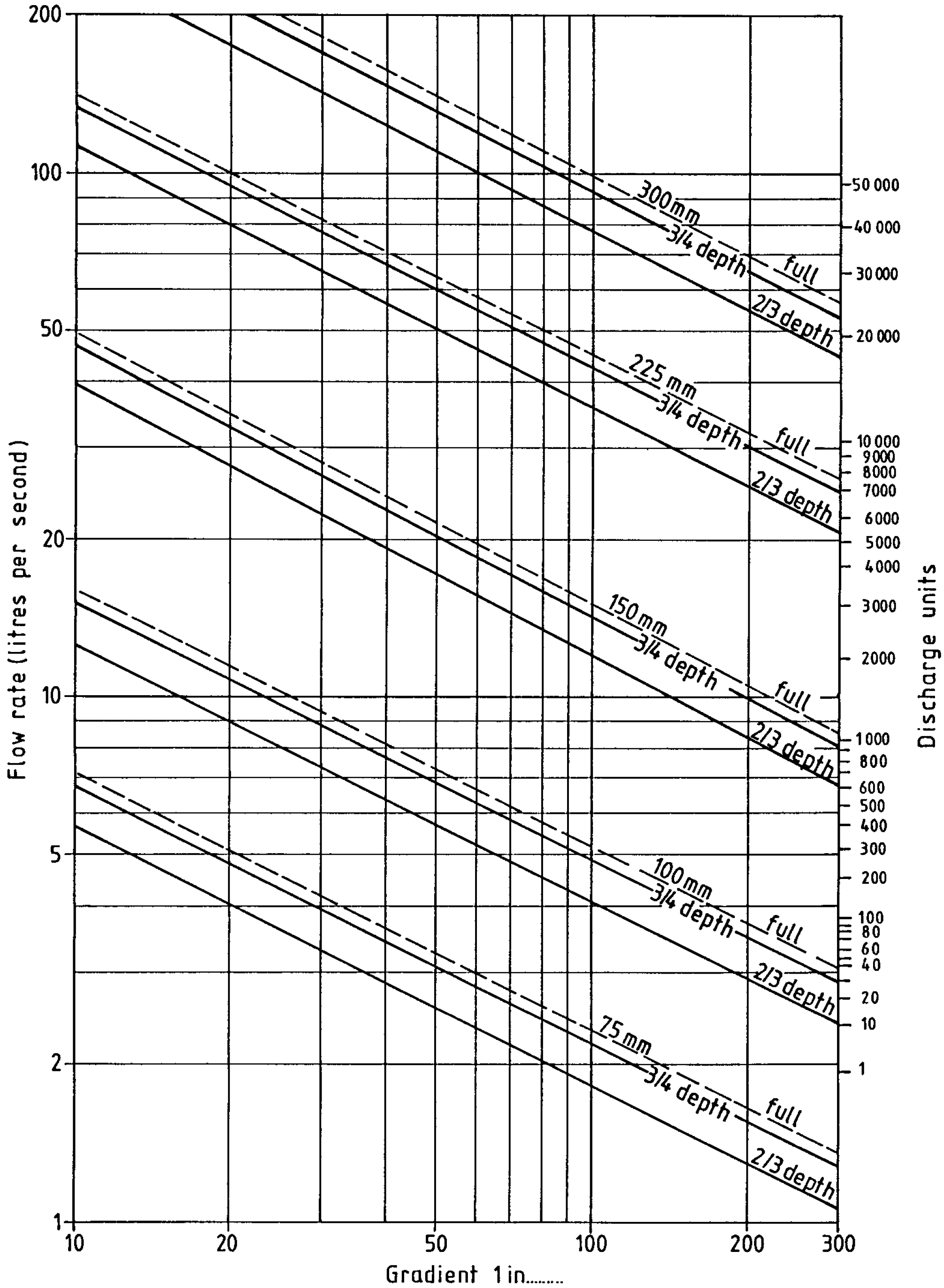


Figure 4 — Discharge capacities of drains running full, 3/4 and 2/3 proportional depth: used pipes in poor condition (hydraulic roughness, k = 1.5 mm)

7.4.4.5 *Pipe roughness.* The hydraulic roughness of new and clean pipes will be reduced by sewage continuously passing through them. This is because slime, mostly microbiological, adheres to and accumulates on their interior surfaces. This slime blankets most of the effects of the other factors affecting the hydraulic roughness. In combined drains, as in surface water drains, grit or silt deposited on the invert has the same effect.

7.5 Trade effluent

The peak rate of flow due to the discharge of a trade effluent should be measured or assessed from the water consumption of the process from which it is derived and steps taken to limit or balance the rate of discharge as necessary.

7.6 Connections to foul drains

7.6.1 *General.* A connection to a foul drain from a sanitary appliance, a discharge stack, a gully or a branch drain should, where convenient and practicable, be made to an inspection chamber or manhole. However, provided that effective access to all pipe runs is achieved for maintenance, removal of blockages and testing, it may be made to a junction.

However made, it should be so arranged that the discharge is swept in the direction of flow at the point of connection.

The length of a connection from an appliance should preferably not exceed 6 m and that from a group of appliances 15 m (see clause **13**).

7.6.2 *Connection to inspection chamber or manhole.* A branch connection should have an angle of entry not greater than 90° at the internal face of an inspection chamber or manhole (but see **13.4.4**). Where practicable it should be installed at half pipe level of the main channel to provide a cascade entry, and the connection so shaped as to discharge into it with minimum turbulence and without causing backing-up into other connections.

Where the invert level of an incoming drain is less than 1 m above that of an inspection chamber or manhole an external 45° ramp may be used (see also **7.6.6**).

7.6.3 *Connection to junction.* A connection between a branch drain and any other drain made to a junction should be arranged so that the tributary discharges to the receiving drain in the direction of flow. Where practicable, the discharge should be at half pipe level or above. Where the branch is laid in a direction opposite to that of the main flow, the connection should be made with an appropriate long radius bend and a 45° junction.

7.6.4 *Connection from a discharge stack.* The bend at the foot of a discharge stack should have a minimum centre line radius of 200 mm (see BS 5572). A better performance will be achieved by the use of a long radius bend or two 45° bends. This should always be done where the internal drainage system is designed on the single stack principle or where abuse by the user could lead to blockage at the bend. The need for other changes of direction should be avoided by careful planning, including adaptation of the structural design if necessary.

7.6.5 *Connections for stub stacks.* It has been common practice to connect isolated ground floor waste appliance(s) other than WCs to a trapped back inlet gully. Unless a trapped back inlet gully is specially required a direct connection should be made to the drainage system, provided that the appliance itself has a trap and discharge pipework complying with the recommendations of BS 5572.

7.6.6 *Connection by drop-pipes.* Where the invert level of an incoming drain is 1 m or more above that of the manhole, a drop-pipe may be provided to convey the discharge to the lower level. It may be practicable to connect more than one branch drain to a single drop-pipe. Suitable access should be provided to facilitate testing and clearing of blockages.

Where space is available without adversely affecting access or working space, a drop-pipe may be installed inside a manhole. This is seldom practicable if the drop-pipe is larger than 150 mm diameter. It should then be constructed outside the manhole and provided with structural protection and support suited to the pipe material and ground conditions.

7.6.7 *Connections to an existing drain.* Where it is impracticable to construct an inspection chamber or manhole for a connection to an existing drain, a junction should be inserted. Where this is impracticable a saddle may be used providing the receiving drain is at least one size larger than the branch drain and the saddle connection is made so that the flow enters above the horizontal diameter.

7.7 Connections to public foul sewers

The position, method and timing for making a connection to a public sewer should be agreed with the appropriate drainage authority. The branch drain should be so laid as to provide an adequate hydraulic gradient and to ensure that the minimum length of drain is subjected to backflow should the sewer surcharge.

An authority may require the provision of an intercepting trap on a drain as a rodent control measure.

7.8 Connections to private foul sewers

The position, method and timing for making a connection to a private sewer should be negotiated and agreed with the owner(s) of the sewer and any necessary wayleave arranged. The branch drain should be laid so as to provide an adequate hydraulic gradient and to ensure that the minimum length of drain is subjected to backflow should the sewer surcharge.

7.9 Connections to septic tanks, settlement tanks or cesspools

Where a drain or private sewer is connected to a septic or settlement tank, the entry velocity should be restricted so as to ensure that quiescent conditions within the tank are disturbed as little as possible. In the case of an incoming drain of up to 150 mm diameter this is usually achieved by adopting a gradient not steeper than 1 : 50 for a length of at least 12 m immediately upstream of the tank. Provision should be made for effectively rodding the incoming drain and its connection to a cesspool or tank.

Information on the design of small sewage treatment works and cesspools is given in BS 6297.

7.10 Ventilation of foul drains

Ventilation should be achieved through the connection of ventilated discharge stacks, but where none is available, e.g. from a group of single storey dwellings, it is essential that a ventilating pipe be provided preferably near the head of the drain run, or where required by the building control authority.

Where an intercepting trap is required by an authority, ventilation of the drain should be provided near to the trap as well as elsewhere in the system.

A branch drainage connection, particularly to a sealed system, will need to be ventilated if the vertical distance between appliance and drain could cause self-siphonage. In the case of a WC discharge it has been found that a vertical distance between the crown of the trap and the drain invert of 1.5 m is satisfactory without ventilation.

8 Surface water drainage

8.1 General

The outfall of a surface water drainage system should discharge into a surface water sewer, a combined sewer, or if neither is available, to a soakaway, a watercourse, or to a storage container.

8.2 Drainage to a sewerage system

When a surface water drain is connected to a surface water sewer, an intercepting trap should not be provided. Where the connection is made to a combined or partially separate sewer, a trap should be provided in order to prevent sewer gas entering the surface water drain.

8.3 Disposal of surface water

In the absence of a surface water or combined sewerage system, disposal into soakaways, ditches, land drainage, canals, natural watercourses or other water bodies, e.g. ponds, lakes is desirable, if practical and permissible. It is essential to discuss the proposal with the relevant authority (see clause **3**).

8.4 Drainage to a soakaway

In the absence of a suitable sewer, and if it is not desired to conserve rainwater, it is often practicable to dispose of surface water to a soakaway. Where ground conditions are suitable and where it is desirable to maintain groundwater levels, soakaways should be considered. They also reduce the hydraulic loading on downstream sewers and water-courses.

If drainage to a soakaway is to be adopted, the subsoil and the general level of the ground water should be investigated. A soakaway is not desirable nearer to a building than about 5 m, nor in such a position that the ground below foundations is likely to be adversely affected.

A soakaway consists generally of a pit from which water may percolate into the surrounding ground. Small pits may be unlined and filled with hardcore for stability or the soakaway may take the form of seepage trenches following convenient contours. Larger pits may be unfilled but lined, e.g. with brickwork laid dry, jointed honeycomb brickwork, perforated precast concrete rings or segments laid dry, and the lining surrounded with suitable granular material. An unfilled pit should be safely roofed and provided with a manhole cover to give access for maintenance purposes.

A soakaway can be used most effectively in pervious subsoils, such as gravel, sand, chalk or fissured rock, and where it is completely above the water table. Seasonal variations in the water table may necessitate an increase in the storage capacity.

In ground with low permeability, it is necessary to provide storage capacity to retain the flows during prolonged or heavy rainfall. A capacity equal to 12 mm of rainfall over the areadrained should be adopted. Its effective depth is measured below the invert of the lowest incoming drain. This can be achieved by the provision of one soakaway or a number linked at overflow level by piped seepage trenches. Similar trenches can be used to provide means of overflow from a soakaway.

Where any doubt exists as to the suitability of the ground, it may be necessary to obtain permeability figures by test. BRE Digest 151 [6] describes a simple test for the measurement of rate of percolation into the ground which is then used to determine the size of soakaway for the area to be drained by reference to a graph (see also BS 6297).

8.5 Drainage to a watercourse or other water body

Where surface water is discharged to a nearby ditch, stream, river, canal, pond or lake (see **8.3**), the invert level of the outfall should be approximately 150 mm above the normal water level. Where periodic backflooding is likely to occur and it is not practicable to discharge at a higher level, a non-return valve should be fitted.

The outfall should be so formed as to avoid, or provide protection against, local erosion. It may be necessary to provide additional protection to the outfall opening to prevent damage or interference.

8.6 Drainage to storage containers

Where it is required to conserve it for use, water from paved areas or roofs may be drained to a storage cistern which should be securely covered, with provision for inspection and cleaning, and provided with an overflow to a nuisance-free outfall.

8.7 Flow balancing

Where high rates of discharge of surface water occur, it may be necessary to provide a retention tank or balancing pond to intercept and hold back temporary peak storm discharges in order to avoid flooding. Suitable arrangements should be made for the maintenance and safety of the tank or pond and the surrounding area.

8.8 Determination of flow: surface water

8.8.1 *General.* If an area is sewered on the separate system, all foul water should be excluded from the surface water drains. If sewered on the combined or the partially separate system, and the new development is to be similarly served, the appropriate drains should provide capacity for foul and surface water (see **7.4** and **8.8.2** to **8.8.8**).

8.8.2 *Flat rate of rainfall.* The method adopted for the assessment of the peak rate of discharge of surface water from building development will vary according to the area and type of development. For areas which require a main surface water drain up to 200 m in length, a uniform rate of rainfall intensity may be adopted. A rate of 50 mm/h is commonly used for such areas, but higher rates may be applicable in specific circumstances (see BS 6367).

The whole of the rainfall on impervious areas should be assumed to reach the drains. The impervious areas should include the horizontal projection of the roof areas, paved areas and half the area of the exposed vertical face of tower buildings (see BS 6367).

For larger areas the peak rate of discharge should be assessed as described in **8.8.3** to **8.8.8**.

8.8.3 *"Wallingford Rational" method.* When a design based on a uniform rate of rainfall is not appropriate, the use of the "Wallingford Rational" method for design of storm sewers is recommended for catchment areas of less than 150 hectares where the time of concentration is up to 30 min and the pipe size is up to 1 m.

This method is a development from the Lloyd-Davies formula and is described in Volume 4 of the Wallingford Procedure [7].

The Lloyd-Davies formula states that

$$Q = A_p \times i \times C_r \times C_v \times 2.78$$

where

- Q is the rate of run off (in L/s);
- A_p is the contributing impermeable area (in ha);
- i is the mean rate of rainfall (in mm/h);
- C_r is the dimensionless routing coefficient;
- C_v is the volumetric run-off coefficient.

This formula enables the calculation of run-off to reflect the nature of the catchment and substrata since recent research has shown that the volume of run-off is related to soil type as well as impermeable area.

In order to determine the rate of flow in a drainage system it is therefore necessary to know the intensity of rainfall to apply corresponding to the return period chosen, the impermeable area contributing to each part of the system and the appropriate coefficients.

8.8.4 *Intensity of rainfall.* It is assumed that:

a) the variation in the rate of rainfall during a storm and in the volume of water retained in the drainage system may be neglected;

b) the maximum discharge of stormwater from an area occurs when the duration of the storm is equal to the time of concentration, t, of the area. The time of concentration is the longest time taken for the rain falling on the area to reach the drain plus the time taken to travel to the point under consideration, i.e.:

$$t = \text{time of entry} + \frac{\text{length of drain}}{\text{full bore velocity of flow}}$$

c) the time of entry may be regarded as representing the delay and attenuation of flow over the ground surface.

The following values are recommended:

Return period	*Time of entry (minutes)*
5 years	3 to 6
2 years	4 to 7
1 year	4 to 8

For each return period the larger times of entry are applicable to large, flat sub-catchments (area greater than 400 m^2, slope less than 1 : 50) and the smaller values to small, steep sub-catchments (area less than 200 m^2, slope greater than 1 : 30).

NOTE These values of area and slope refer to the sub-catchments contributing to each pipe length.

Rates of rainfall for any urban or rural area in Great Britain can be obtained on application to the Meteorological Office, Bracknell (Reference Met 08). Volume 4 of the Wallingford Procedure [7] contains a manual method of calculation and the computer version of the methods with the rainfall data (see **8.8.3**).

8.8.5 *Impermeable area.* For the purpose of calculations, the surface area contributing to flow in drains is normally taken as the area of paved surfaces connected to the drainage system, and unpaved areas are assumed not to contribute.

8.8.6 *Dimensionless routing coefficient,* C_r. The value of the routing coefficient should, theoretically, vary with the shape of the time-area diagram and the shape of the rainfall profile. For use with the "Wallingford Rational" method (see **8.8.3**) a constant value of 1.3 is recommended.

8.8.7 *Volumetric run-off coefficient,* C_v. The volumetric run-off coefficient may be defined as the proportion of rainfall on the paved areas which appears as surface run-off in the storm drainage system.

The coefficient ranges from about 0.6 on catchments with rapidly-draining soils to about 0.9 on catchments with heavy soils. These values reflect the loss of some rainfall from impervious areas through cracks and into depressions and by drainage onto pervious (unpaved) areas. Similarly, any run-off from pervious areas onto the impervious areas is also incorporated.

Alternative methods of determining C_v to take account of specific soil characteristics and regional variations in catchment wetness are described in Volume 1 of the Wallingford Procedure (see **8.8.3**) [7].

8.8.8 *Method of calculation.* The procedure described in items a) to g) should be adopted.

a) Prepare a key plan of the proposed drainage network, to identify the trunk and branch lengths of the system.

b) Determine the impermeable areas contributing to each length of drain.

c) Select a pipe size in order to determine the time of flow through the drain.

NOTE For this the Hydraulics Research Station "Tables for the Hydraulic design of pipes" are recommended [5].

Take the time of concentration as the cumulative time of flow plus a time of entry (see item c) of **8.8.4**).

d) Select the rate of rainfall corresponding to the time of concentration and chosen return period of storm from the appropriate Meteorological Office data.

e) Select the volumetric run-off coefficient.

f) Calculate the expected peak flow using the above formula.

g) Check the chosen pipe size, change if obviously too large or too small, and repeat steps c) to e).

This procedure is applied to each length throughout the system.

A full explanation of the method, including a pipe numbering system and determination of impermeable areas, rates of rainfall and volumetric run-off coefficient is given in Volume 4 of the Wallingford Procedure [7].

8.9 Connection of gullies

A gully may be connected directly to a drain, to a suitably located inspection chamber or manhole, or to a soakaway. In the case of a drain connection, a gully having rodding access should be provided and the connection made by a junction or, if impracticable in the case of an existing drain, by a saddle.

For details of methods of making connections, see clause **24**.

8.10 Connection of rainwater pipes

A rainwater pipe may be connected to a drain or to a suitably located inspection chamber, manhole or gully, or to a soakaway. Where not otherwise available, access should be provided on or at the foot of the pipe in such a manner that rodding is practicable and adequate working space is available.

Where positioning of a rainwater pipe coincident with a structural foundation is unavoidable, the connection should be made with the minimum of changes in direction, and additional access points should be provided if necessary to facilitate effective maintenance.

For further details of methods of making connections, see **7.6** to **7.9** and **24.3**.

8.11 Connections to public sewers

See **7.7**. An intercepting trap should not be provided for a connection to a surface water sewer unless required by the drainage authority.

8.12 Connections to private sewers

See **7.8**.

8.13 Ventilation

Ventilation can usually be achieved by the direct connection of rainwater pipes or the use of untrapped gullies in suitable positions (see **7.10**).

9 Combined drainage

9.1 Drainage to a sewerage system

The outfall of a combined drainage system should discharge into a combined sewer.

9.2 Determination of flow: general

If an area is sewered on the combined system and new buildings are to be similarly drained, capacity should be provided for foul and surface water.

9.3 Determination of flow: combined drains

A combined drainage system should be capable of accepting the sum of the peak foul water and surface water flows which can normally be achieved by a design based on the surface water flow. Where, however, there is sustained foul flow of sufficient volume relative to the surface water flow, additional capacity should be provided (see **7.4**).

9.4 Trade effluent

See **7.5**.

9.5 Pipe sizes and gradients

See **6.3** and, if appropriate, **7.4.4**.

9.6 Connections to combined drains

Connections from sanitary appliances, discharge stacks, rainwater pipes, surface water gullies or waste gullies should be made as described in **7.6**, **8.9**, **8.10** and **8.11**, subject to the following recommendations.

The design should ensure that surcharge which could adversely affect normal ventilation or reduce the hydraulic gradient on an incoming drain is minimized.

A rainwater pipe may discharge direct to a combined drain providing that the outlet(s) it serves is not so sited as to give rise to nuisance by reason of its ventilation of the drain, and that it is installed to the same specification as a foul water discharge pipe (see BS 5572). If these criteria cannot be met the rainwater pipe should discharge into a trapped gully.

A surface water gully connected to a combined drain should be provided with a trapped outlet.

It may be convenient and economical to connect rainwater pipes and surface water gullies to a separate collecting drain without trapping, and to provide an intercepting trap or a reverse acting disconnecting trap at the point of its connection to a combined drain.

9.7 Connections to public combined sewers

See **7.7**.

9.8 Connections to private combined sewers

See **7.8**.

9.9 Ventilation

See **7.10**. Additionally special measures may be necessary when a system is subject to surcharge conditions (see **12.4**).

10 Groundwater drainage

10.1 General

The drainage of groundwater may be necessary for the following reasons:

a) to increase the stability of the ground;

b) to avoid surface flooding;

c) to alleviate subsoil water pressures likely to cause dampness to below-ground accommodation;

d) to assist in preventing damage to the foundations of buildings;

e) to prevent frost heave of subsoil which could cause fractures to structures such as roads or concrete slabs.

Where it is required to reduce the ground water level permanently in order to enable development to proceed, expert advice should be sought.

10.2 Layout of field drain pipes

10.2.1 *General.* The selection of an appropriate layout depends on the nature of the subsoil and the topography of the site. See "The design of field drainage pipe systems", MAFF [8].

10.2.2 *Natural system.* This system consists of pipes laid to follow the natural depressions or valleys of the site, with branches discharging into a main drain at the lowest level.

10.2.3 *Herringbone system.* This consists of a main drain into which discharge, from both sides, smaller branches laid parallel to each other, at an angle to the main. The system has wide applications due to its versatility, because a number of these herringbone units can discharge into a collecting drain, depending on the size of the site.

10.2.4 *Grid system.* This consists of a main drain or drains laid near the boundaries of a site, into which branches discharge from one side only. It is applicable where the terrain has a general fall in one direction.

10.2.5 *Fan-shaped system.* This consists of drains laid to converge on a single outlet at one point.

10.2.6 *Moat or cut-off system.* To protect a building, drains may be laid on one or more of its sides to divert the flow of groundwater.

10.3 Spacing of branch drains

The information given in Table 5 may be used as a guide to the spacing of branch drains.

10.4 Mole drains

In clay, or heavy soils, an alternative to pipes is the mole drain. This type of drain is not suitable for light soils or made-up ground. The life of mole drains is unlikely to exceed 10 years, after which the operation may need to be repeated (see **23.2**).

Table 5 — Spacing of branch drains

Soil	Distance between branch groundwater drains for various depths to invert of main drains	
	Mains 0.8 to 1.0 m deep	Mains 1.0 to 1.5 m deep
	m	m
Sand	—	45 to 90
Sandy loam	—	30 to 45
Loam	16 to 20	20 to 30
Clay loam	12 to 16	15 to 20
Sandy clay	6 to 12	—
Clay	2 to 6	—

Mole drains are suitable for either natural or grid layouts. They should be made at depths from 0.3 m to 0.75 m and may be placed from 3 m to 5 m apart, depending on site conditions.

10.5 Groundwater drains under buildings

The laying of groundwater drains under buildings should be avoided in order to obviate any ill-effects on the foundations of changing the groundwater level or transporting away fine material.

Should it be necessary to route a groundwater drainage system under a building, this should be done using jointed non-porous pipes (see **6.6**).

10.6 Discharge of groundwater to an outfall

The connection of a groundwater drainage system to an outfall should normally be made through a catchpit designed to intercept and retain soil particles and other suspended matter.

10.7 Discharge of groundwater to a watercourse

A groundwater drainage system may discharge through a catchpit or directly into a ditch or watercourse (see **8.5**).

10.8 Discharge of groundwater to a soakaway

In suitable ground conditions, a groundwater drainage system may discharge to a soakaway, preferably through a catchpit.

10.9 Discharge of groundwater to a drain

Where the alternative outlets of **10.7** and **10.8** are not available, a groundwater drainage system may discharge into a surface water, combined or foul drain, through a catchpit. A connection to a combined or foul drain should be made through an intercepting trap or reverse acting disconnecting trap. Where the drainage system discharges to a public sewer, the approval of the drainage authority should be obtained.

10.10 Connection of catchpits

Jointed pipes should be provided over a length of at least 2 m upstream of a catchpit, and for its outlet drain. Adequate access should be provided for inspection and for removal of collected solids.

10.11 Level of groundwater

The standing level of groundwater will vary with the season, the amount of rainfall and the proximity and level of watercourses. It should be ascertained by means of boreholes or trial holes over a considerable period and the seasonal variations recorded together with the highest water level achieved. The direction of flow of the groundwater may usually be judged by the general inclination of the land surface and, wherever practicable, the main lines of groundwater drains should follow the natural falls.

10.12 Flow rate

The flow rate for field drain design should be 5 L/(ha s) for normal conditions, but higher rates should be used where surfaces are of high porosity.

10.13 Pipe sizes and gradients

Main groundwater drains should be not less than DN 100, and the branches not less than DN 75. Pipes should be laid at 0.8 m to 1.0 m depth in heavy soils and deeper in light soils (see Table 5), the gradients being determined by fall of the land rather than by considerations of self-cleansing velocity.

For areas such as playing fields, the main drain should be not less than DN 75, with branches not less than DN 50.

11 The structural design of drainage

11.1 General

11.1.1 *Basis for design.* The following information on the structural design of pipelines is based mainly on the work of Marston, Spangler and Schlick of lowa University, supplemented by data obtained by tests carried out in the UK.

The design of bedding for pipelines is based on the principle that the ability of a pipe to carry a load may be increased by the provision of suitable bedding. A rigid pipe has inherent strength but by providing a degree of encasement higher loads may be carried. A flexible pipe on the other hand will deform under the application of loads and requires support from surrounding material, and thus from the sides of the pipe trench, in order to avoid excessive deformation of the pipe.

The load on a pipeline depends on the diameter of the pipe, the depth at which it is laid, the trench width, the traffic or other superimposed loading and the prevailing site conditions.

The limits of cover for rigid pipes up to DN 300 have been computed from the loads produced by different surface loading conditions, plus backfill, for the various bedding constructions (see Figure 5 and Table 6). Wide trenches, which produce the highest loading conditions, have been assumed and a factor of safety has been applied.

Bedding arrangements for flexible pipes in both narrow and wide trenches are given in Figure 6.

11.1.2 *Pipes at shallow depths.* Where pipes are to be laid at less than 1.2 m below the wearing surfaces of roads or less than 1 m below road formation level or less than 0.9 m in fields and gardens, protection should be provided against loads other than final backfill and wheel loading or impact, e.g. site construction traffic, the possibility of subsequent building works or agricultural activities, the erection of fences, or from other mechanical damage and frost.

Rigid pipes of less than DN 150 laid with less than 0.3 m of cover, or of DN 150 or greater with less than 0.6 m of cover should, where necessary, be protected by surrounding them in concrete. At depths greater than these, the bedding conditions given in Table 6 apply.

Ductile iron, although classed as flexible, has high inherent strength and can usually be laid without special embedment. Where laid with less than 1.0 m cover, except under roads, ductile iron pipes need no special protection. Under roads a granular surround should be provided where they are laid with 1.0 m to 0.3 m of cover, and where less than 0.3 m of cover is provided, a concrete surround may be necessary.

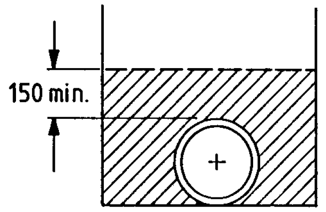
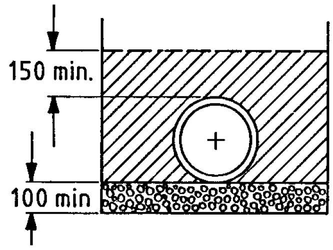
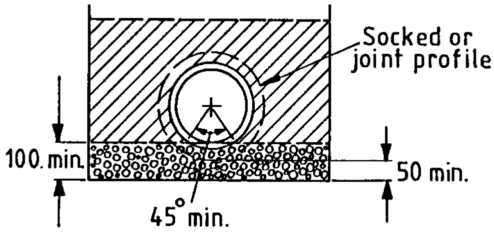
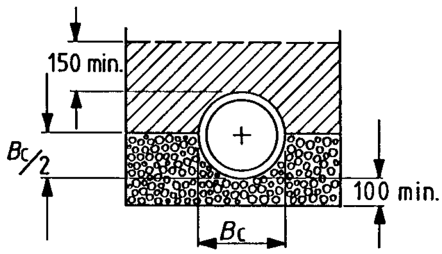
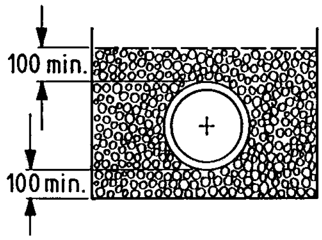
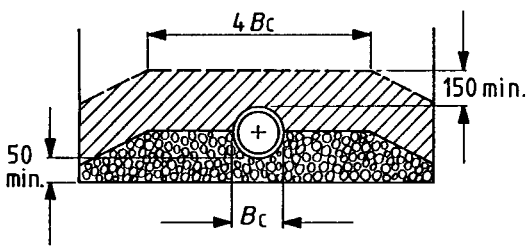
Flexible pipes laid at depths less than 0.6 m, not under a road, should where necessary be protected against risk of damage, for example by placing over them a layer of concrete paving slabs with at least a 75 mm layer of granular material between pipes and slabs.

Pipes laid at a depth less than 0.9 m below the finished surface of a road should be suitably protected with a reinforced concrete surround or by means of reinforced bridging slabs of adequate strength.

11.1.3 *Special site conditions.* In some situations, for example where a drain passes beneath or near to a foundation of a structure, the load expected to be carried by the pipeline cannot readily be assessed and a completely rigid system of protection such as a concrete encasement or a 180° concrete cradle may be appropriate.

Any vertical construction or movement joint in concrete protection should be provided over the full width and depth of the concrete and located at the leading edge of a socket of a flexible joint or a sleeve coupling.

It is desirable to seek expert advice where pipes are laid on piles or beams, or where more than one pipe is laid in a trench. Unstable soils such as soft clay, silt, or fine sand may provide diminished support for pipes and bedding materials, especially if there is a high water table.

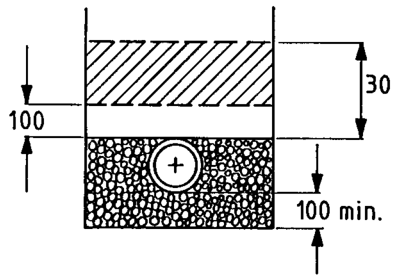
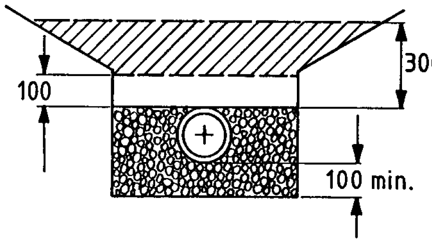
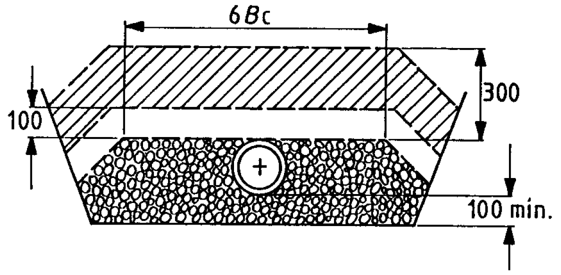
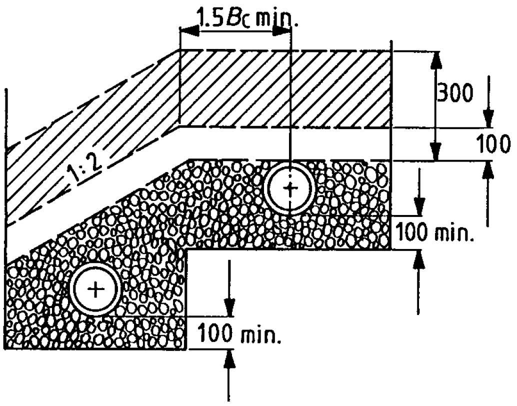
Figure	Bedding class		Bedding factor	Comments
5a	D		1.1	Pipe laid on trimmed trench bottom.
5b	N		1.1	Pipe laid on a flat layer of granular material with CF[a] not greater than 0.3.
5c	F		1.5	Pipe laid on flat layer of granular material with CF[a] not greater than 0.2. Illustrated after settlement. See **11.2.6**.
5d	B		1.9	Pipe laid on granular material to half diameter with CF[a] not greater than 0.2.
5e	S		2.2	Pipe fully surrounded by granular material with CF[a] not greater than 0.2.
5f	B (example)		1.9 (example)	Construction as in Figure 5b, Figure 5c, Figure 5d and Figure 5e, except that when the trench width exceeds four times the outside diameter of the pipe barrel, the granular material may be sloped down from that width to the trench formation.

All dimensions are in millimetres.

NOTE 1 **5.7.5** gives recommendations for granular material for bedding.
NOTE 2 **5.7.6** gives recommendations for selected material for sidefill and initial backfill.
NOTE 3 **18.8**, **20.2** and **20.3** detail pipelaying procedures.
NOTE 4 Where there are sockets, these should be not less than 50mm above the floor of the trench.

[a] CF = Compaction fraction (see Appendix D)

Figure 5 — Beddings for rigid pipes

Figure	Type of trench		Comments
6a	Typical		Pipe surrounded in granular material except above the crown where selected fill may be suitable (see **20.3**).
6b	Vee		A sub-trench should be dug as shown, with construction as in Figure 6a.
6c	Wide		Construction as in Figure 6a, except that when the trench exceeds six times the outside diameter of the pipe barrel, the granular material may be sloped down from that width to the trench formation.
6d	Stepped dual		Construction as in Figure 6a for top pipe.

All dimensions are in millimetres.

NOTE 1 **5.7.5** gives recommendations for granular material for bedding.
NOTE 2 **5.7.6** gives recommendations for selected material for initial backfill.
NOTE 3 **18.3**, **20.2** and **20.3** detail pipelaying procedures.
NOTE 4 Where there are sockets, these should be not less than 50 mm above the floor of the trench.

Figure 6 — Beddings for flexible pipes

11.2 Rigid pipes (asbestos cement, clay, concrete or grey iron)

11.2.1 *General.* A suitable method of design is one that relates the British Standard test strength of a pipe to the maximum external design loads likely to be imposed upon it in the ground, assuming uniform longitudinal and constant cross-sectional support of the pipe. This method has been used in compiling Table 6. Bedding constructions for rigid pipes are shown in Figure 5.

11.2.2 *Pipe strength.* The crushing strength of the pipe may be obtained from the relevant British Standard or from the pipe manufacturer if the British Standard does not contain a crushing strength requirement.

11.2.3 *Soil density.* A soil density of 2 000 kg/m^3 has been assumed in compiling Table 6 and Figure 5.

11.2.4 *Traffic loads.* The following static wheel loads and impact factors have been assumed in compiling Table 6 and Figure 5. The main road traffic load includes an impact factor (see BS 5400-2).

	Wheel load	No. of wheels	Impact factor
Main road	112.5 kN	8	included
Other road	70 kN static	2	1.5
Field and garden	30 kN static	2	2.0

11.2.5 *Total design load.* The limits of cover have been calculated for the worst combination of fill and traffic loads occurring over the length of drain. If any other surcharge load is likely to be imposed its effect should be calculated and the pipeline and bedding designed accordingly.

11.2.6 *Pipe settlement.* A pipe will normally settle under the bedding arrangements shown in Figure 5. The extent of this settlement will depend upon the total load and the shape, grading, physical properties, and degree of compaction of the bedding material, but in no case should it exceed that illustrated for class F bedding.

11.2.7 *The use of Table 6.* Table 6 shows the relation between pipe crushing strength, bedding class, range of cover and surface conditions, and is applicable to asbestos cement, clay and concrete pipes.

If the trench formation is capable of being hand trimmed to receive the pipeline directly upon it and if the actual cover is included in the range for class D, this class of bedding may be used. However if the cover is within the range of class D but it is considered to be impracticable to trim the trench bottom, then bedding of class N can be used (see also **18.2** and **20.2**).

In all cases if the cover requirements for a particular pipe strength and traffic condition preclude the use of class D or N bedding, the bedding construction required for that cover, as given in Table 6, should be used.

For intermediate pipe strengths not shown in this table, linear interpolation will give the permissible depth range for a given bedding.

Generally, for any length of drain between points of access, the pipe strength and class of bedding selected for the worst condition should be used for the whole of that length of drain.

Pipe strength and beddings for the majority of building drainage work may be determined using this simplified method. Full calculation based on Marston theory allowing for the narrowest practical trench width and the actual soil density plus the appropriate traffic wheel load may result in a more economic design.

11.2.8 *Higher strength pipes.* For pipes of higher strength than those shown in Table 6, e.g. grey iron pipes to BS 437 or BS 4662, and asbestos cement pipes to BS 486, laying depths and bedding requirements may be obtained from the pipe manufacturers.

11.3 Flexible pipes (ductile iron, GRP, steel and uPVC)

11.3.1 *General.* A flexible pipe may be defined as one that, under soil and surcharge loads, is capable of deflecting to a significant extent without any sign of structural distress.

The pipe derives its load bearing capability from its bedding or surround. Under soil and superimposed loading the pipe deflects vertically and horizontally thereby developing passive support at the sides of the pipe.

The ability of a flexible pipe to resist the loads placed upon it is dependent on two factors; the pipe stiffness and the passive resistance (soil stiffness) developed in the surrounding material. Design is based on the extent to which deformation may be safely allowed to proceed. Pipe stiffness varies according to the material of manufacture and the extent of deformation allowable decreases as pipe stiffness increases. Soil stiffness varies according to the nature of the subsoil material and the type and degree of compaction of the bedding material.

11.3.2 *Depth range.* When installed according to the recommendations described in **20.3**, uPVC and ductile iron pipes are suitable for depths up to 10 m without further specific design. For shallow depths see **11.1.2**.

12 Provision of gullies, interceptors and anti-flooding devices

12.1 Gullies

A gully is a drain fitting or assembly of fittings which may have inlets to receive connections from waste appliances or rain water pipes, or both in the case of a combined system. It usually incorporates a trap, or a sump to retain detritus, or both. It should be of a size, capacity and material appropriate for its purpose and location and have a clear waterway such that flow is not restricted. A larger gully intended for interception of detritus should be of such size and form, e.g. externally trapped, to facilitate cleansing by gully emptying equipment. The top of the gully assembly should have a least dimension not less than 150 mm and may be fitted with a grating or with a sealed cover which, where provided, should be airtight and watertight. The outlet of a gully should be of such dimensions and form that a watertight joint can be made to the pipework into which it is to discharge. A trapped gully should provide and sustain under working conditions a water seal of 50 mm minimum depth (see **5.7.2** for information on materials for gullies).

Use of gullies other than for draining paved surfaces should be minimal. Where provided a gully should be fixed as near to the surface as practicable in order that manual cleansing and maintenance can be effectively and safely carried out. The depth from surface level to the base of a gully having a 150 mm diameter shaft should not exceed 600 mm and for larger shafts should not exceed 920 mm. Where effective access for rodding the branch drain is not otherwise provided a gully should incorporate or be associated with access for this purpose. The access sealing device should be fitted so as to be airtight and watertight. A connection to a gully should be made below the grating or cover and, if from a waste appliance, should enter as near as practicable to the water level to reduce the area of potential fouling but at such a level as not to preclude the insertion of testing or cleansing equipment. A trapless gully should not be installed in a foul or combined system closer than 6 m to any opening into a building or in any position where it could cause a nuisance (see BS 6367 for information on size and layout of surface water gullies).

12.2 Drainage of garage areas and vehicle parks[6)]

It is an offence under Section 27 of the Public Health Act, 1936, to allow petroleum spirit to enter a public sewer. Some form of interceptor is therefore necessary to prevent its entry to any drain and thus avoid the accumulation of explosive gases in the system. It is also necessary to intercept mud, oil and other matter which may cause blockage or be harmful to the fabric of a system. The requirements of the drainage authority in respect of the provision of interceptors should be followed.

In an open parking area requiring drainage and where vehicle washing, but not mechanical servicing occurs, a trapped gully or gullies, each with a sump for detritus, should be installed. Floors of covered car parks need not normally be drained unless situated below the level of adjacent drained surfaces, when it may be sufficient to provide a sump with a removable cover to facilitate pumping out, should this be required. This should be located in an accessible position and be provided with a marker. An open ramp draining to a lower level should be provided with a cut-off channel and drain at entry to the building unless an effective water check with any necessary drainage is incorporated. Similar provisions should be made for preventing surface water from a highway discharging to a ramp and, unless approved by the drainage authority, from a ramp to a highway. Surface water from adjacent areas should be diverted from ramps. Where there is a requirement for drainage in open or covered parking areas, gullies should be 225 mm in diameter and 450 mm deep or larger. In covered areas they should be trapped.

An area used principally for vehicle washing should be drained to a chamber of such design and capacity as to exclude mud and oil effectively from the drainage system. The chamber should have adequate access so that removal of its contents can be conveniently and effectively carried out.

6) Recommendations for precautions in respect of explosive gases are contained in CP 2005, BS 5573 and the booklet "Safe working in sewers and at sewage works", published by the National Joint Health and Safety Committee for the Water Service, 1 Queen Anne's Gate, London, SW1H 9BT [1].

The areas on which vehicles stand to discharge petrol to storage tanks or for their tanks to be filled should be drained to an interceptor which will effectively prevent spilled petrol from entering the drain. Drainage from other areas should be excluded. Adequate ventilation should be provided to the interceptor. The ventilating pipe should be as short as practicable and be terminated not less than 2.5 m above paving level nor less than 1 m above the head of an openable window or other opening into a building within a horizontal distance of 3 m. A three compartment petrol interceptor, as shown in outline in Figure 7, has commonly been used in such situations.

Tests carried out at the Hydraulic Research Station (now Hydraulic Research Ltd.) have shown that the performance of the traditional three-compartment petrol interceptor can be significantly improved. In an attempt to simulate conditions in operational installations (for which reliable data are not available) controlled tests were made on a three-compartment interceptor at various flow rates using a mixture of 500 p.p.m. of petrol in clean water. Separation rates of 93 % to 94 % were achieved, even when the petrol concentration was increased to 1 000 p.p.m., but significant re-entrainment of petrol occurred in trailing flow conditions. Various modifications were made to eliminate re-entrainment and, when oils were used under the same conditions, separation rates of around 90 % were obtained. When the second dividing wall between the compartments was removed 98 % and better rates of removal of oil were achieved.

Figure 8 shows an arrangement incorporating the modifications which were tested. Such an arrangement should enable rates of separation of petrol of at least 98 % to be achieved at flow rates up to 7.5 L/s. The installation is not suitable for interception of large spills.

Where it is not practicable to arrange for the inlet drain to be surcharged, as shown, a baffle may be provided extending 1.5 diameters above the "100 mm below invert" level of the inlet pipe, over the full width of the compartment, but some loss of efficiency may occur under operational conditions.

The test installation was unroofed. Adequate ventilation should be provided in covered installations and, where appropriate, should include ventilation of the inlet drain at a point above its surcharge level.

Where vehicle servicing is regularly carried out, effective arrangements should be made for the separate collection and disposal of surplus oil. Where there is a risk of oil being discharged to or washed into a drainage system, specialist advice should be obtained on the provision of a purpose designed oil separator.

Sumps, mud and oil interceptors, petrol interceptors and oil separators should be of watertight construction in brick, concrete or other suitable material having adequate strength and chemical resistance comparable to that of manholes. They should be positioned so that cleansing is practicable and can conveniently be carried out. Regular inspection and cleansing of these facilities and of gullies are essential if they are to be effective.

12.3 Grease traps

Grease is a normal constituent of water-borne wastes from kitchens and food preparation rooms where small quantities arise from the washing of used crockery and utensils. Where waste macerators are installed the quantities of grease and fats discharged are likely to be greater. Nevertheless, in a properly designed drainage system free from obstruction, grease and fats are unlikely to cause trouble except at those sensitive points where changes in the hydraulic or temperature conditions occur, e.g. a pump sump. Deposits may occur at such points and are likely to have an adverse effect on performance. The most satisfactory arrangement is to ensure that facilities are available at restaurant kitchens for bulk collection and removal of grease, fats and oil and to prohibit their deliberate discharge to drainage systems. The provision of a grease trap is not then normally necessary and should be avoided.

It may, nevertheless, sometimes be necessary to provide a grease trap where the drainage from a large kitchen is discharged near a sensitive point in a drainage system. Where provided, a grease trap should not be installed in a food storage, preparation, cooking or service area nor in any position where nuisance might be caused. As an alternative measure to protect a sensitive point, a proprietary emulsifier may be introduced into a drain or to an element in a system, e.g. a pump sump, in order to maintain grease-free conditions. This should be done only when it can be established that any resulting emulsified grease will not cause a nuisance or pollution downstream.

Table 6 — Limits of cover for rigid pipes laid in trenches of any width

Nominal bore	Class of bedding construction	Crushing strength	Main traffic roads		Other roads		Fields and gardens	
			Min.	Max.	Min.	Max.	Min.	Max.
mm		kN/m	m	m	m	m	m	m
			[a]		[a]		[a]	
		20	0.7	3.7	0.7	4.1	0.4	4.2
		22	0.6	4.2	0.6	4.6	0.4	4.7
	D and N	28	0.4	5.7	0.5	6.0	0.3	6.0
		38	0.3	8.1	0.4	8.2	0.2	8.2
		20	0.5	5.5	0.5	5.8	0.3	5.8
		22	0.4	6.2	0.5	6.4	0.3	6.4
100	F	28	0.3	8.1	0.4	8.2	0.2	8.2
		38	0.2	10.0	0.3	10.0	0.2	10.0
		20	0.4	7.2	0.4	7.4	0.3	7.4
		22	0.3	8.0	0.4	8.2	0.2	8.2
	B	28	0.3	10.0	0.3	10.0	0.2	10.0
		38	0.2	10.0	0.2	10.0	0.2	10.0
		20	—		1.1	2.5	0.6	2.7
		22	1.1	2.0	0.9	2.9	0.6	3.1
	D and N	25	0.8	2.8	0.8	3.4	0.6	3.6
		28	0.7	3.4	0.7	3.9	0.6	4.0
		38	0.6	5.2	0.6	5.5	0.6	5.6
		20	0.7	3.3	0.7	3.8	0.6	3.9
		22	0.6	3.8	0.6	4.3	0.6	4.3
150	F	25	0.6	4.6	0.6	4.9	0.6	5.0
		28	0.6	5.3	0.6	5.6	0.6	5.6
		38	0.6	7.5	0.6	7.6	0.6	7.7
		20	0.6	4.6	0.6	5.0	0.6	5.0
		22	0.6	5.2	0.6	5.5	0.6	5.6
	B	25	0.6	6.1	0.6	6.3	0.6	6.3
		28	0.6	6.9	0.6	7.1	0.6	7.1
		38	0.6	9.6	0.6	9.7	0.6	9.7
		20	—		—		—	
		25	—		—		0.7	2.2
	D and N	28	—		1.1	2.3	0.6	2.6
		38	0.8	3.0	0.7	3.6	0.6	3.7
		20	—		1.2	2.1	0.6	2.5
		25	0.9	2.3	0.9	3.1	0.6	3.3
225	F	28	0.8	3.0	0.7	3.6	0.6	3.7
		38	0.6	4.8	0.6	5.1	0.6	5.1
		20	0.9	2.4	0.8	3.2	0.6	3.3
		25	0.6	3.7	0.7	4.2	0.6	4.2
	B	28	0.6	4.3	0.6	4.7	0.6	4.8
		38	0.6	6.3	0.6	6.5	0.6	6.6
		22	—		—		—	
		25	—		—		—	
	D and N	29	—		—		1.0	1.6
		34	—		1.4	1.8	0.7	2.3
		35	—		1.4	1.8	0.7	2.3
		47	0.9	2.4	0.8	3.2	0.6	3.3
		22	—		—		0.9	1.8
		25	—		—		0.7	2.2
300	F	29	—		1.1	2.5	0.6	2.7
		34	0.9	2.5	0.8	3.3	0.6	3.4
		35	0.9	2.5	0.8	3.3	0.6	3.4
		47	0.6	4.2	0.6	4.6	0.6	4.7
		22	—		1.1	2.4	0.6	2.6
		25	1.1	1.9	0.9	2.8	0.6	3.0
	B	29	0.8	2.8	0.8	3.5	0.6	3.6
		34	0.6	3.8	0.6	4.3	0.6	4.4
		35	0.6	3.9	0.6	4.3	0.6	4.4
		47	0.6	5.7	0.6	5.9	0.6	6.0

[a] See **11.1.2** before using the above table, which has been compiled using the following:

a) soil density of 2 000 kg/m^3;

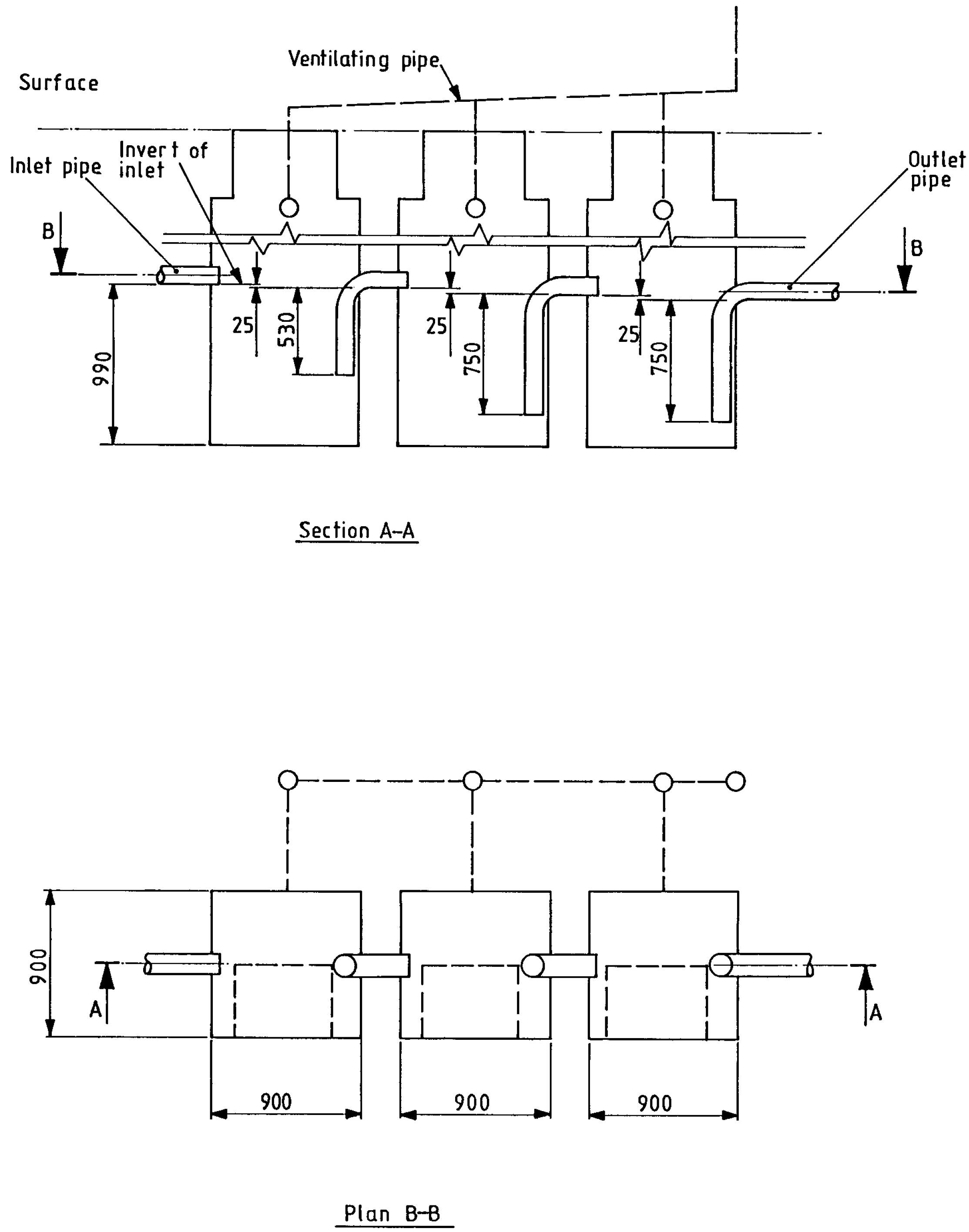
b) factor of safety of 1.25 assuming average site supervision and workmanship;

c) wide trench condition;

d) traffic loads as set out in **11.2.4**;

e) the bedding factors shown in Figure 5.

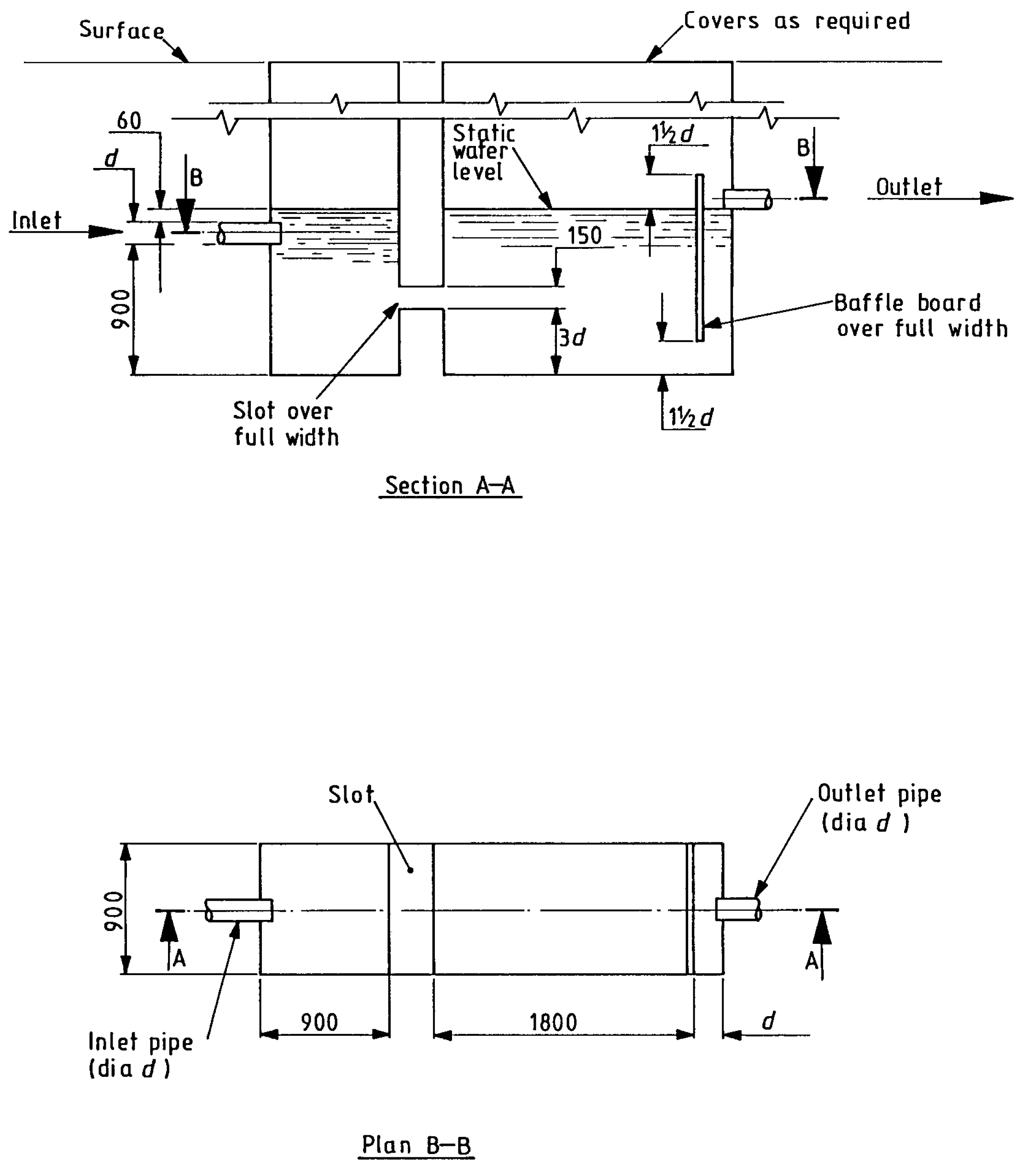
Where the cover is less than 1 m, special factors apply.



All dimensions are in millimetres.

NOTE All pipes within the chambers through which liquid passes should be of iron or other equally robust petrol resistant material.

Figure 7 — Traditional three chamber petrol interceptor



All dimensions are in millimetres.

Figure 8 — Alternative two chamber petrol interceptor (ventilation not shown)

The design and maintenance requirements for a grease trap are such that alternative measures for protecting drainage systems are normally more effective, convenient and economical when all the following factors are taken into account.

a) The trap should have sufficient capacity to accommodate the grease.

b) It should be so sited that it will receive sewage-free waste from a kitchen, is convenient for maintenance and will not give rise to a nuisance or to health or hygiene hazards during operation and cleansing processes.

c) Regular and frequent cleansing is essential if grease is not to be discharged through the trap, and should include the removal of settled solids to avoid putrefaction. It should therefore be capable of being easily cleansed and be covered or provided with suitable safety protection.

d) Labour for cleansing and adequate disposal facilities will be required. Cleansing is an unpleasant operation and in consequence is frequently neglected.

e) The efficiency of a grease trap will be impaired by the use of detergents.

Proprietary appliances are available which are designed to break down grease by biochemical action. They require care and skill in the application of chemicals and regular and frequent attention for servicing.

12.4 Surcharge

12.4.1 *General.* Planning of the site and of buildings and accommodation requiring drainage facilities should be such as to avoid problems associated with surcharge.

Backflooding due to surcharge usually occurs when the capacity of a system is exceeded, e.g. during a storm. The problem is more likely to be met in low-lying areas where a system is laid at shallow depths or with flat gradients. Floors below ground level may be particularly vulnerable. Design or construction faults can also adversely affect performance of a drainage system to the extent of causing localized backflooding independently of surcharge from other sources. An air-lock in a connection between an intercepting trap and a receiving drain or sewer when the point of connection is submerged may give the appearance of surcharge.

Where a drain is liable to surcharge, measures should be taken to protect any building and ancillary area likely to be adversely affected. In sealed systems it should be noted that the first warning of surcharge conditions in a drain may be the back up and overflow of a WC pan. Backflooding is not necessarily serious provided that the level reached is such that no sanitary appliance or drainage opening is likely to be overspilled or its performance impaired or use interrupted. It may lead however to deposition of faecal matter and therefore the need for cleansing after the surcharge has subsided.

12.4.2 *Protective arrangements.* The measures necessary to protect a drainage system or building from surcharge depend upon the particular circumstances in any situation and the risk that can reasonably be tolerated. They should be as simple as practicable and be so arranged as to have minimal effect on normal use of the system and/or building protected. It is essential that all drainage unaffected by surcharge should bypass the protective measures and discharge by gravity into a surcharge-free outlet or, if unavoidable, into the surcharged part of the system. Surface water connections and discharges from appliances upstream of the protective measures should be kept to a minimum. This will enable such measures to be designed for maximum protection and minimal maintenance.

The simplest form of device is a flap valve which may be installed at the outlet of a pipe to protect it from back-flooding. It relies on a build-up of head on the inlet side to open the flap under normal flow conditions and a generous upstream gradient is therefore desirable. Debris lodged on the valve seating or stiffness due to lack of use or maintenance may prevent it seating effectively under surcharge conditions. Consequently its applications are limited and best confined to surface and clean water systems.

An anti-flood valve of the flap and float pattern with a robust one-piece body is a more effective device. A float operates in a side chamber ventilated to atmosphere, the flap and float being positioned at 90° to each other and attached to a horizontal spindle supported at a central pivot point.

The most effective arrangement is to install an in-line valve which may be manually or automatically operated.

The use of a device relying only on a floating ball is not recommended.

One or more of the above devices may be assembled for use in appropriate situations. An associated visual and/or audible warning system is desirable and, in the case of a manually operated in-line valve, is essential. Where any type of anti-flood device is fitted it may be necessary to provide additional ventilation of the protected drain to ensure preservation of trap seals (see BS 5572).

Warning of surcharge conditions may be provided by installing a gully, or a rodding eye incorporating a warning valve, located at a lower level outside a building.

Anti-flooding devices should be properly and regularly maintained. The occupier of protected accommodation should be clearly informed of any limitations, such as restricted use or inherent operational hazards, which such devices may impose.

Where a high risk area exists, or where it is essential that all parts of a system provide effective drainage under all conditions, the provision of sewage lifting apparatus for such an area should be considered.

13 Access to drains

13.1 General

Access is required to drainage installations for testing, inspection, maintenance and removal of debris. Access to drains allowing rodding in both directions can be provided by inspection chambers and manholes, and by some access fittings whereas rodding eyes allow for rodding downstream only.

13.2 Provision of access to drains

The guiding principle is that every drain length should be accessible for maintenance and rodding without the need to enter buildings. Access should be provided at the head of each run of drain and at changes in direction, gradient or pipe diameter[7].

Table 7 indicates the recommended maximum distance between rodding eyes, access fittings, inspection chambers and manholes. These are based on standard rodding techniques and the need for removing debris.

Where a branch drain joins another drain without the provision of an inspection chamber or manhole at the junction, access should be provided on the branch drain within 12 m of the junction.

13.3 Rodding eyes and access fittings

13.3.1 *General.* Rodding eyes and access fittings provide limited access and should be used in accordance with **13.2** and with the maximum spacing recommendations given in Table 7.

13.3.2 *Rodding eyes.* A rodding eye provides access at surface level for the clearance in one direction only of obstructions and debris using normally accepted manual rodding techniques. It should be constructed in pipework preferably of the same diameter as the drains it serves and should connect to the drain at an angle not steeper than 45° from the horizontal. It should preferably be carried up to ground level at the same angle to permit easy rodding and to reduce resistance to the passage of rods.

13.3.3 *Access fittings.* Access fittings provide for rodding in more than one direction and for testing. On a buried drain they are used in three ways:

a) as an opening in the top of the drain having a sealed cover and a separate cover bedded at surface level;

b) with a raising piece terminating with a suitable cover at surface level;

c) with a sealed cover located within an inspection chamber or manhole, in which case spacings in Table 7 should be as for an access fitting.

13.4 Inspection chambers and manholes

13.4.1 *General.* Inspection chambers and manholes should be resistant to water penetration, be durable and be designed to minimize the risk of blockage. Provision to prevent flotation may be necessary.

Preformed and precast units should be installed strictly in accordance with manufacturers' instructions.

13.4.2 *Dimensions.* Dimensions depend on the size of the main drain and on the number, size and position of branch drains entering. The size of inspection chambers should be such that the drain can be cleaned from the surface. The design of manholes should permit entry without restricting operational space.

Subject to the minima given in Table 8, internal dimensions for manholes with a number of branches may be estimated for straight inverts as follows.

a) *Length.* The length should be 300 mm for each DN 100 or DN 150 branch on the side having most branches plus an allowance at the downstream end for the angle of entry.

b) *Width.* The width should be the sum of the widths of the benching, plus 150 mm or the diameter of the main drain, whichever is the greater. The benching width should be 300 mm where there are branches or 150 mm where there is no branch.

[7] For drains larger than DN 300 see CP 2005.

Table 7 — Maximum spacing of access points

Distance to	From access fitting		From junction or branch	From inspection chamber	From manhole
	1	2			
	m	m	m	m	m
Start of external drain[a]	12	12	—	22	45
Rodding eye	22	22	22	45	45
Access fitting (1) min. 150 mm × 100 mm or 150 mm dia.	—	—	12	22	22
Access fitting (2) min. 225 mm × 100 mm	—	—	22	45	45
Inspection chamber	22	45	22	45	45
Manhole	22	45	45	45	90

[a] See **7.6.1** for distance of first access point from start of drain, i.e. stack or ground floor appliance outlet.

Where manholes or inspection chambers with curved channels cannot be avoided, their dimensions should be based on the foregoing principles.

13.4.3 ***Materials of construction for inspection chambers and manholes***

13.4.3.1 *General.* Materials of construction for inspection chambers and manholes include:

a) brickwork;

b) concrete, in situ and precast;

c) plastics (uPVC, polypropylene and GRP);

d) vitrified clay.

13.4.3.2 *Brickwork chambers.* The chamber and shaft, if any, should normally be built in English bond but resistance to water penetration may be increased if the brickwork is built in “water” (manhole) bond. The wall thickness should be adequate to resist external pressures due, e.g. to soil and ground water, but in any case not less than 200 mm. Where groundwater pressures are continuously high, it may be necessary to use double leaf (collar jointed) construction (see BS 5628-1) or tanking to maintain water pressure resistance. In granular soils above the water table, inspection chambers 0.9 m or less in depth (unless in roads, see below) may be built in brickwork not less than 100 mm thick.

Durability and resistance to water penetration should be achieved by using bricks and blocks complying with the recommendations of **5.7.3** and **5.7.4** respectively. In addition, all mortar joints should be completely filled and flush pointed as the work proceeds. Further guidance is given in sections three and four of BS 5628-3:1985.

A sulphate-resisting cement should be used where there is a danger of sulphate attack.

The dimensions of brick manholes should be the nearest brickwork sizes above the minima given in Table 8. Where, due to the number of side branches, larger chambers are required, the increase in size should be in multiples of the brick size adopted. Brickwork should be set out so that the required bond is achieved with the minimum of cut bricks.

Although fired clay products are themselves resistant to most forms of chemical attack, chemical action resulting in sulphate expansion can occur in the mortar joints between the bricks if concentrations of sulphate are present in the bricks, the soil or ground water. Concrete bricks or blocks should not be used in contact with the ground from which there is a danger of sulphate attack unless they have been specifically made for this purpose (see BRE Digest 89 [9]).

The usual method of roofing brick inspection chambers and manholes is by means of a concrete slab. The slab should be designed to carry the weight of any ground above plus all probable superimposed loads. Where such manholes are built under roads, the roof of the chamber should be designed to carry the loads given in BS 5400-2 with due allowance for load distribution by the depth of earth above the slab and impact effect. Concrete slab construction can also be used to reduce access shafts inwards if necessary to accommodate the cover frame.

Where the cover is subject to wheeled traffic, the frame should be bedded on to the roof slab on one or more courses of brickwork or on a precast concrete seating unit.

An inspection chamber or manhole should be built on a base of concrete of mix design C 20 P (see Table 1) not less than 150 mm thick.

Pipes of size DN 300 or larger, when built into walls, should have either one brick relieving arch turned over the pipe to the full thickness of the brickwork, or a concrete lintel or other effective means of relieving the load.

Seepage through the clay bricks, particularly engineering bricks, should be negligible and leakage is most likely to occur through joints in the brickwork, joints around pipes and adjacent to bases and benchings. Joints should therefore be filled with well compacted mortar and should preferably be 4 mm to 6 mm thick, but not thicker.

The pipes in and out of manholes should be bedded on mortar and built in as the brickwork proceeds.

13.4.3.3 *In situ concrete.* For inspection chambers and manholes constructed of in situ concrete the thickness of the walls should be not less than that stated for brick manholes (see **13.4.3.2**) and the concrete should be in accordance with BS 8110[8)] or alternatively Table 1 of this standard.

13.4.3.4 *Precast concrete.* Inspection chambers and manholes of precast concrete are built in sections: materials, dimensions and test methods are described in BS 5911-1 and BS 5911-2. The base may be either of precast concrete or in situ concrete similar to that described for brickwork (see **13.4.3.2**).

Where manholes or inspection chambers are constructed wholly above the water table, rebated joints sealed with cement mortar can be satisfactory, In waterlogged ground or where the water table is above the base, joints should be made watertight, preferably using a non-rigid jointing material such as a mastic sealant or a rubber ring joint.

Where inspection chambers and manholes are installed in unstable ground or are likely to be subjected to exceptional or eccentric loads, a 150 mm surround of at least mix design C 20 P concrete should be provided. Care should be taken to compact this underneath incoming and outgoing pipes. Any joints in concrete surrounds should be staggered with the manhole construction joints.

Special precautions should be taken where precast concrete is used in soils in which Portland cement concrete is liable to be attacked (see **5.4**).

13.4.3.5 *Precast concrete segmental manholes.* Precast concrete segmental manholes may be constructed where larger chambers are required. These are usually built up from a firm base a ring at a time, backfilling evenly as work proceeds, but some are supplied with a special cutting ring for sinking as a caisson. Two types of joint are available, either bolted with a tongue and groove location or a knuckle joint. The former may be sealed with a preformed mastic between the units and are usually provided with a caulking groove for secondary sealing. The knuckle jointed type is usually used for soakaways, the segments being perforated to increase percolation. Precast concrete panels are available to provide a flush finish to the segments when required.

Cover slabs are supplied either as precast sections or a combination of sections and prestressed concrete beams.

13.4.3.6 *Plastics.* Inspection chambers and manholes are available moulded in thermoplastic and thermosetting materials such as polypropylene, uPVC, or GRP, either as integral bases or as complete chamber units.

13.4.3.7 *Vitrified clay.* Inspection chambers are available in vitrified clay to the requirements of BS 65.

The integral base provides a variety of inlet and outlet connection positions. Flexible joints, incorporating elastomeric sealing rings, connect raising pieces to the base and allow for depth variations.

13.4.4 *Channels and benching.* An open channel of half-round section should extend the whole length of the inspection chamber or manhole. A vertical benching should be formed from the top edge of the main channel to a height not less than that of the soffit of the outlet. It should be rounded off to a radius of about 25 mm and then sloped upwards at a gradient of about 1 : 12 to meet the wall of the chamber.

Side branches of diameters up to and including 150 mm should discharge to the main channel in the direction of flow, preferably at half pipe level. Where the connecting angle is more than 45°, three-quarter section bends should be used. Vertical and side benchings should be shaped so as to contain the flow without permitting fouling and to facilitate rodding of branch drains. A branch with a diameter of more than 150 mm should be set with the soffit level with that of the main drain.

[8)] In preparation. Revision of CP 110.

Table 8 — Minimum dimensions for rodding eyes, access fittings, inspection chambers and manholes

<table>
<tr><th rowspan="2">Type of access</th><th rowspan="2">Depth to invert</th><th colspan="2">Min. internal dimensions</th><th colspan="3">Min. nominal cover size</th></tr>
<tr><th>Rectangular length and width</th><th>Circular diameter</th><th>Rectangular length and width</th><th>Circular diameter</th><th>Remarks</th></tr>
<tr><td></td><td>m</td><td>mm</td><td>mm</td><td>mm</td><td>mm</td><td></td></tr>
<tr><td>Access fitting</td><td>0.6 or less except where situated in a chamber (see **13.3**)</td><td>1) 150 × 100
2) 225 × 100</td><td>150
—</td><td>150 × 100
225 × 100</td><td>150
—</td><td>The depth restriction is imposed because of the limited access afforded by these items and is based on the ability to manipulate a stopper at arm's length from the surface.</td></tr>
<tr><td>Inspection chamber[a]</td><td>0.6 or less

1.0 or less</td><td>—

450 × 450</td><td>190 mm dia. for drains up to 150 mm dia.
450</td><td>—

450 × 450</td><td>190

450[b]</td><td>The depth restriction is imposed as for the access fitting.
The extra internal size enables manipulation of a stopper from the surface at the increased depth.</td></tr>
<tr><td>Manhole[c] or inspection chamber</td><td>1.5 or less
Greater than 1.5</td><td>1 200 × 750
1 200 × 750</td><td>1 050
1 200</td><td>600 × 600
600 × 600</td><td>600
600</td><td>Larger size required for shallow manholes.
Generally in accordance with "Safe working in sewers and at sewage works" published by the National Joint Health and Safety Committee for the Water Services.</td></tr>
<tr><td>Manhole shaft[d] (where applicable)</td><td>Greater than 2.7</td><td>900 × 840</td><td>900</td><td>600 × 600</td><td>600</td><td>Minimum chamber width 840 mm.</td></tr>
<tr><td>Rodding eye</td><td></td><td colspan="2">Preferably same size as drain, but not less than 100 mm diameter</td><td>—</td><td>—</td><td></td></tr>
</table>

[a] A covered chamber constructed on a drain or sewer so as to provide access thereto, for inspecting, testing or the clearance and removal of obstructions, and usually situated in areas subjected to light loading only.

[b] In the case of clayware and plastics inspection chambers the clear opening may be reduced to 430 mm in order to provide proper support for the cover and frame.

[c] A working chamber with cover constructed on a drain or sewer within which a person may inspect, test or clear and remove obstructions in safety.

[d] Minimum[e] height of chamber in shafted manhole 2 m from crown of pipe to underside of reducing slab.

[e] The term "minimum" as used in this table refers to the smallest acceptable nominal dimension and does not exclude normal negative manufacturing tolerance below the nominal size.

In inspection chambers and manholes of brickwork, precast concrete or in situ concrete, main and branch channels should be bedded and jointed in 1 : 3 cement mortar, and in situ benchings floated to a hard smooth surface with a coat of 1 : 3 cement mortar laid monolithic with the benching. To ensure that the channel and the branch junctions are properly supported, the bedding and the benching should be laid in a single operation.

Plastics channel sections (see CP 312) are available and are used in a similar manner to traditional materials, but special care should be exercised to ensure adequate bonding with the base (see also **13.4.3.5**).

13.4.5 ***Access to manholes***

13.4.5.1 *Step irons.* Manhole step irons should comply with BS 1247. For brick or in situ manholes, they should be built into the wall at every fourth course or at intervals of between 230 mm and 300 mm. Unless of the straight bar corner type they should be set, staggered, in two vertical runs, which should be constant at approximately 300 mm centres horizontally. The top step iron should be positioned so that direct access to it by an operator is practicable and should be fixed not more than 750 mm below the surface, depending on the cover and slab arrangement. The lowest step iron should be fixed not more than 300 mm above the benching. Precast concrete manholes should have step irons let in.

13.4.5.2 *Ladders.* Where access ladders are manufactured from low carbon steel, the material should comply with BS 4360. Stringers should be not less than 65 mm × 12 mm section, 300 mm apart in the clear and drilled with holes of 20 mm diameter for shouldered 22 mm diameter rungs at 300 mm centres. Every rung should have 1.5 mm shoulders formed on each end and the ends of all rungs should be neatly riveted over. At the top, the stringers should either be bent to a radius of 150 mm, allowing for a straight length of 225 mm to be bolted into the brickwork and 25 mm for turning up on the back of the wall, or they should be bolted to built-in stays. Low carbon steel stays, not less than 65 mm × 12 mm section, should be provided at intervals not exceeding 2.4 m for building into the brickwork, and fixed to the ladder stringers with 20 mm diameter bolts and nuts. The ladder and stays should be galvanized after manufacture by the hot-dip process (see BS 4211).

13.4.6 *Drop-pipe manholes.* Drop-pipe manholes are designed to accommodate significant differences between invert levels by building a manhole on the lower drain and providing a vertical or nearly vertical drop-pipe from the higher drain (see **7.6.6**). The pipe may be either outside the manhole or supported on brackets within the manhole, which should be suitably enlarged. If the drop-pipe is outside the manhole, a continuation of the drain should be built through the manhole wall to form a rodding eye. A drop-pipe fitted within the manhole should be able to withstand maintenance operations and have rodding access.

A drop-pipe on a branch drain should terminate at its lower end with a bend turned so as to discharge its flow at 45° or less to the direction of flow in the lower drain.

Where the difference in invert levels is less than 1.0 m, a ramp may be formed by increasing the gradient of the last length of the upper drain to about 45°.

13.4.7 *Manhole and inspection chamber covers and slabs.* Ductile and grey cast iron and cast steel covers and frames for manholes and inspection chambers are specified in BS 497 in three grades to suit varying conditions. Precast concrete shaft and chamber cover slabs for use with metal covers and frames are specified in BS 5911-1 and BS 5911-2 respectively. Covers used for manholes within buildings should be airtight and mechanically secured. Precast concrete covers for inspection chambers are specified in BS 5911-2.

14 Ground movement

14.1 General

Movement may occur in superficial deposits or may result from underground mining operations and precautions are necessary where pipes are laid in ground where such movement is likely to occur.

14.2 Pipes laid in made ground

Ground which has been formed by loose tipping or has received inadequate compaction during placing may be subject to continuing consolidation and uneven settlement, Pipework laid in such ground should be of flexible material or should have flexible joints to allow uneven settlement to be accommodated without damage or loss of performance, Pipe gradients should be as steep as conditions permit to ensure that a backfall is not induced as a result of settlement.

14.3 Pipes laid in natural ground

Movement of the superficial deposits on which pipework is laid may be due to seasonal swelling and shrinkage, settlement, especially where fibrous organic soils are encountered, or to slope instability. A soil survey should be made to assess likely movement.

14.4 Pipes laid in fluid ground

Where pipework is to be laid in ground which is fluid or waterlogged expert advice should be sought.

14.5 Mining subsidence

14.5.1 *General.* Undermined ground is displaced downwards and inwards towards the centre of the subsided area and damage may be caused by both vertical and horizontal displacement. Vertical displacement can vary in magnitude over the subsided area resulting in a tilting of the ground, whilst the strains resulting from horizontal displacement can range from zero through maxima of compression and tension and back to zero over a distance of only a few hundred metres.

The effects of undermining can be predicted with reasonable accuracy and the Area Surveyor and Minerals Manager of the National Coal Board in the case of coal mining, or the responsible company in the case of other minerals should be consulted for advice on precautionary measures to be adopted.

14.5.2 *Effect upon pipework.* Differential subsidence may change pipe gradients by 1 : 50 in extreme cases but on average the value is more likely to be of the order of 1 : 400. Change in length may amount to 1 % in exceptional cases but will commonly be of the order of 0.25 %. Precautions taken to accommodate this movement will, in a majority of cases, automatically cater for any vertical movement, the latter being of secondary importance over short distances. The extent of movement of superficial deposits can only be assessed by consideration of the findings of a site investigation.

14.6 Pipelines in unstable ground

Rigid pipes with flexible joints or flexible pipes should be used in unstable grounds. Provision for change in length of pipelines can be made by the use of telescopic joints whilst angular deflections can be accommodated by the use of flexible joints.

15 Sewerage and surface water lifting installations

15.1 General

The following information relates only to sewage lifting installations in which the diameter of the delivery main does not exceed 150 mm but the same basic design principles may be applied to surface water lifting installations. For larger installations reference should be made to CP 2005.

Sewage lifting may be necessary where the levels of a building or site make it impracticable to provide a gravity connection to a suitable outfall or where a gravity drain would be subjected to unacceptable surcharge from the sewer.

The installation should be sited as near as practicable to the appliances or areas to be served having regard to constraints such as noise, structural or spatial requirements, access and potential nuisance.

15.2 Location

15.2.1 *General.* Within a building, location is normally dictated by layout and structural considerations, For an external installation other factors need to be taken into account as described in **15.2.2** to **15.2.5**.

15.2.2 *Siting.* An installation should be sited, where practicable, on the leeward side of occupied buildings and where the minimum disturbance to the environment and landscaping will be caused. Adequate means of pedestrian and vehicular access should be available for construction, installation of apparatus and maintenance.

15.2.3 *Sub-soil and ground water conditions.* Investigations may be necessary to determine ground conditions, which could affect the choice of construction materials. Ground conditions may be such that:

a) cathodic protection may be necessary for a packaged installation within a steel shell;

b) anti-flotation measures may be necessary during construction and use due to seasonal variations of the ground water level;

c) special provisions may be necessary for protection against subsidence.

Where there is a possibility of the existence of subterranean workings, the appropriate authority should be consulted.

15.2.4 *Surface flooding.* Where an installation has to be sited in a low-lying area which is subject to flooding, it should be protected by ensuring that the lowest operating floor level of the sewage lifting plant room, any points of entry to a sump, drywell and other openings at risk, are above the highest recorded flood level with an adequate margin of safety.

15.2.5 *Adoption.* Where a development necessitates the provision of a pump or ejector station, a mutually beneficial arrangement may be possible if it can also serve nearby unsewered property. It may then be appropriate for adoption by the water authority together with any part of the drainage system which is also suitable. This may affect the siting of the station and early consultation with the authority is essential.

15.3 Types of apparatus

15.3.1 *General.* Sewage lifting apparatus used for building drainage normally incorporates pneumatic ejectors or rotodynamic pumps.

15.3.2 *Pneumatic ejectors.* A gravity type ejector consists of a sealed cylindrical vessel to receive incoming sewage. When the vessel is full the contents are automatically discharged by compressed air to a drain at a higher level. A lift and force type ejector is similar but sewage is lifted from a sump into the vessel from which it is ejected to a higher level by compressed air. A supply of compressed air, usually provided by an associated compressor, is necessary for both types.

15.3.3 *Centrifugal pumps.* The most common form of rotodynamic pump used for lifting unscreened crude sewage is a centrifugal pump having an open type impeller. Such a pump should be capable of passing a sphere of 87 mm diameter, or 3 mm less than that of the pump inlet, whichever is the greater, unless the impeller blades are capable of macerating solids or a macerator is employed before pumping. Where a motor size in excess of 7 kW is required, consideration should be given to a smaller size of throughway than that mentioned above in order to enable greater efficiencies to be achieved. This type of pump can be obtained as a horizontal or vertical unit with an independent or a close-coupled power unit, usually an electric motor. Close-coupled pump and motor units are available for submerged operation.

15.3.4 *Other types.* A composite unit is available comprising a centrifugal pump and an ejector type receiver into which sewage flows by gravity. Solids are separated as they enter the receiver and are subsequently lifted by the pumped sewage liquor.

Other rotary and positive displacement pumps may have advantages for particular applications.

15.3.5 *Separate and packaged units.* Most ejectors and pumps can be supplied as free standing units, with separate control panel and direct-drive motors and accessories for on-site assembly, as appropriate, or factory assembled ready for installation. Packaged units including ejectors/pumps and all necessary equipment may be supplied in a shell ready for operation with the minimum of site work. Connection to inlet and outlet drains and appropriate services may be all that is required.

15.4 Power units

15.4.1 *Electric motors.* An electric motor is the most practicable and widely used power unit. The characteristics of the electricity supply may influence the type of motor that may be used since the starting current load differs significantly between different types of motors. The electricity supply authority should be consulted to determine whether any restrictions will apply.

15.4.2 *Internal combustion engines.* An internal combustion engine may be used either where an electricity supply is not readily available, or to drive a standby generator for use where any interruption in the electricity supply would have serious consequences. It may also be used as a standby unit in conjunction with an electric motor. When maintained in good operating order, it is reliable and efficient but it requires frequent attention for reliable operation.

15.5 Selection of apparatus

15.5.1 *General.* Sewage lifting apparatus should be selected for its suitability for a particular application, its durability and economy in whole-life cost, taking account of the following:

a) nature of the accommodation to be served;

b) space or site available;

c) sewage inflow rate;

d) depth of incoming drain(s);

e) required discharge head;

f) consequences of failure;

g) availability of maintenance facilities and replacement parts;

h) standardization.

Where sewage is to be lifted in a building drainage system, the choice of discharge capacity may be governed by the need to provide a self-cleansing velocity in the delivery main. It may sometimes be necessary to restrict the discharge rate to suit the capacity of the receiving system. In the absence of any such constraints, a discharge rate equal to six times the average 24 h flow may be assumed. Discharge rates less than six times the average may be adopted when draining a large development. Different factors apply for partially separate and combined systems for which storm flows should be calculated and the appropriate capacity provided. The most suitable apparatus should be selected for the required discharge capacity taking account of the considerations listed and a balanced system provided in which sewage is not held long enough for septic conditions to develop.

15.5.2 *Choice between ejectors and pumps.* Choice between ejectors and pumps is influenced by the following factors.

a) *Location.* Where the planning of a building is such that access to sewage lifting apparatus is possible only from within, the use of an ejector or similar apparatus in which sewage is completely enclosed is preferable. This makes the provision of a sump normally associated with a pump unnecessary, enables structural provision to be kept to a minimum, and makes for improved hygiene.

b) *Flow rate.* An ejector is not usually installed where the incoming sewage flow rate exceeds 7 L/s. Whatever apparatus is selected, the delivery rate should be such as to support a velocity in the delivery main that will prevent the settling out of solids, i.e. 0.7 m/s to 1.0 m/s.

c) *Head.* Ejectors and pumps are suitable for lifting sewage against low total heads. Ejectors are generally considered unsuitable for total heads in excess of 25 m.

15.6 Arrangements

15.6.1 *General.* Ejectors, air compressors and pumps should preferably be installed in duplicate to allow for maintenance and to provide standby facilities in the event of a breakdown.

15.6.2 *Air compressing plant.* Generally, compressors are driven by electric motors but other types of drive are available. Compressors used in building drainage work are usually of a size which can be effectively air-cooled. Larger units may need to be water-cooled. Where duplicate compressors are provided their operation should alternate periodically between "duty" and "standby". The use of an air receiver with an ejector installation is strongly recommended to ensure that instantaneous and satisfactory discharges are achieved without the provision of an oversized compressor.

15.6.3 *Pumps.* A pump requires a suction well. The arrangement may take the form of a sump where vertical spindle or fully submersible pumps are used, or a sump and a dry well where horizontal spindle or close coupled vertical spindle pumps are used. Such arrangements involve structural and locational considerations which will influence the type of pump selected.

15.6.4 *Pump drive.* An extended drive shaft for vertical pump units needs careful alignment and can involve increased maintenance, particularly where the sump is deep. Where headroom over the suction well is restricted in relation to the length of shaft, it may be necessary to install and remove the shaft in sections. A long shaft may result in loss in efficiency and the size of the power unit may need to be increased to compensate. A horizontal pump/motor unit or close coupled vertical pump/motor assembly should give the best operational performance, but its use may not be practicable where there are structural complications, or potential flooding problems.

15.6.5 *Priming.* Flow is achieved when a pump starts up by the action of atmospheric pressure on the surface of the pumped liquid and it is therefore necessary to ensure that a pump can be primed and the priming sustained. This can be achieved by positioning the top of the pump casing, or the open end of the suction pipe, as appropriate, so that it is always submerged by 1.5 times the diameter of the open end of the suction pipe or 150 mm, whichever is the greater. Where a suction pipe is lower than the pump casing, a device is necessary on the casing to prevent an airlock occurring as the liquid level in the sump rises. Theoretically, the maximum suction lift is the equivalent of atmospheric pressure but in practice it is normally limited to about 2 m to 4 m, due to friction losses and the impracticability of achieving and maintaining sub-atmospheric pressure in the pump and suction pipework. With high suction lifts the use of a priming device may be necessary.

15.7 Sump (wet well) design and capacity

A sump should be of watertight construction and be so arranged as to be fully accessible, provide safe working space and be self-cleansing as far as practicable.

The maximum number of starts of a pump occurs when the incoming flow rate is half the pump delivery rate and the effective sump capacity should be such that the optimum number of starts does not overload the electrical equipment. For most building drainage applications this is achieved if the effective capacity is equal to the discharge in 2 or 3 min pump running time, related to the actual head conditions anticipated in the installation. A sump should have a capacity below the level of the lowest incoming drain such that it will contain that part of the contents of the delivery main as will flow back should it be necessary to empty the main for maintenance purposes.

Where, in a small installation, pumps operate in a sump, space should be provided for not only the pump but also for the means of fixing and controlling it and for the processes of installation, maintenance and renewal.

To allow for satisfactory operation of float, mercury or similar switch control, the minimum effective depth, i.e. the difference in level of pump cut-in and cut-out, should be not less than 150 mm. The standby pump should be arranged to cut-in not less than 150 mm above the duty pump cut-in level. An alarm should be arranged to operate at a higher level again so as to provide visual and/or audible warning should the stand-by pump fail to start or to lower the level of sewage in the sump. An adequate freeboard should be provided between this level and the invert level of the lowest incoming drain.

In exceptional circumstances consideration may need to be given to the provision for overflow from a sump so as to afford protection of equipment in the event of a complete failure. Such an arrangement would require the agreement of the water and/or local authority.

15.8 Drywell

A drywell should be of watertight construction and should provide ample space for easy installation, maintenance, and removal of all apparatus. Provision should be made for the removal of liquid which may have escaped from pump or valve glands or by other leakage. This may be achieved by the installation of a suction device, e.g. a small-valved branch suction pipe, to empty a small sump and discharge this liquid into the adjacent sump, by manual or automatic control.

15.9 Ventilation

In order to avoid accumulation of foul air, or build up of air pressure, which may restrict gravity flow into a sump, it should be adequately ventilated to atmosphere. This may be achieved by providing a separate ventilating pipe of not less than 75 mm diameter from a point at as high a level as practicable. The ventilating pipe may be combined with the vent section of any discharge stack connecting to the sump, providing the arrangement is adequately sized. In a deep sump it may be necessary to provide mechanical ventilation for use when entry is proposed. It should discharge independently of any other system.

The air exhaust pipe from an ejector body should not be connected to any section of an above ground sanitary pipework installation. It should either discharge to atmosphere at a safe outlet, or to a separately ventilated inlet inspection chamber or manhole, if one is provided.

Adequate ventilation should also be provided to a drywell or room containing electrical equipment in order to assist in the avoidance of condensation.

15.10 Control gear

15.10.1 *General.* Automatic control of power units is essential and should be achieved as simply as practicable in relation to the needs of the system.

15.10.2 *Electric motor starting equipment.* Starters should be suitably rated for their duty. A rate of up to 15 starts per hour is normal but, for a sump of limited capacity particularly where high in-flow rates could occur, a heavy duty starter may be necessary. Each starter unit should incorporate a suitably rated externally operated mains isolator mechanically interlocked with the door of the starter panel.

Starters should incorporate under-voltage and overload trips in each phase for full motor protection. Automatically controlled starters should be provided with facilities for resetting the overload trip by hand. Hand resetting facilities may be required for both under-voltage and overload protection devices.

15.10.3 *Motor control.* Provision should be made for manual control of each motor independent of any automatic control facilities provided in the starter unit. In addition an emergency stop button should be provided at each motor.

A control unit should incorporate a switching sequence that will allow for any one pump or air compressor on standby to be automatically locked in to substitute for, or supplement, the duty unit should the need arise.

In the event of a power failure, the control switchgear should allow for motors to be started in proper working sequence when the power is restored.

In addition to any necessary apparatus and accessory devices for starting, stopping, regulating and protecting motors, control units should incorporate facilities for audible and visual warning set to operate in the event of malfunction.

15.10.4 *Recording equipment.* Equipment which records the running time of each pump or the number of operations of ejectors may be incorporated in a control console.

15.10.5 *Location of electrical equipment.* Control units and associated electrical equipment should be located in a dry, dust free, well ventilated atmosphere as close to the sewage lifting apparatus as practicable, and above any known flood or sewage surcharge level. Where equipment could be affected by a potentially explosive atmosphere, flame-proof motors and/or intrinsically safe electrical apparatus and circuits should be provided. Where a starter panel is located in a low-temperature area, thermostatically controlled panel heaters are desirable, provided with a separate ON/OFF switch so as to be capable of operation only when required.

15.11 Pipework and valves

15.11.1 *Pipework.* All suction and delivery pipework should be adequately sized to pass sewage solids and to deal with the flow so as to achieve a minimum velocity of 0.7 m/s in the delivery main for self-cleansing purposes.

When conveying crude sewage, it should be not less than 100 mm internal diameter unless maceration is employed. Pipework should be of appropriate strength for pressures likely to be encountered (see **5.6**).

All pipework should be planned to facilitate ease of erection and be accessible for effective maintenance. Flanged or suitable mechanical joints should be incorporated to facilitate dismantling. Pipework should be arranged so as to prevent the occurrence of an airlock. Changes in direction should be kept to a minimum and should be achieved by the use of medium or long radius bends. A suction inlet pipe should face downwards and terminate not less than 75 mm above the floor of the sump or the equivalent of the suction pipe diameter, whichever is the greater. Where delivery pipework is connected to a common delivery, a special junction or breeches piece should be used. All pipework should be adequately supported and anchored to avoid unacceptable stresses. Rest-bends, supported on suitable stools or wall brackets, should be used where appropriate. Where a pipe passes through any part of a structure, provision should be made for any differential settlement or movement which may occur. Where practicable, a pipe passing through the wall of a sump or dry well should be built in as the construction proceeds. Adequate provision should be made for watertightness around the pipe.

A delivery main from a sewage lifting installation should rise continuously to its point of discharge. Where this is not practicable, an air valve or other device is necessary at any high point for the release of air.

15.11.2 *Valving.* Each pump or ejector should be provided with a non-return valve on its discharge pipe as close to the body of the unit as practicable, followed closely by a sluice valve. The provision of an additional sluice valve on a common delivery pipe from two units is desirable for maintenance purposes. Similarly it is essential for isolation purposes where a common delivery main serves more than one lifting installation. A sluice valve may also be provided on a gravity drain into a sump to enable the flow to be controlled, if necessary, during maintenance work. A non-return valve should be fixed in a horizontal position to reduce the effect of solids building up against the face of the valve, thereby impeding its opening, and to reduce slamming when it closes. It should be provided with a robust external lever and, where subjected to a high head, a valved by-pass, to facilitate manual opening. A sluice valve should preferably be fixed in a vertical position, an arrangement which may also reduce space requirements. All valves should be positioned to allow for easy operation.

15.12 Point of discharge

A delivery pipe connected to a sanitary pipework system should be arranged so that it does not cause surcharge or adversely affect the pneumatic equilibrium of the system (see BS 5572). Where connected to a buried drainage system, it should discharge at a suitable point where gravity flow may commence and be so arranged that it may discharge freely without its outlet becoming submerged and without it impeding the normal flow. Ventilation is desirable at this point in larger systems to assist the avoidance of septicity.

15.13 Surge in delivery mains

Automatic starting and the controlled or uncontrolled stopping of sewage lifting apparatus may cause surge pressures to occur in the delivery pipework. In many building drainage systems these maximum and minimum pressures are likely to be within the design limits of the pipework and fittings. Where longer pipelines (greater than 0.8 km), undulating pipelines, high pumping velocities or high static heads are proposed, specialist advice should be sought. Advice should be obtained initially from the manufacturer of the lifting apparatus.

15.14 Maintenance facilities

A sewage lifting installation should be arranged so that it is safe to operate and maintain, and is adequately lit and ventilated. Where toxic gases are likely to occur and cannot be effectively cleared by natural means, mechanical ventilation is essential. Lighting, ventilation and emergency control switches should be located so as to be readily accessible on entry.

Adequate space should be provided where an operator can work in safety. All openings and moving equipment should be provided with effective guards or covers. An entry point should be conveniently positioned and should be provided with a hand rail to assist access. Where a cover is provided, it should preferably be hinged and have an arrangement for retaining it in the open position. A securely fixed corrosion resistant ladder should be provided in any situation where it is necessary to gain access to another working level or to a sump. Lifting equipment, e.g. an overhead beam and hoist, should be provided for removal of pumps, motors, ejectors and other heavy equipment[9)].

15.15 Planned maintenance

Planned maintenance should be carried out and should incorporate the recommendations of the equipment manufacturers. Regular checks should be made of alarms, control equipment, level control mechanisms and switches, moving parts of apparatus, shaft bearings and valves. Lubrication, cleansing and other servicing should be carried out as necessary. Appropriate technical data should be kept in a designated place together with a permanent record of operation, inspection and maintenance.

15.16 Notices

Operating, emergency and fire instructions should be clearly displayed incorporating appropriate pictorial symbols where practicable and advantageous.

[9)] Further guidance is given in "Safe working in sewers and at sewage works" [1].

Section 4. Work on site

16 Organization

16.1 General responsibilities

16.1.1 *Supervision.* For the satisfactory execution of the contract, it is essential that effective supervision is exercised by the client's representative on site and by the contractor. There are three main areas of responsibility; the safety of personnel, compliance with the contract documents, and the standard of workmanship in constructing the scheduled work.

To achieve these requirements, the work requires to be efficiently organized and should be planned in advance.

Liaison and cooperation should be maintained with the authorities and owners or occupiers of land or property likely to be affected.

16.1.2 *Existing works, land drains and services.* The position of services and the likelihood of their exposure should be established with the appropriate authority before site work is commenced and methods of dealing with them agreed.

Record should be kept of the condition of any drain, manhole or other existing work which may be uncovered. Any defects evident should be pointed out immediately to the appropriate authority.

It is advisable also to record the location of other services exposed, if only to locate them later should some defect arise.

The course of buried land drains should be recorded. All such drains interrupted by the excavation should be replaced, using a jointing system that enables a free flow and alignment to be maintained. Evidence of pollution from outside sources should be reported to the appropriate authority for remedial action to be taken.

The above precautions should always be taken even if the drains appear to be unused. Alternatively, a new intercepting drain may be provided to pick up a series of existing land drains.

16.2 Safety

16.2.1 *General.* The main areas of danger are associated with excavation and support, plant, materials and access (see clause **18** and BS 6031) and reference should be made to the enactments listed in clause **4**. CIRIA Report No. 97 also comprehensively covers trenching practice [10].

Prior to commencement of work, the approach to its execution should be considered, including where machine working can and cannot be employed, bearing in mind safety as well as economy.

Before excavation is commenced, the site should be fenced or boarded so as to prevent unauthorized access. Adequate safeguards such as gangways, handrails, notices or direction boards and lighting at night, should be provided.

Excavated material should not be placed where it can obstruct the vision of vehicle drivers.

16.2.2 *Warnings to traffic.* Where alternating one-way traffic is necessary, proper methods of traffic control should be provided. Automatic light signals may be useful if adequately maintained and if timed for the traffic which may have peak periods in opposite directions at different times. Such light signals should be placed on the left-hand side of each traffic lane where practicable. Stop-go signs should be used where manual control is operated.

Drivers approaching an obstruction should be given adequate warning by means of reflectorized traffic signs as prescribed in the Traffic Signs Regulations and General Directions 1975 (SI 1975 No. 1536). Where required by the Regulations the signs have also to be directly illuminated. The signs should be placed and maintained in accordance with advice issued by the Department of Transport contained in the Traffic Signs Manual, Chapter 8 "Traffic safety measures for road works" [11]. Non-prescribed signs should NOT be used (see BS 873).

When traffic flows are light in one or both directions, temporary light signals may be operated in vehicle-actuated mode rather than on fixed time settings.

Road danger lamps as prescribed in the Traffic Signs Regulations 1975 and specified in BS 3143, should be set out to delineate obstructions throughout the hours of darkness in accordance with the advice contained in the Traffic Signs Manual, Chapter 8 [11].

16.3 Planning the work

16.3.1 *Sequence of operations.* In the interest of efficiency and speed of construction, the sequence of operations should be planned so that the work advances steadily. The operations of drain construction should be carried out in the following sequence:

a) setting out;

b) breaking up of hard surfaces;

c) excavation, trench support, support of existing services and dewatering of trench;

d) preparation of trench bottom;

e) initial bedding or other support;

f) pipe laying and jointing;

g) inspection and preliminary test of the pipeline for watertightness;

h) completion of bedding including sidefill;

i) backfilling of trench and withdrawal of trench support;

j) disposal of surplus soil;

k) temporary reinstatement of surface;

l) final testing of drain;

m) permanent reinstatement of surface;

n) subsequent maintenance of surface.

16.3.2 *Precautions.* Excavation should not be commenced until an adequate supply of pipes and fittings is available. A reserve of appropriate materials and equipment should be kept on site for the immediate support of unexpected bad ground.

The drain construction should be organized so that there is sufficient labour and materials to keep the completed excavation ahead of pipe laying with the smallest possible length of trench standing open at any one time. If excavation proceeds more rapidly than pipes can be laid and tested, particularly where mechanical means of excavation are used, there is an increased risk of slips or subsidence. Provision should be made for the trench walls to be adequately supported at all times.

Pumping equipment should be available on site where there is a probability that water may be encountered.

When work is likely to be suspended for any appreciable length of time, the construction schedule should be arranged so that lengths of trench are not left open.

Unless prior agreement has been obtained as to restrictions being unnecessary, construction traffic should be allowed to cross a completed pipeline only at well defined crossing places where “sleeper bridges” or other suitable protective means have been provided. Crossing places should be accurately established, referenced and boldly marked.

17 Setting out

17.1 Establishment of line and level

The centre line and width of trench should be accurately set out and established by means of suitable markers and/or reference points. Where the width of a trench for foul or surface water drainage is not specified, it should be as narrow as working conditions permit. A typical working width for a trench is 450 mm or 1.5 × o.d. pipe barrel + 250 mm, whichever is greater.

In setting out drainage work, care should be taken to relate it to that for the new building work and to existing structures.

Sight rails should be set in position using appropriate surveying methods. Preferably, three sight rails should be fixed on each length of trench at any one gradient. Alternative methods such as laser or ultrasonic beams have been developed[10) and may be advantageously used where appropriate.

All setting out references, of whatever form, should be clearly marked to indicate to what they refer.

17.2 Secondary checks

The proposed alignment of trenches should be checked for avoidable encroachment on apparent routes of other services and obstructions such as chambers, street lamps, etc.

Similarly, the location of inspection chambers and manholes should be considered with regard to their being so positioned that branch drain alignments can be achieved.

18 Trenching, excavation and timbering

18.1 Usual methods of excavation

18.1.1 *Preparation.* The usual manual and mechanical methods of excavating trenches and headings in various soils, including rock and of support work are described in BS 6031 and CIRIA Report No. 97 [10].

Great care should be taken to determine the nature of the ground to be excavated and whether there are any adjacent infilled trenches or the like.

The interruption of buried services is undesirable and may be dangerous. Every effort should be made to locate these before commencing excavation. Hand excavation may be desirable.

All pipes, ducts, cable mains or other services exposed in the trench should be effectively supported by suitable slings. Careful consideration should be given to the temporary and permanent support of existing mains and service pipes so that they are not exposed to longitudinal beam loading.

18.1.2 *Excavated material.* Excavated material should be deposited at least 1.5 m from the edge of a trench and the proximity and height of the soil should be controlled so as to prevent danger of instability or damage to other services.

Unless otherwise specified, surface material, such as turf, topsoil, hardcore or other suitable material should be set aside for use in reinstatement.

10) See “A manual of setting out procedures” published by CIRIA [12].

Where hand excavation is necessary, intermediate stages may be required, limited by the height to which a person can throw with a shovel. In deep trenches mechanical hoisting may be more economical.

18.1.3 *Trench support.* Adequate trench support should be provided, where necessary, to ensure stability and safety (see BS 6031). In the case of unstable ground such as running sand or silt, additional measures such as dewatering operations, or consolidation by freezing or other, chemical means may be necessary (see CP 2004).

The spacing of the struts and the consequent sizes of waling should be determined by the individual length of pipes to be laid, the depth of the trench and the method of excavation to be used, e.g. crane and skip or hydraulic excavator.

The proximity of traffic or retaining walls, or other special features or circumstances may necessitate special support arrangements. When this occurs, or in bad ground, it may be advisable to leave the timbering in position. Sheeting driven below the trench formation should be left in position at least up to the level of the crown of the pipe.

18.1.4 *The use of explosives.* The use of explosives may be necessary in hard rock. Blasting should be carried out only under competent supervision and with the written permission of the authority in charge of the work, and in compliance with local authority or police requirements. Further guidance on the safe use of explosives is contained in BS 5607.

Explosives and other rock breaking techniques that are available should be used with due regard to their effect on surrounding ground, structures, and services.

18.2 Bottoming for pipes in poor ground conditions

18.2.1 *Uniform soils.* In wet, fine grain soil such as soft clays, silts or fine sands, suitable blinding or other stabilizing material should be placed on the virgin soil, immediately after the last cut and before any traffic is permitted, on the trench bottom to prevent disturbance and softening of the foundation.

Peat and some saturated clays tend to swell, when relieved of load, and shrink when reloaded. If clay overlies sand or gravel which contains water under artesian pressure, the trench bottom may heave and blow if the water pressure is not relieved. In these circumstances local experience should be a valuable guide.

18.2.2 *Non-uniform soils.* Pockets of peat, chalk slurry or unconsolidated ground occurring below foundation level should be removed, wherever practicable, and replaced with suitable well-compacted material. If such conditions are too extensive for remedy, it may be economic to resort to piled support for the pipes, or to soil stabilization by one of the methods described in CP 2004.

In mixed soils containing soft spots, rock bands or boulders, the foundation should be tested at frequent intervals and the soft spots should be hardened by tamping in suitable material. The hard spots should be generously undercut and large boulders should be removed. The resulting holes should be filled with suitable material, the object being to make the foundation as uniform as possible.

18.2.3 *Rock.* In rock, the bottom should be trimmed and screeded either with concrete or with not less than 200 mm of bedding material so that there is no rock projection that could damage the pipes.

Where first class workmanship and supervision can be guaranteed and where the variation in depth of bed does not exceed 25 mm and the o.d. of any socket does not exceed the o.d. of the pipe barrel by more than 50 mm (i.e. with a socket depression of 25 mm), the minimum depth of granular bed may be 100 mm.

The minimum depth of bed should be increased where the variation in bedding is liable to exceed 25 mm so as to ensure a minimum depth under the socket of 75 mm.

18.3 Placing of backfill

18.3.1 *Above trench formation or granular bedding.* Selected material and backfill (see **5.7.6**) should be placed as soon as the pipes are correctly jointed, bedded, tested and approved.

For pipes with class D, N or F bedding (see Figure 5), the selected material should be placed under the haunches, care being taken not to displace the pipe from its correct line and level.

Sidefill should be placed uniformly on each side of the pipe in layers not exceeding 100 mm in thickness, each layer being compacted by hand tamping until the pipe has a minimum of 150 mm compacted cover.

Backfill should be placed in layers not exceeding 300 mm uncompacted thickness, each layer then being well compacted. Mechanical compaction equipment should not be used until there is a minimum of 450 mm of compacted material above the crown of the pipe.

The need for effective compaction is especially important at all stages to minimize subsequent settlement (see clause **22**).

18.3.2 *Filling where there is concrete bedding.* Side filling and backfilling should not be commenced until the concrete has achieved adequate strength. As a guide this will normally be achieved 24 h after placing but it may be necessary to extend the time in adverse weather.

18.3.3 ***Filling of headings*** (see also **19.2**)

18.3.3.1 *General.* A heading may require to be filled from either end. However, drainage is often made easier by filling from the high to low ends. The materials and methods used to backfill headings should be chosen with the object of preventing damage to adjacent structures and roads.

If selected excavated material as recommended in **5.7.6** is used as sidefill and over the pipes in the heading, it should be hand-packed and rammed in 75 mm to 150 mm inclined layers to give a thoroughly compacted surround, with density and moisture content comparable with the undisturbed soil.

The filling operation should be closely supervised and observation of the quantity of material being returned to the heading should indicate whether this work is being correctly executed.

All timbering that can be removed safely should be taken out as the filling proceeds. Where it is necessary to leave in the timbering, it should be suitably protected against deterioration. If sills have to be left in, their upper surface may be flush with the excavated formation when the ground is as hard or harder than the sill material. When the ground is softer, the sill should be set below formation level so that it will not form a hard spot.

18.3.4 *Use of concrete for backfilling.* In headings under roads and especially near existing buildings or where existing pipes pass over the heading, it is most important to avoid subsequent settlement that could damage the existing structures or the new pipeline. Particular care should be taken to compact the side fills and a cushioning layer of excavated material should be placed over the pipeline. The gap between this layer and the crown of the heading should be well packed with concrete, rammed in as the filling proceeds. This top layer is likely to be difficult to fill and compact, and meticulous supervision is therefore essential if future problems are to be avoided.

Where a heading is situated near to or under a wall or other structural foundation, it may be necessary to pack the heading with concrete (see Figure 9).

Concrete for filling headings can normally be lean mix, but in the presence of ground water and silt or fine sand, a denser mix may be required to avoid loss of soil in the pores. The concrete may be placed at the crown of the heading in a dry condition if sufficient moisture is present in the soil to hydrate it after placing.

In situ concrete bedding as specified in **5.4.1** should reach a crushing strength of at least 14 N/mm^2 before being loaded. Where space is restricted around larger pipes, it may be necessary to fill the heading completely with concrete, after placing the structural concrete.

18.3.5 *Backfilling around manholes and inspection chambers.* Backfilling around manholes and inspection chambers should generally be carried out as for trenches and as part of the same operation. Care should be taken to raise the fill equally all round the shaft and so as to avoid unbalanced lateral loading.

18.3.6 *Removal of timbering.* The trench support timbering should be withdrawn in stages as the backfilling proceeds. Particular attention should be paid to the compaction at the sides of the trench where the previous layer of backfill is thus disturbed.

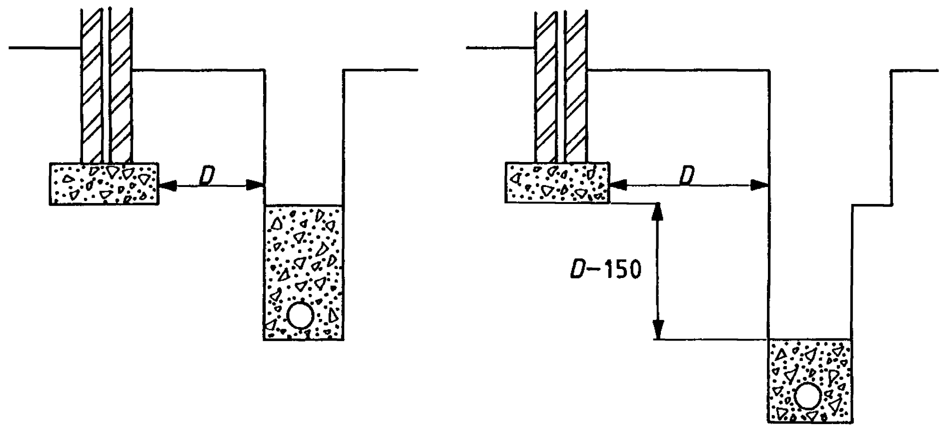
18.3.7 *Service crossings.* During backfilling the new support should be made as nearly as possible uniform with that on either side of the trench and any crossing refounded on adequately and uniformly compacted fill.

18.3.8 *Topsoil.* In agricultural land or gardens, the excavated materials, especially the turf and topsoil, should be replaced in their original strata.

19 Alternatives to trench construction

19.1 General

There is, at any specific site, a depth below ground surface at which it is more satisfactory to excavate in heading, or by boring or jacking, rather than in trench.



When D is less than 1 m, concrete fill to level of foundation bottom

When D is 1 m or more, concrete fill is to within D − 150 mm of level of foundation bottom

Figure 9 — Concreting of drains laid near foundations

19.2 Drains in heading

19.2.1 *General.* Where the construction of drains in heading is adopted, proper design is essential. Attention should be paid to the factors described below and in CP 2005.

In all cases where drains have to be constructed under roads and thoroughfares maintainable at public expense, it is necessary for the highway authority to be consulted and they may insist on construction in heading. In developed areas this method has the advantage that damage to existing gas, water, electricity and other services is more easily avoided, but the line of proposed heading should be, as far as practicable, clear of all permanent underground works such as pipes, cables, chambers, basements or other structures.

However carefully the work may be executed, the possibility exists of settlement of the ground above the pipeline. It is therefore essential to consider the effect of such a construction on buildings, underground works, roads or paved areas. In stable ground, the cover over a heading should normally be not less than about twice the height of the excavation. In unstable ground expert advice should be obtained.

19.2.2 *Subsoil conditions.* A knowledge of subsoil conditions is essential.

19.2.3 *Dimensions.* To enable the work of pipe laying, jointing and packing of a heading to be satisfactorily carried out, the dimensions inside the timbering should be not less than 1.4 m high × 0.75 m wide at floor level.

19.2.4 *Temporary access.* The number of any temporary shafts between manholes should be determined by the necessity to maintain traffic flow and the need to achieve economy of construction costs.

19.3 Thrust boring

Thrust boring is normally used for pipelines up to 200 mm overall diameter where a "mole" forms a hole by displacing and compacting the soil radially as it travels forward. Accuracy and driven length is dependent upon ground conditions. Care should be taken to ensure that the stability of any adjoining service or structure is unimpaired.

19.4 Pipe jacking

Pipe jacking is akin to shield tunnelling as concrete or steel pipes are jacked through the ground behind a purpose made shield.

Excavation is normally manual, although mechanical methods may be employed either within the shield or the shield itself may be mechanized. The diameter range is from 900 mm upwards. Concrete pipes incorporate flexible watertight joints making the finished pipeline suitable as the primary conduit. Accuracy and driven length depend on ground conditions but introduction of inter-jacking stations within the pipeline allow substantial distances to be jacked.

19.5 Auger boring

The auger boring technique relies on excavation by an auger, behind which a pipeline is jacked, and is suitable for pipes up to 1 500 mm nominal size. Accuracy and driven length are dependent on ground conditions.

Auger boring may be used also for placing a sleeve pipe.

19.6 Cut and drive method of construction

The cut and drive method is a compromise between trench and heading construction, and is often adopted at depths less than those at which a heading is normally practicable. Short lengths of trench should be excavated and connected together by headings of a length to suit local conditions. This method is particularly suitable for use under roads, as obstruction to traffic is minimized.

20 Pipe bedding and laying

20.1 Inspection and storage of pipes on site

Pipes are liable to damage in transit or storage, especially the spigot ends, and notwithstanding tests that may have been made before despatch, each pipe should be carefully examined on arrival at the site. Defective or damaged pipes should be rejected and marked in a conspicuous manner. Sound pipes should be stored as recommended by the manufacturer to avoid overloading of bottom layers in the stack and damage to joints.

Protective coatings should be carefully examined for damage. Significant damage should be made good but if there are major defects in the coating the pipes should be rejected.

Where pipes are provided with factory applied jointing material, they should be examined when delivered. Each pipe and joint should be carefully examined for soundness and cleanliness immediately before laying.

Jointing components, including lubricants supplied separately from the pipes, should be examined for soundness and to establish compatibility with the pipes. They should be stored as recommended by the manufacturer.

20.2 Laying pipes on trench formation

Where the design permits and the nature of the ground is such as to allow it to be trimmed to provide a uniform bearing, pipes may be laid on the formation. Socket and joint holes should be as short as practicable, scraped or cut in the formation, and deep enough to give a minimum clearance of 50 mm between the socket and the formation.

When the formation is prepared, the pipes should be laid upon it true to line and level within specified tolerances. This should be checked for each pipe and any necessary adjustments to level should be made by raising or lowering the formation, always ensuring that the pipes finally rest evenly on the adjusted formation throughout the length of the barrels. Adjustment should never be made by local packing.

Where the formation is low and does not provide continuous support, low areas should be brought up to the correct level by placing and compacting suitable material.

20.3 Laying pipes on granular beds

20.3.1 *General.* The trench should be excavated to a depth such as to allow the specified thickness of granular bedding material to be placed beneath the barrels. Any mud should be removed and soft spots should be hardened by tamping in gravel or broken stones. Rock projections, boulders or other hard spots should be removed. In fine grain soils, disturbance of the trench bottom should be minimized by placing a layer of blinding material about 75 mm thick. Such precautions will be necessary in bad weather and/or wet ground conditions.

The granular bedding material should be placed to invert level and should extend usually to the full width of the trench (but see Figure 5 and Figure 6). A shallow depression should be formed for the barrel of the pipe. Socket holes should be formed at each joint position. These should be deep enough to prevent the weight of the drain and the load upon it bearing on the socket or coupling and should be a minimum of 50 mm deep, leaving a minimum depth of 50 mm of granular bedding material beneath the joint.

Pipes should be laid directly on the granular bed and adjusted to correct line and level within the specified tolerances. Sidefill of either granular material or selected backfill material, depending upon the class of bedding specified, should be placed evenly on either side of the pipe taking care not to disturb the line and level. Bedding material should not be compacted in the socket holes. It is sufficient that they be filled as a result of the general placing of sidefill.

The side support available for flexible pipes depends upon the extent and the degree of compaction of the bedding, and the nature of the surrounding soil. For this reason, flexible pipes other than ductile iron should be installed with materials as described in **5.7.5**. If the trench is deeper than 2 m to 3 m in poor soil, or selected material (see **18.3.1**) is not available, the bedding material should extend to at least 100 mm above the crown to provide a protective cushion. The material should then be compacted equally on both sides of the pipe using hand rammers or lightweight vibrators. Mechanical compaction at this stage may be unnecessary when the compaction fraction of the material does not exceed 0.15, e.g. when using single sized aggregate. It is desirable that vertical deformation of flexible pipes should be limited to 5 % on completion of the backfilling, which will be achieved by the proper selection and placement of bedding, sidefill (see **5.7.5**) and backfill (see **5.7.6**) material in accordance with this code.

20.3.2 *Additional recommendations for flexible pipes.* In trenches with a width less than 6 × o.d. of pipe, the bedding should extend to the trench walls (see Figure 6a and Figure 6b). In wider trenches, pipes should be installed as shown in Figure 6c and Figure 6d.

20.4 Laying pipes with concrete bed, bed and haunch, and surround

Surrounding or bedding with concrete is generally not justified unless required to meet specific site or structural conditions. However, where in situ concrete bedding is required, the trench bottom should be prepared to give a firm foundation as in **20.3**, using a blinding layer if necessary. The level of this formation should allow for at least 100 mm of concrete under the pipe barrel. The pipes should be supported clear of the trench bottom by means of blocks or cradles of compressible material placed under the pipes immediately behind each socket. Expanded polystyrene or impregnated fibre building boards are examples of suitable material that will yield under load sufficiently to permit the barrel of the pipe to rest uniformly on its bed after normal setting shrinkage of the concrete has occurred. The use of rigid temporary type supports is inadvisable but where it is necessary to use them they should be removed as the concrete bed is placed. The concrete bed should extend at least 100 mm on each side of pipes up to 300 mm diameter. Haunching and surround should not be placed until the pipework has been inspected and deemed satisfactory.

Where flexible joints are employed, the overall flexibility of the drain should be maintained by the provision of flexible joints in the concrete. These should be formed through the full cross section of the concrete by providing compressible materials such as expanded polystyrene or impregnated fibre building boards at the face of each pipe socket or sleeve. This is to ensure that any subsequent flexing occurs only at a pipe joint.

The concrete should be so placed that the pipes or lateral construction joints are not displaced and the flexibility of the joint not impaired.

Concrete should be mechanically mixed until there is a uniform distribution of the materials and the mix is uniform in colour. It should be transported to the point of placing as rapidly as practicable by methods that will prevent segregation or the loss of any of the ingredients, and be placed without delay. Thorough compaction should be achieved by rodding, tamping or vibration so as to form a void-free mass round any reinforcement and into the corners of the formwork or excavation. Exposed concrete should be cured by keeping it in a damp condition, the period of curing depending on the exposure conditions. In situations where the concrete is protected from sun and wind, no particular requirements are necessary. Where the concrete is exposed to the effects of sun and wind, it will generally be sufficient to cure it for a period of 4 days.

Concrete may suffer permanent damage if its temperature falls below 0 °C before it is mature enough to resist disruption by freezing. When concrete is placed at air temperatures below 5 °C, the aggregates and mixing water should be free from snow, ice and frost, and the fresh concrete at the time of placing should have a temperature of not less than 5 °C, with a minimum of 10 °C being preferable.

NOTE This is normally possible to achieve with most mechanically mixed concrete.

All surfaces with which the fresh concrete will come into contact, including those of formwork, reinforcement and hardened concrete, should be free from snow, ice and frost and should preferably be at a temperature close to that of the fresh concrete.

It is important to ensure that the temperature of the concrete should, at no point, fall below 0 °C. This should be achieved in most situations providing reasonable precautions are taken but particular care is needed when small quantities of fresh concrete are placed against larger quantities of hardened concrete at a lower temperature. The recommendations given in this code will be sufficient in most instances but for any main structural work reference should be made to BS 8110[11)].

20.5 Setting cover frames

Unless prefitted cover frames are supplied for inspection chambers, cover frames should be bedded in with the lid in position to prevent twisting of the frame. The cover frame should be solidly bedded over its whole area in cement mortar so as to obtain even bearing on the top of the shaft. This is important to prevent breakage of the cover under load. Frames in roads should be set to conform to the camber and fall of the road surface.

21 Jointing pipes (see also **14.6**)

21.1 Flexible joints

Changes in the character of the subsoil such as the moisture content, the bedding and compaction conditions, and the nature of the subsoil itself may cause differential settlement in any buried drains. Flexible joints should be used to provide flexibility, longitudinal travel and ease of jointing. They are available for all types of pipe and the pipe maker's recommendations regarding the making of the joints should be closely followed. It is important that the joint should be made with the sealing ring supplied by the manufacturer and that the manufacturer's recommendations should be followed where a lubricant is required. The jointing surface and sealing rings should be clean and dry prior to any application of recommended lubricant.

To allow for telescopic movement, a small gap should be left between the spigot end and shoulder of the adjoining socket or between pipe ends.

Holes for pipe sockets or joints should always be formed in the bedding and care taken to avoid disturbance of the bedding when placing and jointing the pipes.

Most small diameter pipes can be jointed by hand. Where a winch or other pulling device is necessary, its anchorage should be so placed as to avoid disturbance to the pipes already laid, e.g. on the remote end of the pipeline.

Pipes should be correctly aligned during laying and jointing. Those of nominal size DN 225 or less can be adjusted true to line after jointing, but larger pipes should be correctly aligned as they are difficult to move afterwards.

During the making of rolling-ring joints, the rings should roll evenly and to facilitate this the axes of the two pipes should be aligned. Some rolling-ring types of joints have a tendency for the ring to roll back and, with small diameter pipes, to force the spigot of the last pipe out of its socket, unless the pipe is temporarily restrained.

21.2 Rigid joints

21.2.1 *General.* There are two types of rigid joints; spigot and socket joints, and flanged joints.

If rigid joints are used underground, e.g. for drop-pipes, care is necessary to cater for ground movement.

When a pipe length has to be shortened and this results in part of a factory prepared flexible joint being removed, a rigid joint may be used. Where a mortar joint is incorporated into a flexibly jointed drain, the length of the rigid pipe so produced should not exceed the pipe length being used elsewhere in the pipeline.

Flanged joints should not be buried without special protection of the bolts against corrosion.

Rigid joints may be used for adaptors for pipes of different materials, although for most pipe systems adaptors with flexible joints are available.

21.2.2 ***Rigid joints for flexible pipes***

21.2.2.1 *General.* Rigid joints are sometimes used with flexible pipes. The manufacturer's jointing recommendations should always be carefully followed and care taken to avoid entry of jointing material into the pipe.

21.2.2.2 *Pitch fibre pipes.* Taper joints for pitch fibre pipes depend for their watertightness on accurate machining of the tapered joint surfaces. The driven fit will not permit any draw, and the pipes are dependent upon their inherent flexibility to accommodate ground movement. Where large ground movements are probable the rolling-ring type of joint (snap ring) should be employed.

21.2.2.3 *Plastics pipe.* Solvent welded joints for plastics pipe will not permit draw and, as the drain is subject to distortion with changes of temperature, allowance normally should be made for lengthening and shortening by the provision of telescopic joints.

[11)] In preparation. Revision of CP 110.

If any solvent is spilled in the trench, the polluted bedding should be removed immediately otherwise the pipe may be attacked and weakened. Clean bedding material should then be placed (see **5.7.8**).

21.2.3 *Rigid joints for rigid pipes.* Rigid joints should be used only where there is rigid durable support for the pipeline.

21.3 Cutting pipes

Where it is necessary to cut rigid pipes, this should be done with a suitable pipe cutter so as to leave a clean end square to the axis of the pipe. Pitch fibre pipes can be cut with a coarse-tooth saw and plastics pipes with a fine-tooth saw.

The sawing of asbestos-cement pipe attracts the provisions of the Asbestos Regulations 1969. Adequate methods to control levels of dust during such operations have to be employed and these are detailed in Guidance Note EH 36 [14].

When required by the pipe manufacturer, cut spigots should be chamfered.

21.4 Jointing pipes and fittings of different materials

Where it is necessary to make joints between different materials, a special adaptor should be used. Most pipe manufacturers supply suitable adaptors.

22 Prevention of displacement of drains

Deflection of a pipeline should be avoided during testing and the placing and compaction of sidefill. The risk of movement is greater with lightweight pipe materials. To prevent displacement, stout raking pegs may be driven but these should be removed when side filling is near completion. Where sidefill is placed and compacted equally on both sides of a pipe, such pegs are not necessary.

Bedding and sidefill material should be thoroughly compacted, care being taken to avoid damage to the pipes. Where pea gravel is used (and to a lesser extent where any nominal single sized material is used) over-compaction may cause lifting of a pipeline, thus spoiling the intended gradient. This is more likely to occur with lightweight pipe and/or where a trench is waterlogged. Filling the pipeline with water will help to avoid such disturbance.

When a trench is left open at the end of a day's work and flexibly jointed pipes are being laid on a granular bed, a distance of 1.0 m of properly placed and consolidated bedding should be left without a pipe upon it. This prevents settlement of the last pipe, particularly in wet weather.

Pumping mains should always be restrained by the provision of anchorage at bends, junctions and blank ends. Because of the high pressures involved partial backfilling should be carried out before testing to prevent the pipeline "kicking".

23 Groundwater drains (see also clause **10**)

23.1 Field drains

Trenches for plain ended or ogee jointed pipes should be just wide enough at the bottom to accommodate the pipes and should be trimmed to form a uniform bed for the pipes.

All pipes should be laid to planned lines and gradients. Plain pipes should be laid with open joints but perforated and porous pipes should be fitted tightly together. Perforated pipes should be laid with holes equally distributed about the vertical axis of the drain and in the lower half of the pipe.

23.2 Mole drains

A mole drain is formed by means of a mole plough which consists of a beam to which is attached a steel blade. On the lower end of the blade is fixed a bullet-shaped steel tool which forms the drain. Mole ploughs are available in diameters from 50 mm to 150 mm and lengths from 300 mm to 700 mm. The plough is pulled by a tractor or by cables operated from a winch to form a cavity in the subsoil for drainage purposes. Clay subsoils are most suitable for drainage by this method.

Mole drains should be made from 300 mm to 750 mm deep and 3 m to 5 m apart depending on site conditions. The best time for mole draining is usually in March and April but it may be practicable to do this work in early summer or late autumn or occasionally in dry winter months when the clay subsoil is moist and sufficiently plastic.

23.3 Rubble drains

Where a rubble drain is required, it should be constructed by excavating a trench and filling it with selected rubble or stone through which water can percolate. Renewal may be necessary from time to time.

23.4 French drains

Where a french drain is required, it should be constructed by excavating a trench and laying therein open-jointed pipes of perforated or porous material. The pipes should be surrounded with fill through which water can percolate freely.

23.5 Filter drains

A french drain or rubble drain may not prevent the migration of fine soil particles with groundwater. Where it is essential to prevent this migration, the pipe should be surrounded with graded granular material or a polypropylene or fabric filter designed in accordance with the principles of soil mechanics.

24 Connections

24.1 Location of existing drain or sewer

Before pipe laying is commenced, the position and level of the drain or sewer to which it is proposed to make a connection should be confirmed, if necessary by excavation. In the case of a sewer, reference should be made to the drainage authority or to the owner as appropriate. Similar confirmation should be obtained from the appropriate statutory authority or owner in respect of any adjacent services, particularly those which may affect or be affected by the connection.

Formal notice requiring a connection to a public sewer has to be given to the drainage authority who may themselves expose the sewer and make the connection to it, or may authorize the work wholly or in part to be done by others, to their requirements and under their supervision.

Arrangements for making a connection to a private sewer should be agreed with the owner(s) of that sewer, and suitably documented between the parties concerned.

24.2 Excavation

24.2.1 *General.* Excavation in a highway should be carried out only with the approval of the highway authority (see also clause **18**).

24.2.2 *Open excavation.* Exposure of existing drains or other services should be carried out with care to avoid damage and temporary support provided where needed. The size of the excavation should be no larger than is necessary to provide working space for making the connection.

The excavation should be kept free from water whilst an opening is made in a pipeline. Excavated material should be kept clear of the opening and extraneous liquid or solid matter prevented from entering the pipe.

24.2.3 *Excavation in heading.* Where a drain or sewer is located beneath a busy road or street or where it is anticipated that a large number of other services would be met in open excavation, it may be more practicable and convenient to construct a connection in heading provided that sufficient depth of cover is available. A local or highway authority may direct that this be done.

24.3 Methods of making connections

24.3.1 *General.* A connection to an existing drain or sewer should be made by one of the methods described in **24.3.2** to **24.3.6**, and in such a manner as to minimize any interruption of the flow.

At the point of connection, a branch should have its centre line above the centre line of the drain or sewer to which it is connected, except that where man-entry to the sewer is possible it should connect at a lower level so that discharge does not cause a hazard to operatives.

The minimum of disturbance to a pipeline should be caused when a connection is made. New joint holes should be formed in the bedding where required for insertion of junctions and couplings. Where structural protection is disturbed by making a connection, it should be made good. On completion, the new work should be inspected and tested, to the extent that it is practicable, in accordance with clause **25** and, when all joints are sound, the pipework should be provided with suitable structural protection appropriate for the pipe material, jointing system and location.

24.3.2 *Connection to an inspection chamber or manhole.* Where a connection is made either direct or by a drop-pipe to an open channel, the benching should be carefully cut away and a suitable channel branch bend, preferably three-quarters section, inserted, or an in situ entry channel formed. The incoming flow should enter at the top of the channel, in the direction of the main flow and without causing turbulence or backing up in the main or other branches. The benching should be reinstated.

Where the connection is to a sealed system, it will normally be necessary to break out and replace the access fitting unless it already has a suitable spare branch. It may be more practicable and convenient to construct a new inspection chamber or manhole.

24.3.3 *Construction of an on-line inspection chamber or manhole.* A new inspection chamber or manhole may be constructed on an existing drain or sewer, the crown of which, in suitable materials, may be cut out leaving a channel. The connection can then be made in the normal manner and the construction, including the base and benching, completed with the minimum of interruption of the flow.

24.3.4 *Connection by a junction.* Where a pipe junction is to be inserted in a line of pipes, it may be necessary to disturb or remove one or more pipes depending on the material of the pipes, their length, joint types and bedding. In order to maintain pipe continuity, only sufficient length of pipe should be removed to enable the junction to be inserted in the pipeline. The operation may involve the insertion of a short length of pipe in addition to the junction. Whether socketed or sleeved joints are used, they should be appropriate to the pipeline, ensure accurate centring and concentricity about the pipe ends and provide an effective seal. The junction should be fixed at the appropriate angle to receive the incoming branch drain.

Where a junction is provided for future use, it should have an effective removable seal and its position should be accurately measured and recorded.

24.3.5 *Saddles.* A saddle may be difficult to connect satisfactorily and should be used only when other methods are impracticable. Where one is used, it should be located on the upper half of the pipe, preferably with its axis at 45° to the vertical plane. The pipe should be cut into by the cautious enlargement of a small hole or by trepanning or, where practicable, by the use of a suitable saw and purpose-made template, taking care to prevent any materials from entering the pipe. The hole should be accurately trimmed so that the saddle fits with at least half of the width of its shoulder bearing on the pipe over the whole circumference of the shoulder. The saddle should be of the correct size for the pipe and connection (see **7.6.7**) and be secured by a method appropriate for the pipe material. After all joints have set, the connection should be provided with suitable structural protection.

24.3.6 *Connection to a large pipe.* Where practicable, a connection to a large pipe should be made by working both from inside and outside so that any debris can be cleared away. The incoming pipe should be properly jointed in position and finished so that it does not protrude.

24.4 Branch connecting drain

When a junction or saddle has been installed and, where appropriate, the jointing medium has set, the connection to it should be made with a long radius bend. This should be followed, where required, by a test junction fixed with the socket uppermost (or an arrangement appropriate to the pipe system) to allow the insertion of a plug for testing and connecting the drain. The drain should be laid in a straight line between the bend and the first inspection chamber or manhole. All open ends should be temporarily sealed during the progress of the work to prevent ingress to the pipes. A test junction should be effectively sealed after the work has been proved sound and before backfilling.

Section 5. Inspection, testing and maintenance

25 Inspection and testing of drainage works

25.1 General

Site inspections and tests are necessary to ensure that materials and components are properly installed and that they will adequately fulfil the functional and performance requirements of the drainage system without creating a health risk or causing a nuisance.

Generally, drainage works are inspected and tested in two stages; as the work proceeds and immediately before the works are handed over upon completion. The works should be protected during all stages of construction, and the entry of foreign matter into any part of the system prevented.

25.2 Testing sequence

25.2.1 *First stage testing.* Tests should be carried out to locate and remedy any defects in soundness that may exist at the time of construction. Such tests should take place immediately before the work is covered up so as to facilitate replacement of any faulty pipes or pipe fittings or to rectify any joint defect. Inspection of the pipeline will reveal any defects in the support and bedding.

25.2.2 *Final testing.* Testing and inspection should take place immediately before handover when all relevant works have been completed.

25.3 Pre-test procedures

25.3.1 *Safety.* Before any tests are applied, attention should be given to the safety of the operatives and other persons involved in the testing operation[12)]. It is essential that proper means of access should be provided to the area of work and the sides of any trench or excavation in which work is to be tested adequately supported and free from hazards.

Where a water test is to be applied, drain stoppers and bags should be properly secured in position and provision made for the final removal of the stopper or bag from surface level by means of a strong cord attached to the inlet ferrule.

25.3.2 *Cleansing.* All obstructions, debris and superfluous matter should be removed from sections of pipeline, inspection chambers, manholes, or similar underground chambers and they should be flushed out before testing.

Great care should be taken when a chemical cleaning agent is used to remove deposits of cement mortar from the surfaces of benchings and channel inverts. Protective clothing, including gloves and eyeshields, should be provided for operatives using or handling the chemicals. On completion of the work, all treated surfaces should be thoroughly hosed down.

25.4 Checking the bore

Before any tests are applied, a disc or ball type profile testing device should be passed through all drains and private sewers between inspection chambers, manholes or other suitable points of access and through all accessible branch drains.

25.5 Witnessing and documentation of tests

All tests should be carried out and recorded in the presence of an authorized testing officer and a record made. A certificate signed and dated by the testing officer should be issued upon the completion of a satisfactory test. The certificate should indicate the location and give a brief description of the work. Alternatively, a set of construction drawings, deposited on site, may be used by the testing officer who should date and sign the relevant drawing against the section of the work tested and found satisfactory. Where a public authority has a statutory right to inspect and test drainage works, sufficient notice should be given to the authority for this to be carried out.

25.6 Soundness tests for gravity drains and private sewers

25.6.1 *General.* A water test is generally preferred since it relates very closely to conditions found in practice. It is also less stringent than an air test but it suffers from the disadvantage of providing and disposing of large quantities of water. An air test is easier to apply but results can be affected by small changes in temperature. A change in temperature of 1 °C will result in a corresponding change in air pressure of about 38 mm water gauge. Therefore, if the pressure drop is marginally above that recommended in **25.6.2.1**, the pipeline should not be deemed unsatisfactory on the air test alone.

25.6.2 *Water test*

25.6.2.1 *General.* Gravity drains and private sewers up to and including 300 mm diameter should be tested to an internal pressure of 1.5 m head above the invert of the pipe at the high end of the line and not more than 4 m head at the lower end.

[12)] See clause **4**.

Testing should be carried out between inspection chambers, manholes or other suitable points of access and through any accessible branch drains. Where the test head of water is in excess of 4 m at the lowest point of the pipeline under test (including the minimum test head of 1.5 m), the pipeline may be tested in sections by means of appropriately placed test branches. The test branches may be extended up to the finished surface with a suitable termination and used as additional points of access. Alternatively, where it can be achieved satisfactorily, the pipeline may be subjected to an air test.

Solvent welded uPVC pipelines should be allowed to stand for 1 h to 2 h before applying the test and should be suitably anchored to prevent flotation when the test is applied before backfilling the trench.

Where cement mortar joints are used, they should be left for at least 24 h before testing.

25.6.2.2 *Test procedure.* Use the test procedure given in items a) to f) as follows.

a) Fit expanding plugs or bag stoppers, suitably secured to resist the full hydrostatic head, at the lower end of the pipe and in any branches as necessary.

b) Fit a similar plug or bag stopper into the top end of the pipeline together with a standpipe or flexible tube leading from a container connected to the plug or bag.

c) Fill the pipeline with water making sure that there are no pockets of trapped air.

d) Fill the standpipe or other test apparatus to a height of 1.5 m above the pipe or channel invert.

e) Allow the pipeline to stand for 2 h for absorption, topping up as necessary.

f) After 2 h, measure the loss of water from the pipeline by noting the quantity of water needed to maintain the test head in the apparatus over a period of 30 min.

25.6.2.3 *Acceptance criteria.* The rate of water loss should not exceed 1 L/h per metre diameter per linear metre run of pipe, For various pipe diameters this rate of loss over a 30 min period may be expressed as follows:

DN 100 pipe	0.05 litres per metre run;
DN 150 pipe	0.08 litres per metre run;
DN 225 pipe	0.12 litres per metre run;
DN 300 pipe	0.15 litres per metre run.

25.6.2.4 *Interpretation of results.* A change in water level in the test apparatus may be due to one or more of the following causes, which can generally be rectified or appropriate allowances made for in the testing procedure:

a) absorption by pipes or joints;

b) exposure of pipes in direct sunlight, or changes of ambient temperature when pipes are laid, i.e. the expansion/contraction of thermoplastic pipes or rigid pipes acting as a "thermal sink";

c) trapped air;

d) leakage past expanding plugs or bag stoppers.

Other causes of test failure may include any of the following items 1) to 4). Such causes should be rectified by replacement of the defective work and the tests repeated until soundness is achieved:

1) sweating of pipes or joints;

2) damaged, faulty or improperly assembled pipe joints;

3) cracked pipe barrels;

4) deformation of flexible pipes in the immediate vicinity of a joint resulting in a loss of joint integrity.

NOTE Some pipes absorb more water or trap more air at the joints than others. Allowance should be made for this when carrying out the test.

If when carrying out a final water test, the minimum test head is determined by the overflow level of any gully, inspection chamber, manhole, etc. in connection with the work being tested, the prior approval of the testing officer should be sought.

25.6.3 *Air test*

25.6.3.1 *General.* The test should be carried out by inserting expanding drain plugs or inflatable canvas or rubber bags in the upper and lower ends of the pipeline, and pumping air in under pressure. Where cement mortar joints are used, the joint should be left for at least 24 h before testing. Solvent welded uPVC pipelines should be allowed to stand for 1 h to 2 h before applying the test.

25.6.3.2 *Test procedure.* Use the test procedure given in items a) to e) as follows.

a) Fit expanding plugs or inflatable canvas or rubber test bags into the ends of the pipeline and of all associated branches.

b) Connect a glass "U" tube gauge (manometer) to one of the sealing plugs and a means of applying the air pressure to another sealing plug or stopper inserted in the section of pipework under test. For a positive test result over the whole of the pipeline, the manometer and air pressure source should be located at opposite ends of the pipework under test.

c) Apply pressure either by mouth or hand pump to achieve a pressure of slightly more than 100 mm water gauge for pipelines, or where gullies and/or ground floor appliances are connected, of slightly more than 50 mm water gauge.

d) Allow 5 min for stabilization of air temperature.

e) Adjust air pressure to 100 mm or 50 mm water gauge as necessary.

25.6.3.3 *Acceptance criteria.* Without further pumping, the head of water should not fall by more than 25 mm in a period of 5 min for a 100 mm water gauge test pressure and 12 mm for a 50 mm water gauge test pressure.

25.6.3.4 *Interpretation of results.* There are several possible contributing factors that could cause an apparent failure in the air test. These include the following:

a) temperature changes of the air in the pipe due to direct sunlight or cold wind acting on the pipe barrel;

b) dryness of the pipe wall;

c) leaking plugs or faulty testing apparatus.

These factors should be investigated before resorting to the water test.

25.7 Soundness tests for ancillary works

25.7.1 *General.* Recommendations given in this code for the materials, design and construction of inspection chambers, manholes, petrol interceptors and similar underground chambers should ensure a high level of resistance to water penetration, both inwards and outwards.

Inspection chambers and manholes should be so constructed that no appreciable flow of water penetrates the permanent works.

Where construction work has been effectively carried out, visual inspection may be sufficient for acceptance without testing. Inspection should always be made to reveal any possible weaknesses in the structure and particular attention should be paid to the following:

a) step-iron and ladder housings;

b) benchings;

c) pipes entering or leaving the structure;

d) joints in brickwork or blockwork (see **13.4.3.2**);

e) joints between sections of the structure.

If, within the inspection procedure, testing for watertightness is required, the testing regime described in **25.7.3** to **25.7.6** should be applied.

25.7.2 *Reasons for testing.* There may be a need for testing to be carried out in any of the following cases:

a) for petrol interceptors, suction wells and similar structures;

b) where unsatisfactory features have been revealed by inspection, e.g. where there is reason to believe that materials or workmanship have been inadequate;

c) in locations where there is fissured chalk or rock, or pervious subsoil;

d) where frequent surcharging of the manhole or inspection chamber is likely.

25.7.3 *Test head.* Inspection chambers and manholes less than 1.5 m in depth to invert should be filled with clean water to the underside of the cover and frame located at ground or surface level. Where the depth to the channel invert is 1.5 m or greater, the test head should not be less than 1.5 m. The test head for petrol interceptors, suction wells and similar underground chambers should be not less than 0.5 m above the invert of the highest connection to the chamber.

Where the chamber is located in ground subject to pore pressure, the test head should be the mean water table level based on seasonal variations or test heads previously specified, whichever is the greater.

25.7.4 *Test procedures.* Open channel manholes, inspection chambers and other free surface, water containing structures should, whenever possible, be tested independently of any drain or private sewer, particularly where remedial works would be difficult.

For the tests fit an inflatable bag stopper in the outlet of the inspection chamber or manhole and fit expanding plugs or inflatable stoppers in all other connections. Secure all plugs and stoppers to resist the full hydrostatic head and provide means of safely removing the outlet stopper from the surface.

Tests may take either or both of the following forms:

a) an exfiltration test (see **25.7.5**);

b) an infiltration test (see **25.7.6**).

25.7.5 *Exfiltration testing.* Tests should not be carried out until structures have sufficient strength to sustain the pressure exerted by testing; in the case of brick or concrete this will not normally be less than 3 days or more than 7 days after completion of construction.

The external faces of a structure should not usually be backfilled or concrete surrounded (unless the surround forms part of the watertight structure) before the chamber has been accepted as satisfactory. Proper stability should be ensured during the period of test and subsequent concrete placement and backfilling.

Fill the inspection chamber, manhole, etc. with clean water to the required test level and allow to stand for a period of not more than 20 h for absorption, topping up the level as necessary. Measure the fall in water level over a 30 min period after the absorption period has been completed. A shorter period may be allowed for absorption before testing if desired.

Should it prove difficult to fill the structure due to excessive leakage or should any identifiable points of leakage be observed either during the filling, absorption period or test, the test procedure should be stopped and repairs carried out. When repairs are complete and any new mortar or concrete is adequately cured the test procedure should be repeated.

The recommended falls in water level in a 30 min period are given in Table 9 for the minimum recommended sizes (see Table 8).

Where the fall in level during a water test on brick inspection chamber or manhole exceeds 30 mm, but there are no obvious causes for the loss, the water test should be repeated after not less than 30 days when the criteria for acceptance at the period should apply.

25.7.6 *Infiltration testing.* Where the excavation has been backfilled and where it is known that the ground water level is significantly above the crown of the drains connecting to the chamber, mature inspection chambers and manholes should be tested by measuring the volume of water entering the chamber by infiltration over a known period.

The maximum infiltration should not exceed 1 L/m^2 h over the internal surface area of the walls of the whole of the manhole or inspection chamber. Notwithstanding the above, any visible leaks should be repaired.

25.7.7 *Testing of other watertight structures.* Sumps, suction wells, mud and oil interceptors, petrol interceptors, oil separators, septic tanks and cesspools should be tested for watertightness as described in **25.7.5** but over the full height to the designed level of the contents when in operation, and without measurable loss of water after 30 min.

25.8 Hydrostatic testing of ejector mains and sewage pumping mains

25.8.1 *General.* Before carrying out any testing procedure, particularly in an excavation, reference should be made to the safety recommendations given in **25.3.1**.

25.8.2 ***Pre-test activities***

25.8.2.1 *Cleansing and visual inspection.* Before applying a hydrostatic test, all pipework should be cleared of any obstruction, superfluous matter, etc. and flushed out. The pipework should then be inspected and any obvious defects remedied.

25.8.2.2 *Preparation of pipework.* All pipelines subject to static and dynamic thrusts should be provided with properly designed anchorage at all changes of direction and at blank ends. Anchorage for pipelines of uPVC and similar materials may need special consideration.

Buried pipelines should be provided with properly designed concrete anchor blocks at all points of thrust. The pipeline should be anchored by partially backfilling the trench with a suitable material, well rammed without displacing the pipeline. The body of the pipe should be completely covered with the joints kept clear for inspection.

Table 9 — Recommended acceptance criteria for fall in water level of inspection chambers and manholes (over 30 min after a period of absorption of up to 20 h)

Age of construction up to 1.5 m above invert level	Maximum fall in water level in 30 min			
	Brickwork	Concrete sections	Clayware, plastics or any “one piece” chambers	
	More than 1 m deep	1 m or less deep		
3 to 7 days	mm 30	mm 20	mm 10	mm 5
Over 30 days	5		5	5

NOTE 1 In the event of difficulty in measuring small falls in water level, e.g. in deep manholes, the tests may be extended to 1 h and the maximum permitted falls doubled.

NOTE 2 It has been established by research (see BCRA Technical note 373 [15]) that the rate at which inspection chambers and manholes leak decreases substantially with time and that this decrease in leakage rate may continue for several weeks after construction. The maximum falls in level given in Table 9 are values which should ensure that the steady leakage rate of the mature manhole or inspection chamber does not exceed 10 mm/h after a period of 30 days.

Concrete anchor blocks should be so designed as to permit any pipe joints to be re-made, if necessary. The design of an anchor block should also take into account the maximum thrust developed during the test and the safe bearing pressure of the surrounding soil. The concrete should be placed in position in such a manner as not to displace or damage the pipeline. The concrete should be of strength not less than 21 kN/m^2 and a minimum period of 24 h should elapse before pressure testing begins. Normal precautions should be taken during placing and curing of the concrete in respect of segregation, minimum temperature, etc. (see BS 8110[13)]).

When testing a pipeline in sections, sluice valves should not be used as a means of sealing off. In such cases, or where a section of pipe under test terminates with a sluice valve, the valve should be replaced temporarily with a stop end such as a blank flange or plug which should be provided with adequate anchorage against end thrust developed during the test.

Pipelines of uPVC and other thermoplastic pipe materials which have been solvent welded should not be pressure tested until a period of at least 24 h has elapsed from the time of making the last joint.

25.8.3 ***Testing***

25.8.3.1 *Apparatus.* The apparatus generally used for testing a pressure main comprises a water reservoir, a hand operated force pump of the small plunger type, a calibrated pressure gauge, full-way isolating valves and connecting pipework. Suitable apparatus is available as a complete unit or the separate components can be assembled to form a small test rig. The apparatus should be so designed and arranged that it may be removed in whole or part, if the test is to continue for a long period.

25.8.3.2 *Test pressures.* When testing a sewage pumping main, the test pressure should be not less than 1.5 × the "no flow head pressure" of the pump. Where positive displacement pumps are to be used, the main should be tested to a pressure of twice the maximum head of which the pumps are capable.

The test head for a sewage ejector main should be not less than 1.5 × the maximum air pressure at which the ejector operates.

When a pipeline may be subjected to surge conditions, the test pressure should not be less than the maximum calculated surge pressure with a reserve of head to give an adequate margin of safety.

NOTE Specialist advice should be obtained when dealing with surge effects on pressure pipelines, sewage lifting apparatus and ancillary equipment.

25.8.3.3 *Test procedure.* Use the test procedure given in items a) to g) as follows.

a) Ensure that the pipeline to be tested is correctly supported and anchored and is capable of withstanding the maximum thrusts developed during hydrostatic testing. Remove any air valves to prevent valve damage during testing or replace them by plugs.

b) Connect the test apparatus to the lowest part of the pipeline to be tested.

NOTE In an inclined or vertical section of pipe, the pressure gauge should preferably be connected to the lowest level of the pipe to ensure that the test pressure at that point is not exceeded. If, however, the pressure gauge is to be connected elsewhere on the pipeline, then a correction should be made to the test pressure to compensate for any static pressure difference between the gauge level and the lowest level of the pipeline.

c) Slowly fill the pipeline with clean water avoiding secondary surge pressures whilst displacing all air from the system.

d) Allow the charged pipeline to stand for a period of time so that conditions are stable.

NOTE A period of 4 h is generally considered to be both effective and practical for most conditions.

e) Slowly apply pressure to the pipeline until the required test head is reached using the apparatus described in **25.8.3.1**.

f) Isolate the pressurized pipeline from the test pump and allow it to stand for 30 min during which time there should be no drop in pressure. Observe the entire pipeline during the test.

g) If the test is satisfactory, drain down the pipeline and cap off temporarily or, where practicable, connect into the system.

25.8.3.4 *Test results.* Difficulty in reaching the required test pressure may be due to one or more of the following reasons:

a) leaking joints;

b) a defective pipe;

c) movement of the pipeline because of inadequate anchorage or fixings;

d) leaking valves, connections, etc.;

e) air in the pipeline.

25.8.4 *Commissioning.* When all sections of the pipework serving the sewage lifting apparatus have been satisfactorily completed and tested, the entire system should be primed and made operational. This should be carefully carried out to avoid the formation and movement of large bubbles of air. The presence of air in this form can seriously reduce the flow capacity of the system as well as affect its overall performance.

[13)] In preparation. Revision of CP 110.

The complete installation should then be inspected and checked under normal working conditions.

26 Maintenance and periodic inspection

26.1 General

Drainage systems should be inspected at regular intervals and, where necessary, thoroughly cleaned out at the same time. Any defects discovered should be made good.

26.2 Cleaning of the drainage system

The following operations should be carried out during the periodic cleaning of a drainage system.

a) Covers of inspection chambers and manholes should be removed and the sides, benchings and channels cleaned.

b) Intercepting traps, if fitted, should be plunged and flushed with clean water. Care should be taken to see that the stopper in the rodding eye is securely replaced.

c) Main and branch drains should be cleaned (see **26.3**) and afterwards should be flushed with clean water. Any obstructions found should be removed and not flushed into the system.

d) Periodically, accumulated deposits in gullies should be removed. The traps should then be plunged and thoroughly flushed out with clean water.

e) Covers of inspection chambers and gullies should be replaced, bedded in suitable grease or other sealing material and/or bolted down as appropriate to the type. Missing bolts and broken items should be renewed.

26.3 Methods of cleaning

The drainage system should be cleaned, as appropriate, using one or more of the following methods.

a) *Rodding*. Appropriate cleaning tools and techniques should be chosen to avoid damage to the pipework to be cleaned. A set of rods with appropriate ends is basic useful equipment. It is important that correctly designed proprietary ends are used on the rods. Makeshift devices attached to the ends of rods should be avoided as they are not as effective as the correctly designed article and could become detached and create a blockage which would be difficult to remove. Furthermore, it is possible that such devices could cause damage to the pipeline. If the rods have brass ferrules, they should be checked to ensure that their fastenings are secure and that there are no protruding shoulders or fastenings as these can cause damage to drain lines, especially when entering through rodding eyes.

b) *Jetting*. High pressure jetting techniques are suitable for use with all currently available pipe materials, and should also be considered.

c) *Hydraulic rams, compressed air or other gases*. Equipment is available for use with all sizes of drain likely to be encountered in building drainage and is suitable for use with all currently available pipe materials. The principle of operation is that a shock wave is induced and is transmitted by water to the point of blockage, and the technique is effective where the pipe is surcharged or can be filled with water from the blockage to a point where the equipment can be used.

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Appendix B Preparation of plans

B.1 General

Notwithstanding the requirements of legislation for drawings and information to be submitted for formal approval, adequate detailed drawings of the proposed works should be prepared for use in construction and, on completion, for record purposes. The recommendations of BS 1192 should be followed and symbols should be used to make a clear distinction between existing and proposed drains. Where required to assist identification, the following colours should be used.

Foul water drains ________________ red (purple for trade effluent)

Surface water ___ ___ ___ ___ blue

Subsoil drains _ _ _ _ _ _ _ _ _ _ _ _ black

NOTE Existing work is shown by faint lines with crosses at each end, e.g. x________________x

B.2 Layout plans

The following information should be clearly and accurately shown on the layout plans:

a) topographical details of the whole site including buildings and drains, trees and other features, buildings upon adjoining land, the names of streets or roads in the immediate vicinity or adjoining the curtilage and, where appropriate, the proposed development of the area, as obtained from the planning authority;

b) the orientation of the site;

c) the scale of the drawing and the date plus the grid reference where necessary;

d) the proposed buildings with the position of all discharge pipes, rainwater pipes and surface water gullies;

e) the positions and size of all paved areas and the total area of roofs and of the curtilage itself;

f) ground levels as may be required (reduced to Ordnance Datum — Newlyn or, where this is not possible, to an adequately defined datum) and the lowest floor level in each separate building;

g) the position, size, invert level and direction of flow of each existing sewer to which connection is to be made;

h) the position, size, bed and bank levels and direction of flow of any watercourse into which the surface water or treated effluent is to be discharged;

[14)] Available from The Building Research Station, Garston, Watford, Herts WD2 7JR.

i) the position, size, mode of construction, direction of flow, and gradient of all proposed drains, together with the invert level, cover level and a distinguishing number or letter at each proposed inspection chamber, manhole, or access point.

B.3 Detail drawings

Where appropriate, detail drawings to a scale of not less than 1 : 50 should be provided indicating clearly the construction proposed, including the shape and arrangement of the manhole channels, benchings, spacing of step irons and types of covers.

For many purposes it is useful to use a numbering or lettering symbol to identify and locate components and to describe size, depth and invert level, size and type of cover and other constructional details. Changes in wall thickness should also be shown in structural details.

Appendix C Background information on the discharge unit method for estimating drain flow rates

Each type of sanitary appliance discharges its particular flow to a drainage system at a different rate and often at a different time, and flow rates for every appliance cannot therefore be added to derive peak flow rates for design of the drainage pipework. The likelihood of coincident discharges increases with the number of appliances provided and the periods of peak use and, by applying the theory of probability, a realistic assessment of peak flow can be made such that the resulting design flow will seldom be exceeded.

Measurements of times of discharge for each type of appliance have been made and the intervals between use recorded for domestic situations and for offices and similar buildings. Using these data, it is possible to predict for any number of similar appliances the maximum number likely to discharge simultaneously.

Similarly, the rates at which appliances discharge have been measured and by multiplying the probable number of appliances discharging simultaneously by the appropriate rate of discharge, the total probable rate of discharge for a given number of like appliances can be assessed.

The effect on the pipe system of discharges from different types of appliances can be compared by considering the number of appliances required to produce the same probable rate of discharge and a system of "discharge units" has been devised to provide a measure of the peak flow. A discharge unit value is allocated to each type of appliance. The appropriate discharge units for every appliance discharging to any point of the drainage system can then be added together and this total converted to a peak flow rate by the use of a graph (see Figure 2).

For convenience, a graph has been produced as given in Figure 1 to show the number of appliances which are likely to be in simultaneous use out of a given total. The theory and design method are discussed in detail in the paper quoted in Appendix A, reference [13]. See also BS 5572.

Appendix D Compaction fraction test for suitability of bedding material

D.1 Apparatus

D.1.1 *Open-ended cylinder,* 250 mm long and 150 mm + 10 mm, — 5 mm i.d. (150 m diameter pitch fibre or PVC pipe is suitable).

D.1.2 *Metal rammer,* with striking face of 40 mm diameter and of mass 0.8 kg to 1.3 kg.

D.1.3 *Rule.*

D.2 Procedure

Obtain a representative sample more than sufficient to fill the cylinder (about 10 kg). To obtain this sample, heap about 50 kg of the proposed material on to a clean surface and divide it with a spade down the middle into two halves. Divide one of these and repeat this procedure until the required mass of sample is left. Ensure that the moisture content of the sample does not differ significantly from that of the main body of material at the time of its use in the trench.

Place the cylinder on a firm flat surface and gently pour the sample material into it, loosely and without tamping. Strike off the top surface level with the top of the cylinder and remove all surplus spilled material. Lift the cylinder up clear of its contents and place on a fresh area of flat surface. Place about one quarter of the material back in the cylinder and tamp vigorously until no further compaction can be obtained. Repeat with the second quarter, tamping as before, and so on for the third and fourth quarters, tamping the final surface as level as possible.

Measure down from the top of the cylinder to the surface of the compacted material.

NOTE This distance, in millimetres, divided by the height of the cylinder (250 mm) is referred to as the compaction fraction.

D.3 Suitability of compaction fraction for use

Suitability of the compaction fraction for use is as follows.

Compaction fraction	*Suitability for use*
0.15 or less	Material suitable.
between 0.15 and 0.3	Material suitable but requires extra care in compaction. Not suitable if the pipe is subject to waterlogged conditions after laying.
Over 0.3	Material unsuitable.

Index

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Publications referred to

BS 12, *Specification for ordinary and rapid-hardening Portland cement.*
BS 65, *Specification for vitrified clay pipes, fittings and joints.*
BS 146, *Portland-blastfurnace cement.*
BS 146-2, *Metric units.*
BS 437, *Specification for cast iron spigot and socket drain pipes and fittings.*
BS 486, *Specification for asbestos-cement pressure pipes and joints.*
BS 497, *Specification for manhole cover, road gulley gratings and frames for drainage purposes.*
BS 497-1, *Cast iron and cast steel.*
BS 534, *Specification for steel pipes and specials for water and sewage.*
BS 812, *Methods for sampling and testing of mineral aggregates, sands and fillers.*
BS 873, *Road traffic signs and internally illuminated bollards.*
BS 882, *Specification for aggregates from natural sources for concrete.*
BS 892, *Glossary of highway engineering terms.*
BS 915, *High alumina cement.*
BS 915-2, *Metric units.*
BS 1047, *Specification for air-cooled blastfurnace slag aggregate for use in construction.*
BS 1192, *Construction drawing practice.*
BS 1194, *Concrete porous pipes for under-drainage.*
BS 1196, *Clayware field drain pipes.*
BS 1198, BS 1199 and BS 1200, *Building sands from natural sources.*
BS 1247, *Manhole step irons.*
BS 1972, *Polythene pipe (Type 32) for cold water services.*
BS 1973, *Polythene pipe (Type 32) for general purposes including chemical and food industry uses.*
BS 2035, *Cast iron flanged pipes and flanged fittings.*
BS 2494, *Materials for elastomeric joint rings for pipework and pipelines.*
BS 3143, *Road danger lamps.*
BS 3284, *Polythene pipe (Type 50) for cold water services.*
BS 3506, *Unplasticized PVC pipe for industrial purposes.*
BS 3656, *Specification for asbestos-cement pipes, joints and fittings for sewerage and drainage.*
BS 3921, *Clay bricks and blocks.*
BS 4027, *Specification for sulphate-resisting Portland cement.*
BS 4118, *Glossary of sanitation terms.*
BS 4211, *Steel ladders for permanent access.*
BS 4248, *Supersulphated cement.*
BS 4346, *Joints and fittings for use with unplasticized PVC pressure pipes.*
BS 4346-1, *Injection moulded unplasticized PVC fittings for solvent welding for use with pressure pipes, including potable water supply.*
BS 4346-2, *Mechanical joints and fittings principally of unplasticized PVC.*
BS 4346-3, *Specification for solvent cement.*
BS 4360, *Specification for weldable structural steels.*
BS 4622, *Grey iron pipes and fittings.*
BS 4660, *Unplasticized PVC underground drain pipe and fittings.*
BS 4772, *Specification for ductile iron pipes and fittings.*
BS 4962, *Specification for plastics pipes for use as light sub-soil drains.*
BS 5328, *Methods for specifying concrete, including ready-mixed concrete.*
BS 5400, *Steel, concrete and composite bridges.*
BS 5400-2, *Specification for loads.*

BS 5480, *Specification for glass reinforced plastics (GRP) pipes and fittings for use for water supply or sewerage.*

BS 5480-1, *Dimensions, materials and classification.*

BS 5481, *Specification for unplasticized PVC pipe and fittings for gravity sewers.*

BS 5493, *Code of practice for protective coating of iron and steel structures against corrosion.*

BS 5572, *Code of practice for sanitary pipework (formerly CP 304).*

BS 5573, *Code of practice for safety precautions in the construction of large diameter boreholes for piling and other purposes.*

BS 5607, *Code of practice for safe use of explosives in the construction industry.*

BS 5628, *Code of practice for use of masonry.*

BS 5628-1, *Unreinforced masonry.*

BS 5628-3, *Materials and components, design and workmanship.*

BS 5911, *Precast concrete pipes and fittings for drainage and sewerage.*

BS 5911-1, *Specification for concrete cylindrical pipes, bends, junctions and manholes, unreinforced or reinforced with steel cages or hoops.*

BS 5911-2, *Specification for inspection chambers and gullies.*

BS 5911-3, *Specification for ogee jointed concrete pipes, bends and junctions, unreinforced or reinforced with steel cages or hoops.*

BS 5955, *Code of practice for plastics pipework (thermoplastics materials).*

BS 5955-6, *Installation of unplasticized PVC pipework for gravity drains and sewers.*

BS 5955-7, *Recommendations for methods of thermal fusion jointing.*

BS 6031, *Code of practice for earthworks.*

BS 6073, *Precast concrete masonry units.*

BS 6073-1, *Specification for precast concrete masonry units.*

BS 6087, *Specification for flexible joints for cast iron drainpipes and fittings (BS 437) and for cast iron soil, waste and ventilating pipes and fittings (BS 416).*

BS 6100, *Glossary of building and civil engineering terms.*

BS 6100-5.3, *Bricks and blocks.*

BS 6100-6.2, *Concrete.*

BS 6100-6.3, *Aggregates.*

BS 6209, *Specification for solvent cement for non-pressure thermoplastics pipe systems.*

BS 6297, *Code of practice for the design and installation of small sewage works and cesspools.*

BS 6367, *Code of practice for drainage of roofs and paved areas.*

BS 6437, *Specification for polyethylene pipes (type 50) in metric diameters for general purposes.*

BS 8110, *Structural use of concrete.*

CP 312, *Plastics pipework (thermoplastics materials).*

CP 2004, *Foundations.*

CP 2005, *Sewerage.*

PD 6484, *Commentary on corrosion at bimetallic contacts and its alleviation.*

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