cpsa

concrete pipeline systems association

THE COMPLETE TECHNICAL DESIGN GUIDE

Sir Joseph Bazalgette (1819 – 1891) As Chief Engineer of London's Metropolitan Board of Works his major achievement was the creation of a sewer network for central London. Completed in 1858, it extended 82 miles, required 670,000m³ of concrete and is still in use today.

'Sewerage' is the entire system of pipes, manholes, gullies and channels.

'Sewage' is the foul water effluent that flows within a sewerage system.

A 'Sewer' is the pipeline, either for foul or for surface water.

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1: SYSTEM DESIGN

1.1 PIPELINE HYDRAULIC DESIGN

1.1.1 Pipeline Design

Background

There are two main categories of drainage:

1. Surface (or Storm) water systems which generally discharge untreated into rivers or water courses. Surface water includes agricultural, roof or paved areas and highway drainage.

2. Foul water systems that feed into sewage treatment plants. Foul water can be from either domestic or industrial sources.

Up to the early 20th century, the majority of drainage systems were 'combined', that is, the foul and surface water fed into the same main sewer. More recent installations opted for separate systems. To further complicate the situation there are partially separate systems where in times of surface water flooding, provision is made for cross-linking of the two systems. Combined systems are still sometimes used, although the government is insisting that they are phased out and replaced by separate systems.

Even today, for some new installations, mis-connections between surface water and foul water systems are a problem. A clear need exists for improved training and site supervision.

Design considerations

In the design of a surface water or foul water sewer, similar criteria must be considered:-

- average and peak flows and their duration gradient
- the ranking of the sewer and its environs (whether flooding can be tolerated)
- the depth of the sewer
- any topographical or structural feature (such as a valley, building or embankment)
- surface characteristics (road, field or paved area)
- access to the sewer for maintenance (frequency, size and depth of manholes)

Surface water sewers

The volume of water can be estimated by applying one of the traditional methods such as the Lloyd-Davies or 'Rational' method which was modified by TRL and widely used in the UK for many years. More recently the Wallingford Procedure was introduced by the Hydraulics Research Station, now HR Wallingford.

This incorporates sophisticated computer programs that take into account the catchment geography, predicted rainfall intensity, return period and duration of storms, nature of the soil, percentage of impermeable area (i.e. roads, flags and roofs) and the ranking of the area. The procedure includes a simplified method that can be applied without the need to refer to the suite of computer programs.

Foul sewers

Traditionally the volume of flow (generally expressed in litres per second) has been calculated using the general rule of thumb equations of 4 x dry weather flow for a new sewer with joints inherently sound or 6 x dry weather flow in the case of a sewer where infiltration might be expected.

More recently, domestic flow according to "Sewers for Adoption" (Water UK) has been based on 4000 litres/unit dwelling/day. Foul sewage from industrial sources should be assessed taking account of the type of use of the property; this should be discussed with the local authority's planning department to ascertain projected usage and capacity.

Additional discharges arising from infiltration and misconnections to pipelines or manholes must always be considered realistically.

There has been extensive research on the comparative roughness - K_S factor - of pipes of different materials. The findings of HR Wallingford suggest that regardless of material a K_S value of 1.5mm should be used for all foul sewers and 0.6mm for surface water sewers. These recommendations have been incorporated within "Sewers for Adoption" as a robust and practical approach for hydraulic design.

Concrete pipes manufactured to BS EN 1916 and BS 5911-1 readily satisfy these requirements whether for surface water or foul sewage. For self-cleansing properties, the foul sewer must flow at a minimum of 0.75 m/sec at one third of the design flow, the main governing factors being the pipe diameter, the gradient and the volume of effluent. (The larger the pipe and the flatter the gradient, the greater amount of effluent will be required to achieve self-cleansing velocity).

If there is only a small flow, it is unwise to select too large a pipe "to allow for possible development" as this may lead to settling out of solids, long retention periods, blockages and build-up of septicity. A limited period of surcharge and backing up of a sewer is generally preferable to a consistently low velocity and its attendant problems.

Design methods

The various design methods used in the UK have been Crimp and Bruges, Manning, Hazen-Williams, Colebrook-White, Kutter, Chezy, Bazin and Darcy. In recent years the Colebook-White equation for transitional flow has been adopted by TRL as the basis for their design tables and has gradually become accepted nationally.

The general formula for flow in a circular pipe is:

$$\frac{1}{\sqrt{\lambda}} = -2\log_{10}\left(\frac{Ks}{3.71} + \frac{2.51}{Re\sqrt{\lambda}}\right)$$

Where:

λ = Darcy friction coefficient, $64/Re$

Ks = a linear measure of effective roughness (m)

Re = Reynolds number, $\dfrac{V\,D}{\aleph}$ where V = mean fluid velocity (m/s)

                                       D = hydraulic diameter of pipe (m)

                                       $\aleph$ = Kinematic viscosity ($1.31 \times 10^{-6} m^2/sec$) = μ/ρ (m/s) where

                                       μ = dynamic viscosity (Ns/m^2 or kg/ms)

                                       ρ = density of the fluid (kg/m^3)

In engineering terms, the expression for transitional pipe flow may be written:

$$V = -2\sqrt{(2gDi)}\,\log_{10}\left(\frac{Ks}{3.71} + \frac{2.51\aleph}{D\sqrt{(2gDi)}}\right)$$
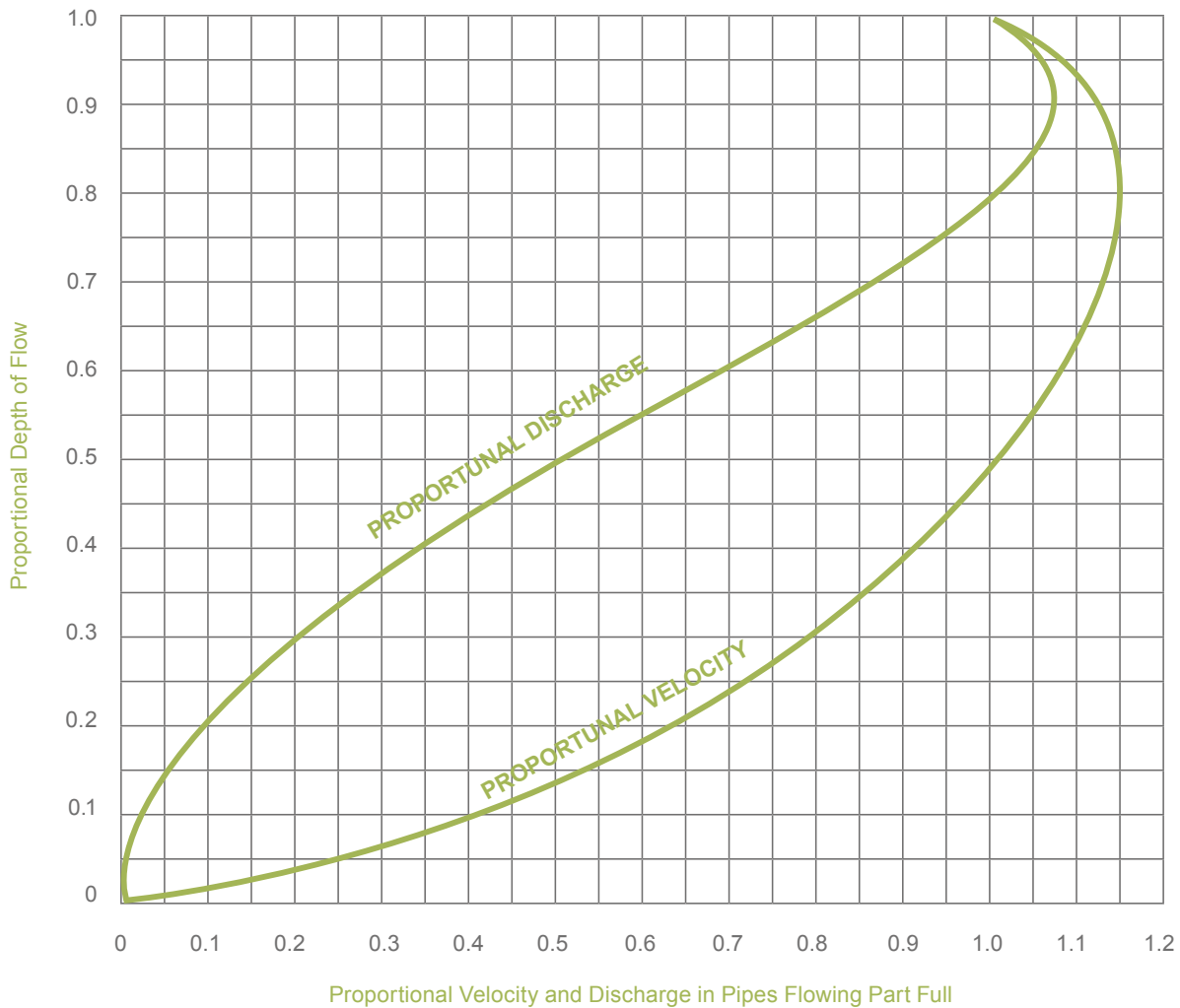
g = gravitational acceleration ($9.81\ m/sec^2$)

i = hydraulic gradient; invert and water surface slope in uniform flow in open channel.

The depth of flow in the sewer will affect the hydraulic efficiency and Chart A1 gives the proportional velocity and discharge in part-full circular sections.

For the full range of Ks values see:

- Tables for the Hydraulic Design of Pipes, Sewers and Channels (8th Edition).
  HR Wallingford, DIH Barr, 2006, Thomas Telford.

- Charts for the hydraulic design of channels and pipes. Hydraulics Research Station Sixth Edition 1990.

It should be noted that the following hydraulic design charts are for reference only to help demonstrate a basic hydraulic design process. Users should acquire the full HR Wallingford publication if they wish to carry out their own design projects. Pipe networks, with interconnecting branches, manholes and changes in pipe size, direction and gradients are far more complex design challenges and would normally require computer modelling software.

Chart A1. Relative Velocity and Discharge in a Circular Pipe for any Depth of Flow.

Proportional Depth of Flow (y-axis)

PROPORTIONAL DISCHARGE

PROPORTIONAL VELOCITY

Proportional Velocity and Discharge in Pipes Flowing Part Full

For design purposes Water UK, via 'Sewers for Adoption', recommends Ks values of 0.6mm for surface (storm) water and 1.5mm for foul sewers irrespective of pipe material. The charts (A2 and A3) relate to those values. Research has shown that whilst for mature foul sewers the Ks value may well exceed 1.5mm over short periods of their service this figure is acceptable as the build-up of slime will reach a maximum and then be reduced by normal flow patterns of the sewer.

For further detailed information on system design see also 'BS EN 752 Drain and sewer systems outside buildings' and 'Sewers for Adoption'.

Note: At the time of writing this guide, a European standard, EN 16933-2 should supersede EN 752 on aspects of hydraulic design for drains and sewer systems

1.1.2 Hydraulic Flow Charts

Chart A2

Ks = 0.6 mm (Storm water sewers)

Hydraulic Flow based on Colebrook-White Pipes flowing FULL.
Roughness Factor, Ks = 0.6 mm.
Water Temperature 15ºC

Chart A3

Ks = 1.5 mm

Ks = 1.5mm (Foul sewers)

Hydraulic Flow based on Colebrook-White Pipes flowing FULL.

Roughness Factor, Ks = 1.5mm
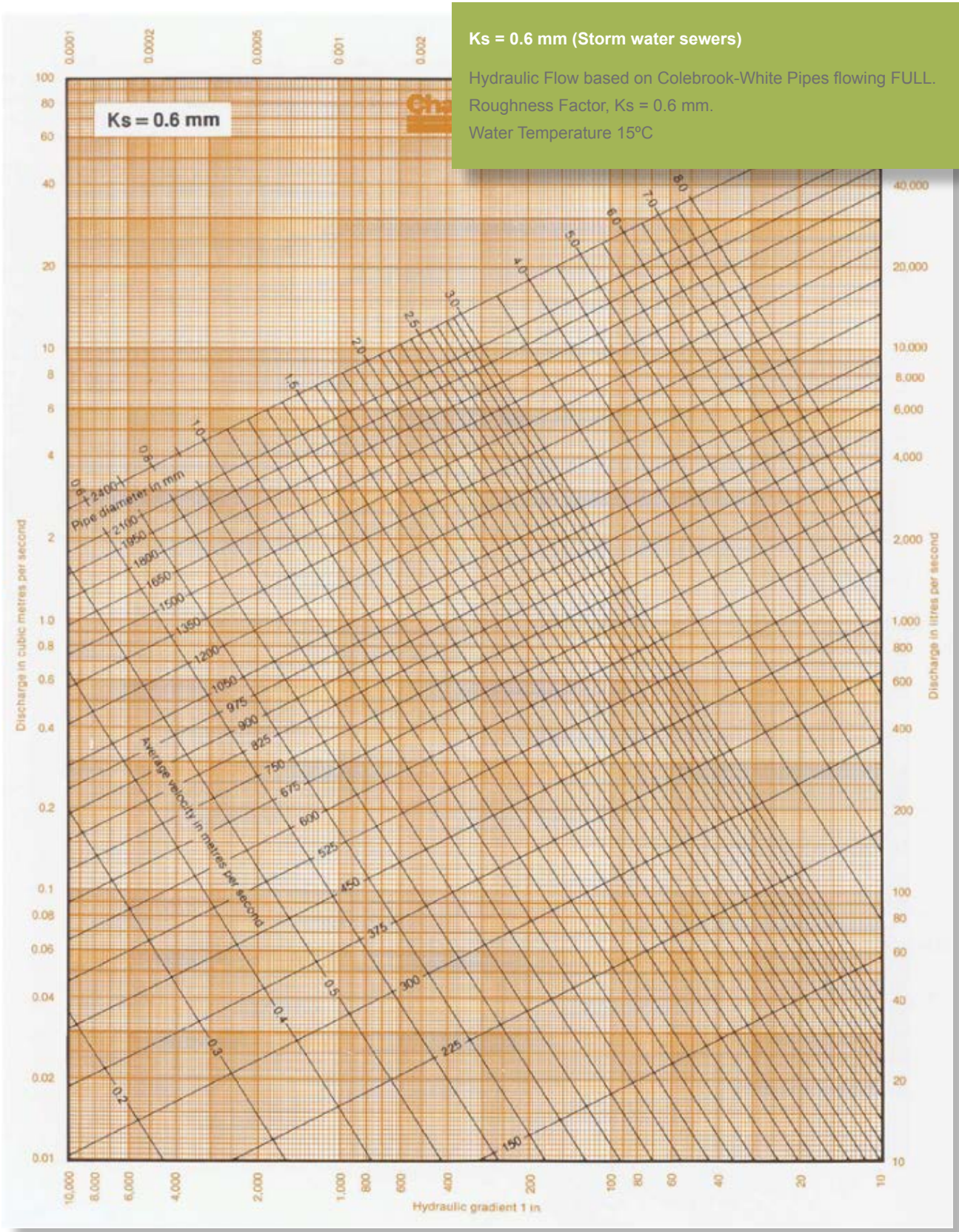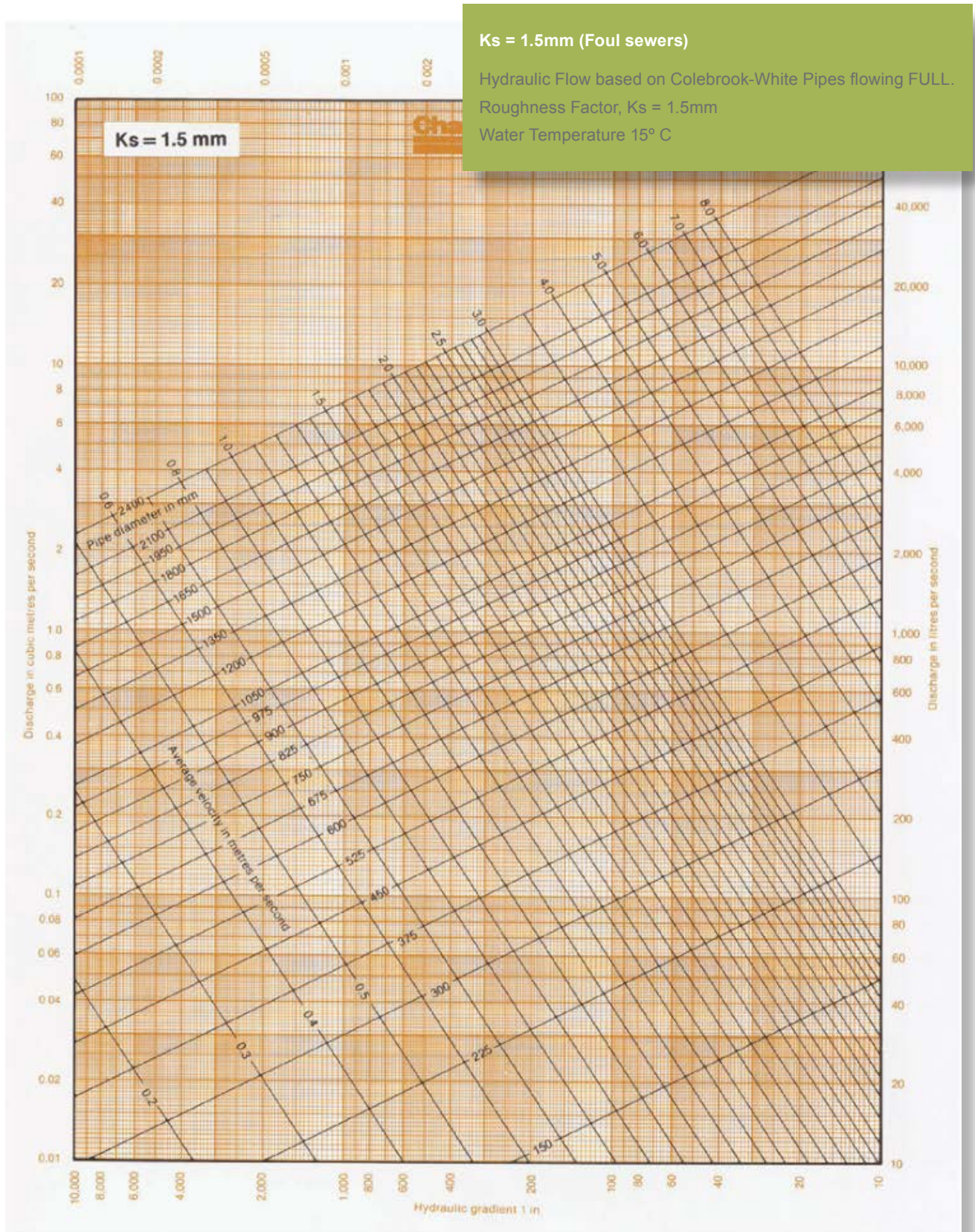
Water Temperature 15° C

1.1.3 Worked examples

1) Design of storm water sewer

Total length of pipeline = 2300m.   Total fall to outlet = 15m.   Design discharge = 0.3m³/s

Determine required pipe size for: a) Pipe flowing full   b) Pipe flowing quarter full

Ks = 0.6 mm

Example 1(b): 2.14m³/s

Example 1(a): 0.3m³/s

1:153

Ks for storm water sewer   = 0.6mm

Hydraulic gradient   = $\delta y/\delta x$

= 15m/2300m

= 0.0065

= 1:153

Example 1a) Pipe flowing full

Step 1:   read off discharge = 03.m³/sec on y-axis and project a line horizontally across the chart

Step 2:   read off hydraulic gradient = 1:153 on x-axis and project a line vertically across the chart

Step 3:   at intersection of Steps 1 and 2 project a line parallel to sloping line for pipe (internal/nominal) diameter lines.

The required pipe size is between DN450 and DN525.

DN450 is insufficient capacity so select DN525.

(a) PIPE FLOWING QUARTER FULL:
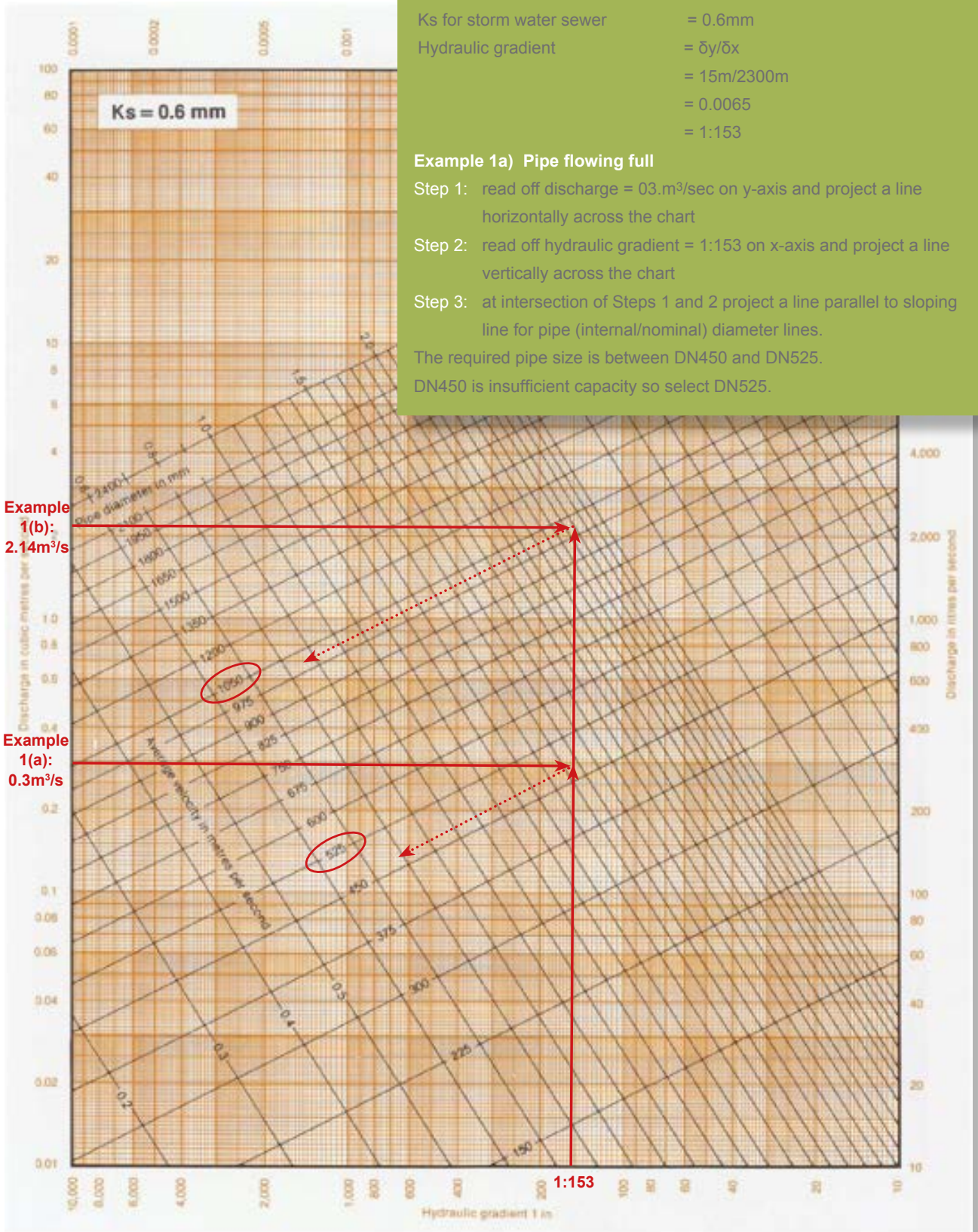
Proportional Velocity and Discharge in Pipes Flowing Part Full
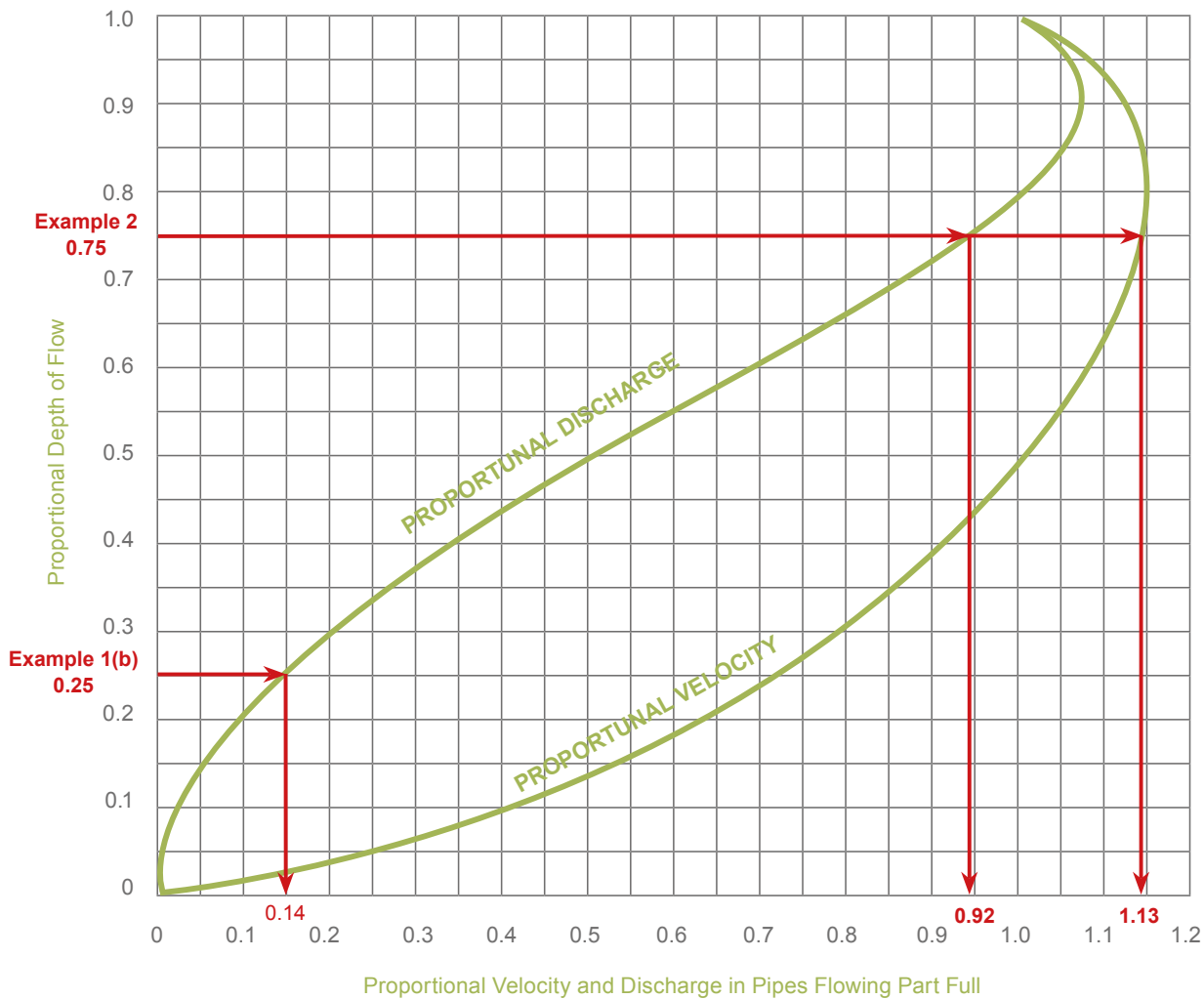
> **Example 1b) Pipe flowing quarter full**
>
> Step 1: read off 0.25 (a quarter) on the proportional depth of flow y-axis and project a line horizontally to intersect with the proportional discharge curve
>
> Step 2: at the intersection of Step 1, project a line vertically down to the x-axis
>
> Step 3: read off proportional discharge = 0.14
>
> Step 4: equivalent full pipe flow is 0.3m³/sec /0.14 = 2.14m³/sec
>
> Step 5: from the chart on page 10, project a line horizontally from discharge = 2.14m3/sec on y-axis
>
> Step 6: project a line vertically from hydraulic gradient = 1:153 to intersect with Step 5
>
> Step 7: project line parallel to sloping line for pipe (internal/nominal) diameter lines.
>
> The required pipe size is between DN975 and DN1050. DN975 is insufficient capacity so select DN1050

2) Design of foul sewer

Housing Scheme =180 houses. Total length of pipeline =1650 m. Total fall = 3.6m

Sewers for Adoption - 4 m³/ dwelling / day. Assume half flow over 6 hours and 6 x average flow as design maximum.

$$= \frac{1}{2} \left(\frac{4(m^3 / \text{dwelling/day}) \times 180 \text{ dwellings}}{6 \text{ (hours)} \times 60 \times 60} \right) \times 6 \text{ (av.Flow)} = 0.1 m^3 /\text{sec}$$

Ks for foul sewer = 1.5mm

Assume pipeline runs ¾ full and self-cleansing velocity = 0.75m/sec

From Proportional Flow Chart on page 11

Step 1: proportional discharge = 0.75 (3/4 full)

Step 2: discharge factor = 0.92

Step 3: equivalent full pipe flow is 0.1m3/sec / 0.92 = 0.11m3/sec

Step 4: pipe flowing full velocity = 0.75/1.13 = 0.66m/sec

On this chart

Step 5: project horizontal line from y-axis at discharge = 0.11m3/sec

Step 6: project parallel sloping line at velocity = 0.66m/sec

Step 7: Intersection of Step 5 and 6 is between DN450 and DN525. DN450 is insufficient capacity so select DN525

1.1.4 Sustainable Drainage Systems (SuDS)

CPSA Proprietary Sustainable Drainage Systems and Components

The use of sustainable drainage systems, known as **SuDS**, and best management practices should be an integral part of any development's surface water management strategy. This should provide a basis for replicating the response of a catchment and its surfaces by mimicking, to some extent, the behaviour of surface water on the developed site as if it had remained undeveloped. Modern sustainable drainage systems should aim to offer improvements to existing surface water runoff, negating any increased risk of flooding by using methods for managing surface water by focusing on three key elements:

- Controlling surface water quantity (reducing off-site low rates)
- Improving surface water quality
- Providing added amenity value to the development

The successful implementation of a sustainable drainage scheme should consider a combination of natural and proprietary techniques, complemented by traditional drainage methods, where appropriate.

It is essential that planners, designers, installers and operators of SuDS systems take into account the importance of whole life maintenance and the use of suitable components that deliver authentic sustainable drainage performance and longevity.

Management Train

The SuDS philosophy is underpinned by the water "Management Train".
The Management Train applies SuDS techniques in series and is based on:

- Prevention; good housekeeping measures within the development

- Source control; runoff managed as close as possible to where it originates as rain

- Sub-catchments; division into small areas with different drainage characteristics and land use

  - Site Control; dealing with runoff within or local to the development

  - Regional Control; e.g. SuDS features within amenity space before final outfall

The Management Train can be divided into the following processes:

• Collection	• Treatment	• Re-use
• Infiltration	• Attenuation	• Conveyance

CPSA Sustainable Drainage Solutions

CPSA members offer a wide variety of proprietary SuDS components and systems suitable for use within a sustainable drainage system.

These are listed in the following table indicating their functions within the Management Train. For specific product information, please consult our members.

SuDS Component		Collect	Treat	Re-Use	Infiltrate	Attenuatte	Convey	
	Circular pipe				●	●	●	Rigid pipeline system with flexible joints for conveyance of stormwater and storage / attenuation, available with optional dry weather flow channel and side entry manhole access. Perforated version enables stormwater to percolate into the ground.
	Elliptical pipe					●	●	Elliptical pipeline system for conveyance of stormwater and storage/attenuation with minimal cover requirement, available with dry weather flow channel and side or top entry manholes.
	Ovoid pipe					●	●	"Egg-shaped" pipeline system with integral dry flow channel. Higher velocity at low flow depths compared to circular pipe providing reduced risk of siltation.
	Flat Pack Tank					●		Modular attenuation tank system using precast panels.
	Manhole					●	●	Off-site, watertight solution pre-benched and configured to required inlet/outlet orientation.
	Soakaway		●		●	●		Perforated chamber which may be open void (providing storage) or contain filter medium (providing treatment) to facilitate percolation of stormwater into the ground.
	Flow Control Chamber					●	●	Off-site solution with pre-installed flow control device such as penstock, non-return valve, weir wall, orifice plate, vortex flow regulator.
	Road Gully	●	●					Designed to receive storm water runoff from paved surfaces and first-line gravity separation of silt.
	Filter Gully	●	●					Gully pre-fitted with filter for removal of oils and silt.

SuDS Component		Collect	Treat	Re-Use	Infiltrate	Attenuate	Convey	
Hydro-dynamic Vortex Separator			•					Chamber for silt capture, litter and some oils.
Treatment Chamber			•					A variety of pre-configured chambers for removal of foreign objects and pollutants such as litter, oil, grease, silt & heavy metals.
Catch Pit			•					For the gravity separation of debris and silt to prevent it passing downstream.
Filter catch Pit			•					Catch pit pre-fitted with filter for removal of oils and silt
Headwall							•	Inlets and outlets, available with flap valves and grills, connecting swales, ponds, detention basins, etc. to underground pipes.
Cascade Unit							•	To protect embankments from erosion.
High Capacity Slot Drain		•					•	Integrated gasket joint and excellent flow characteristics for surface runoff and below ground applications.
Perforated Drainage Trough						•	•	For shallow and deep channel applications.
Box Culvert						•	•	Range of sizes. Available with optional dry weather flow channel.

SuDS Component		Collect	Treat	Re-Use	Infiltrate	Attenuate	Convey	
	Rainwater Harvesting Tank	●		●				Domestic and commercial rainwater harvesting systems
	Rainwater Filter Chamber		●					Rainwater harvesting pre-tank for leaf and grit removal.
	Grey Water Recycling Tank	●	●	●				Domestic and commercial grey water recycling systems

SuDS References

Information sources to help plan, design and implement sustainable drainage:

1. The community for sustainable drainage. www.susdrain.org

2. CIRIA. The SuDS Manual C753. www.ciria.org

3. Local Authority SuDS Officers Organisation (LASOO). How-to guidance on SuDS standards. www.lasoo.org.uk/non-statutory-technical-standards-for-sustainable-drainage

4. CIRIA. Site Handbook for the Construction of SuDS C698. www.ciria.org

5. BS 8582:2013 Code of practice for surface water management for development sites.

6. CIRIA. Designing for Exceedance in Urban Drainage Good Practice C635. www.ciria.org

7. CIRIA. Sustainable Drainage Systems. Hydraulic, Structural and Water Quality Advice C609. www.ciria.org

8. CIRIA. Infiltration Drainage – Manual of Good Practice R156. www.ciria.org

9. CIRIA. Control of Pollution from Highway Drainage Discharge R142. www.ciria.org

10. British Hydrological Society. Sources of Hydrological Data. http://www.hydrology.org.uk/Data_sources.php

11. WRc. Sewers for Adoption (7th Edition). www.wrcplc.co.uk

12. Local Government Association. Flownet Knowledge Hub. A group for all those interested or involved in flood risk and water management. https://knowledgehub.local.gov.uk/group/flownet

13. National Standards for sustainable drainage systems. Designing, constructing, operating and maintaining drainage for surface runoff. www.defra.gov.uk

14. For information on SuDS legislation, questions on government policy and to register to receive updates. email suds@defra.gsi.gov.uk

1.2 PIPELINE STRUCTURAL DESIGN

1.2.1 Design Principles

The forces acting on a cross section of pipeline arise from three main sources:

A) Weight of overlying fill, including any local surcharge.

B) Soil pressures transmitted to the pipe from surface loads, i.e. traffic and other transient loads.

C) Supporting reaction below the pipe.

The weight of water within the pipe is only significant for larger diameter pipes.

A: Weight of overlying fill

There are four main conditions in which pipes are installed:

a) "Narrow" trench.

b) "Wide" trench, or on the surface of ground over which an embankment is then built (positive projection condition).

c) Narrow trench over which an embankment is then built (negative projection condition).

d) Tunnel, heading or by jacking.

The load Wc imposed by the backfill on a pipe in a "narrow" trench can be found from Marston's formula from which the Tables have been compiled in Section 1.2.5.

These Tables are only applicable to rigid pipes laid in "Narrow" trench conditions.

B: Traffic and other transient loads

Measurements have shown that on large civil engineering works pipes may well be subjected to their highest loads during construction. Here, three categories of traffic loading are considered and rigid pipes should normally be designed to withstand the most onerous likely to occur.

If during construction it is clear that excessive site traffic loading will occur, the design should be checked accordingly or special crossing places must be designated.

> **a) Main road loading** is intended to apply to all main traffic routes and to roads liable to be used for the temporary diversion of heavy traffic.
>
> As a guide it may be assumed that such roads carry at least 200 commercial vehicles per day in each direction. HA and HB loading are assumed to use such roads
>
> **b) Light road loading** applies to all other roads where heavy traffic is unlikely to pass.
>
> **c) Field loading** applies to fields, gardens and lightly trafficked access tracks. This loading is also considered to be adequate to cater for occasional heaps or stacks of materials on the ground surface. Massive heaps or stacks likely to produce a more severe loading should be treated as a special design.

In assessing the loading category, regard should be paid to the possible future upgrading of a road. Pipes under verges should normally be treated as though under the road, with the possible exception of motorways and trunk roads and should take account of any planned road improvement. For non-public roads such as industrial estate roads or roads within works, an assessment should be made of the heaviest vehicle likely to use the road, and one of the above three loading conditions selected as appropriate.

C: Supporting reaction below the pipe

British Standards for concrete pipes give maximum crushing loads for each diameter and strength class of pipe. Loads are applied in a 3 edged loading test described in BS EN 1916 and BS 5911-1. The pipe must not collapse under the maximum load specified.

Proof test loads are also specified. Reinforced pipes must not crack by more than a specified amount under the proof load. The only proof load test for unreinforced pipes is the maximum load.

Pipes of a small diameter (up to DN 300) may fail as a beam. BS EN 1916 and BS 5911-1 include suitable values of bending moment resistance.

Pipe bedding

This term is used to describe the complete arc of material within the trench, or in the case of Class "C" or Class "D" beddings, a special preparation of the trench bottom. For further information, see Section 1.2.4 "Pipe Bedding".

Bedding factor

In the standard test on pipes the vertical loading and supporting reactions are line loads and any trench situation in the field is unlikely to produce such an onerous loading condition. The strength of the pipe determined in the crushing test can therefore be multiplied by a bedding factor which represents the amount by which the stresses in the pipe are reduced because of the spreading properties of the bedding for load and reaction.

The value of a bedding factor for a particular method of construction is not a precise figure but is affected by the quality of workmanship. The values given whilst being conservative assume a reasonable standard of workmanship and supervision. If the designer needs a somewhat higher bedding factor than stated a high standard of workmanship and supervision must be specified and guaranteed; alternatively a higher strength pipe may be considered where available. If a higher strength pipe is available adequate time must be allowed for the manufacturer to supply.

Factor of safety

For structural design to BS EN 1295 unreinforced pipes should be designed with a factor of safety (Fse) of 1.25 (generally DN225–DN600 units are unreinforced but some manufacturers may have a different range of such pipes). The factor of safety increases to 1.5 for reinforced pipes. Confirmation should be obtained from the manufacturer or a conservative approach would be to use a 1.5 factor of safety.

1.2.2 Design Assumptions

Surface Conditions

The Tables in Section 1.2.7 are applicable only to a single pipeline laid in its own trench, and have been set out to give the loads on pipes under three surface conditions, Main Roads, Light Roads and Fields.

Alternatively, refer to http://www.concretepipes.co.uk/calculators/structural-design, where specific designs can be entered (note: for single pipe trench conditions only).

Backfill loads

The Tables are calculated using an equivalent soil density of 19.6 kN/m^3 (approximately 2.0 tonnes/m^3).

Traffic loads

The loads referred to in the design principles have values as follows:-

a) Main roads

Static wheel load of 86.5kN and an impact factor of 1.3, giving a Total Static wheel load of 112.5kN; contact pressure 1100kN/m^2.

a) Light roads

Static wheel load of 70kN and an impact factor of 1.5, giving a Total Static wheel load of 105kN; contact pressure 700 kN/m^2.

b) Fields

Static wheel load of 30kN and an impact factor of 2.0, giving a Total Static wheel load of 60 kN; contact pressure 400kN/m^2.

Superimposed loads

These are not included in the Tables. If however such loads are encountered and are of sufficient magnitude, an allowance should be made.

Water Loads

These are included in the Tables. If the pipe is laid below the ground water table, an allowance for this load is not needed. However, as these loads are small by comparison with other loads on the pipe, it has been considered appropriate to include them only for pipes of DN 600 and over.

Frictional factor K

A value of 0.13 has been used for narrow trench conditions.

Recommended minimum cover over pipe

a) It is advisable that pipes laid under roads should have cover over the pipe of not less than 1.2m. This cover should be maintained for main roads, light roads (which may on occasion carry main road traffic) and for pipes laid under grass verges adjacent to a road (Tables A3 and A4). Where pipes have to be laid with less than 1.2m cover special consideration is needed to reduce the risk of damage. Loads in columns headed 0.9 and 1.0 in Tables A3 and A4 should be used only as a guide.

b) For pipes laid in fields a minimum cover of 0.6m should be provided. At shallower depths there is a risk of damage from agricultural operations.

Protection to shallow pipelines

Where pipes are required to be laid at cover depths less than 0.6m, the pipes should be protected as per the recommendations of BS 9295 Annex A, A16.

The preferred method of protection is the use of a reinforced concrete slab being installed over the pipeline (see typical detail right).

Key

1 Backfill
2 Concrete slab
3 Reinforcement
4 Minimum 300 mm
  bearing on original ground
5 Compressible material
6 Pipe
7 Granular surround

Protection to shallow pipeline with slab
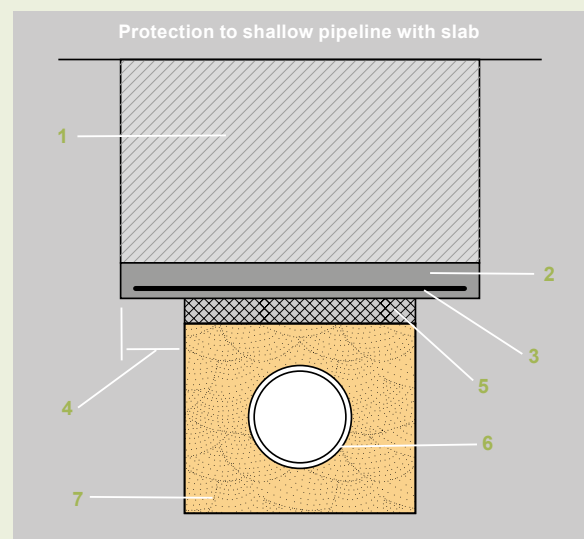
It is important that the slab extends sufficient distance beyond the trench and would depend on soil conditions (minimum bearing of 300mm each side advised). A layer of compressible material directly over the pipeline aids in the prevention of the slab loading directly onto the pipeline should settlement occur.

Another method of protection at shallow cover depth is via the use of a concrete surround. It is important in such installations to install compressible material at least every other pipe joint to ensure that the pipeline retains its flexibility.

Special consideration should be given where construction plant has to cross pipelines with shallow cover depth. Where possible, traffic should be routed over dedicated crossing points. Crossing points may consist of heavy steel plates to transfer vehicle loads or temporary additional cover emplaced over the pipeline.

Pipelines under embankments or laid in deep trenches

Where a pipeline is laid under an embankment, or where the pipeline is installed in a deep trench, it can be critical for the trench width to be kept minimal for a distance above the crown of the pipe. Any slight increase over the designed trench width can greatly increase the pipeline's loading.

Multiple pipes in trench

For convenience, two or more pipelines may be installed in the same trench and at different levels.

Trenches can be excavated to the maximum depth to accept all pipelines, or they may be stepped in construction where levels of the pipelines are different.

Careful consideration should be undertaken to assess the loading and possible implications of installing multiple pipelines in the same trench.

The horizontal distance between adjacent pipelines will largely be dependent on the type of bedding/backfill material used to surround the pipelines. With rounded gravels it's possible to achieve minimal spacing between the pipelines (just room to provide access for the gravel to be working in and around the pipes), whereas an angular/cohesive material may require upwards of 400mm or greater (depending on pipe sizes) to enable suitable access for placement and compaction of the materials.

More advice can be found at BS 9295, A.11.

1.2.3 Design Method

The established method for calculation of loads on buried rigid pipes is summarised in BS EN 1295 National Annex A, the principles of which are explained below. For further information, BS9295 has been published as a guide and background to BS EN 1295.

In general pipelines are laid in trenches and the pipes used are designed to carry the backfill, traffic loads and, when the diameter is 600mm or more, some part of the water load under working conditions.

In order to improve the load carrying capacity of the pipe it is laid on one of several classes of bedding (see Table A2). Each type of bedding is allocated a "bedding factor" (Fm) which may be regarded as a multiplier applied to the test load of the pipe.

The trench is excavated in the natural soil, the pipe is laid on the selected bedding and the trench backfilled. Load on the pipe due to the backfill develops as the fill material settles. The load on the pipe due to the backfill is therefore the weight of the backfill taken over the full trench width but reduced by the shear force from the trench walls acting upwards (see Fig.A1).

This state is called the **narrow trench condition.** The backfill load is calculated by using the Marston formula:

$W_c = C_d\ w\ B_d^2$

Where:

W_c = Backfill load (kN/m)

C_d = Load coefficient, dependent on soil type and ratio of cover depth to trench width

w = Soil density (kN/m^3)

B_d = Width of trench (m)

Provided that the trench width does not exceed the values given in the tables, the loads given are conservative and may be used with confidence.

The trench widths given will provide adequate working space around the pipe for laying and jointing and also sufficient room to place and consolidate the bedding specified.

As indicated, the friction acting against the backfill is provided by the trench walls and is roughly constant at a particular depth. If however the trench width is increased radically, B_d^2 in the Marston formula is also increased and a reappraisal of the load on the pipe must be considered.

Fig A1. Narrow Trench

Fig A2. Wide Trench
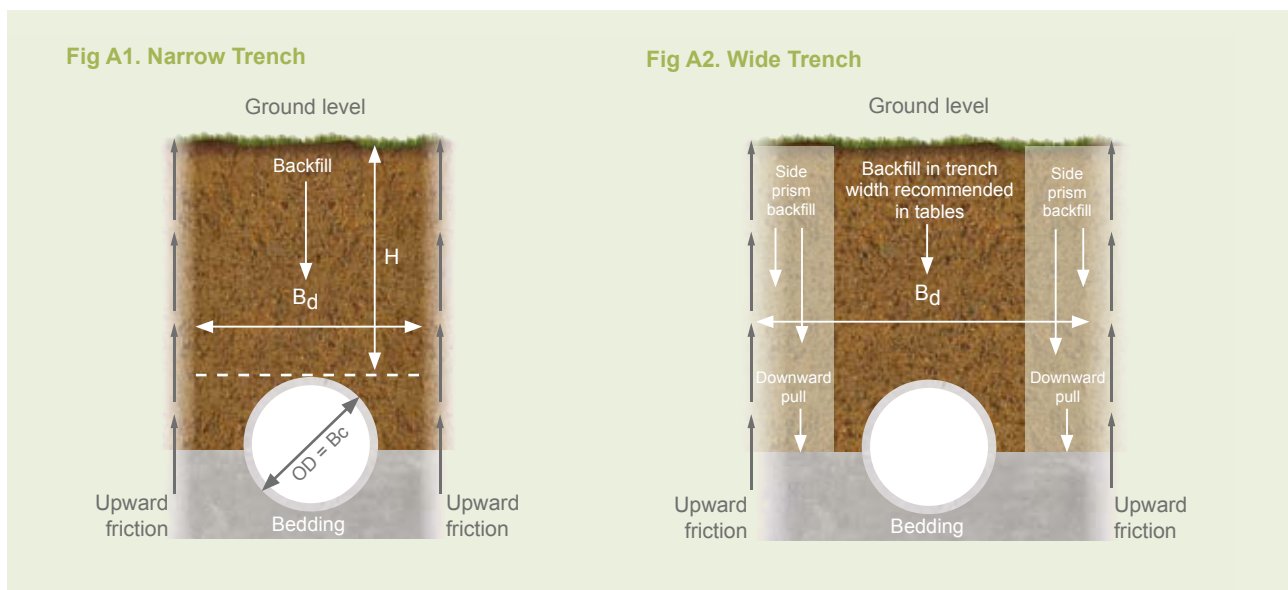
For any depth there is a trench width where friction planes from the trench walls become remote from the pipe and no longer contribute to the reduction of the fill load. In fact the settlement of the side prisms of backfill tend to increase the load (see Fig.A2). This state is called the **wide trench condition.** It is a positive projection condition. The backfill loading on the pipe does not take any relief from undisturbed ground.

In preparing the tables, due consideration has been given as to whether at any trench width and depth, the narrow or wide trench condition and load is applicable, and the standard practice of using the lesser of these values has been adopted. The tables give the total loads for pipes of all diameters specified in BS 5911-1. This load includes loading from backfill and traffic for depths of cover over the top of the pipe as follows:

Main Roads and Light Roads   - 1.2m to 8.0m

Fields   - 0.6m to 8.0m

For DN 600 and above the water load shown is also included.

Table A1. Minimum crushing loads (F_n) for strength class 120 units with a circular bore for use in a trench – BS 5911-1:2002+A2:2010.

Nominal Size DN	Minimum crushing size, F_n kN/m
225	27
300	36
375	45
400*	48
450	54
500*	60
525	63
600	72
675	81
700*	84
750	90
800	96
825	99
900	108
1000*	120
1050	126
1200	144
1350	162
1400	168
1500	180
1600	192
1800	216
2000	240
2100	252
2200*	264
2400*	288

NOTE 1 Classic sizes, denoted by an asterisk, will be phased out if called for by further European harmonisation.
NOTE 2 Sizes DN 225 to DN 600 inclusive are normally only manufactured unreinforced in the United Kingdom.
NOTE 3 Sizes DN 1000 and above are normally only manufactured reinforced in the United Kingdom.
NOTE 4 Table NA.5 of BS EN 1295-1: recommends that the minimum value of safety factor for the structural design of reinforced pipelines should be increased from the normal 1.25 to 1.5 if, as is the case of BS EN 1916: 2002, the proof load is 67% of the minimum crushing load.
* Sizes marked with asterisk are not readily available in the UK

1.2.4 Pipe Bedding

The load bearing capacity of an installed pipeline relates directly to the construction of the bedding which is intended to level out any irregularities in the formation, and provide uniform support around and along the length of the pipe barrel.

Pipe settlement will be kept to a minimum by the proper selection and compaction of the bedding material. The bedding should be compacted to a density not less than that of the natural soil in the sides and bottom of the trench. The bedding directly beneath or above the pipeline must not be over compacted otherwise line loading of the pipes will result.

On steep gradients, or where dewatering has taken place, it is important to restrict ground water movement within the completed trench. Selection of bedding or clay dams across the full width of the trench will assist in this.

Under no circumstances should blocks or bricks be placed beneath pipes. Any pegs used for setting out or levelling must be removed.

Bedding materials

Any stable soil will act adequately as a bedding material provided that it is placed and compacted around the pipeline. From a practical point of view granular material is compacted more readily and has become widely accepted.

The bedding material should be of similar particle size to that in the trench sides. Where the ground is clay or silt, bedding material must consist of all-in gravels to prevent the trench from becoming a drainage channel and carrying away fines from the trench walls and bedding and causing settlement of the pipes.

Granular bedding material

The ideal is crushed rock or gravel but similar locally available material having an angular or an irregular shape may be used. Rounded single sized material is not recommended as it may not provide a stable bed especially for heavy larger diameter pipes.

Water Research Centre (WRc) Information and Guidance Note (IGN) 4-08-01 provides guidance on the particle size of material relating to pipe diameter.

Sands containing an excess of fine particles are more difficult to place and compact and will require a greater degree of supervision on site to achieve a stable embedment for the pipeline.

Selected bedding and fill material

This should consist of uniform readily compactable material, free from tree roots, vegetable matter, building rubbish and frozen soil. When used as fill, the material should not contain large clay lumps or cobbles. When used as bedding, all clay lumps should be excluded.

"As dug" material may be used provided that it is readily compatible and provides stable embedment.

Classes of bedding and bedding factors

The strength of an installed pipeline depends on a combination of the strength of the pipe and the class of bedding.

The selection of the bedding class is influenced by many factors, which include the nature of the ground, the loads acting on the pipeline in the trench, strength class of pipe, and the local cost and availability of the bedding material.

Taking into account the cost of labour, it is generally more economical to lay the pipes on a bedding of non-cohesive materials, or alternatively scarify the trench bottom rather than hand trim the formation.

Normally loading calculations are made considering the pipeline in complete lengths, between manholes. The calculated installation condition to satisfy the most severe loading condition between each pair of manholes is then used throughout the length.

The normally accepted classes of pipe bedding are shown in Table A2 and in Fig A3.

Table A2. Types of Bedding

Bedding Class	Bedding factor	Description	Suitability
Class D	1.1	Hand trimmed flat bottom/ formation	Fine grained soils, relatively dry conditions
Class N	1.1	Flat bed of granular all- in or selected material	Rock, mixed soils
Class C	1.5	Shaped formation (or scarify)	Uniform soils relatively dry General
Class F	1.5	Shaped bedding of granular material	General
Class B	1.9	180° granular bedding material	General
Class S	2.2	Complete surround of non-cohesive granular bedding material	General
Class A Plain	2.6	Plain concrete cradle	Seldom necessary Higher strength pipe with granular bedding is more practicable and economic option
Class A reinforced	3.4	Reinforced concrete cradle	

Geotextiles
Where appropriate, geotextiles may be used to contain bedding materials e.g. in running sand.

Fig. A3. Types of bedding

Class D

Hand trimmed flat bottom. Bedding factor = 1.1
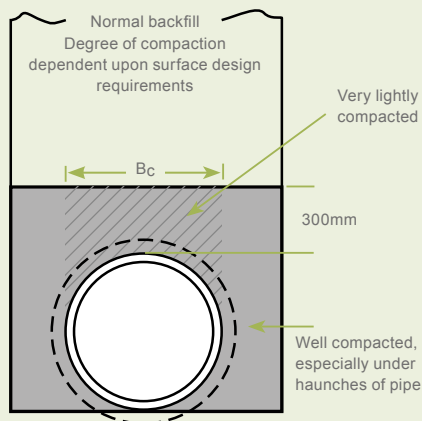
Suitable in fine grained soils and relatively dry conditions. Hand trim formation filling in any hollows. From socket holes as appropriate with 50mm minimum clearance of sufficient length to permit jointing. Pipes are laid directly on the formation.

Class N

Flat granular layer. Bedding factor = 1.1
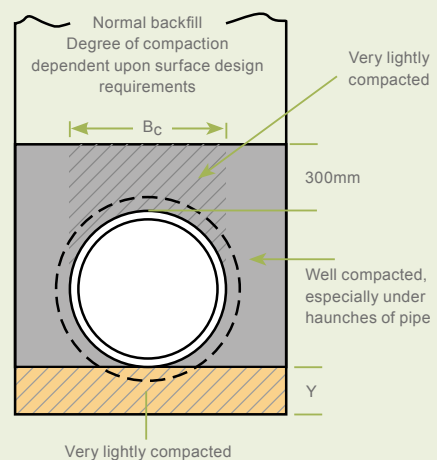
Lay pipes on a flat layer of all-in or selected material (see Note1)

Class C

Hand shaped bottom. Bedding factor = 1.5

Normal backfill
Degree of compaction
dependent upon surface design
requirements

Very lightly
compacted

B_C

300mm

Well compacted,
especially under
haunches of pipe
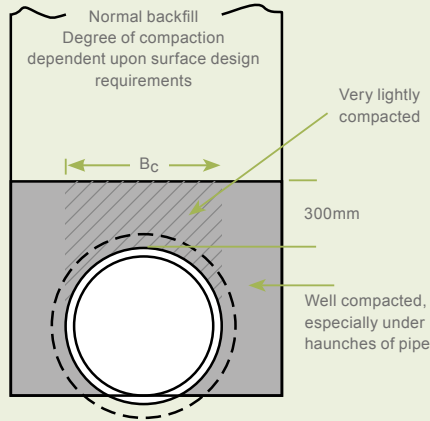
Suitable in uniform soils and relatively dry conditions.
Bottom of the trench, or formation, profiled to fit barrels
over a width of not more than 1/2 B_C with socket holes
to give at least 50mm clearance under the sockets of
sufficient length to permit jointing*
* Scarifying formation is generally adequate in practice

Class F

Granular bedding. Bedding factor = 1.5

Normal backfill
Degree of compaction
dependent upon surface design
requirements

Very lightly
compacted

B_C

300mm

Well compacted,
especially under
haunches of pipe

Y

Very lightly compacted
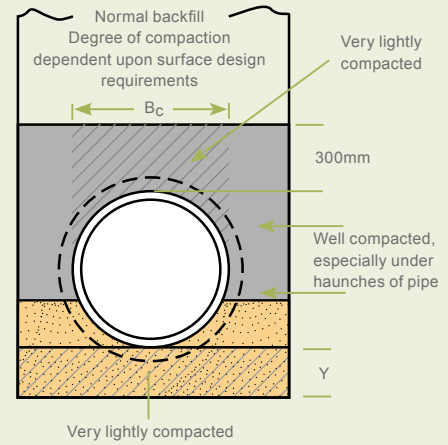
Lay pipes on a flat layer of granular bedding material on the
formation, (see Note1). Scoop out socket holes with 50mm
minimum clearance; lay joint pipes which will settle slightly in
to the bedding. Sidefill, placed and well compacted in layers.

Class B

180º Granular bedding. Bedding factor = 1.9

Normal backfill
Degree of compaction
dependent upon surface design
requirements

Very lightly
compacted

B_C

300mm

Well compacted,
especially under
haunches of pipe

Y

Very lightly compacted
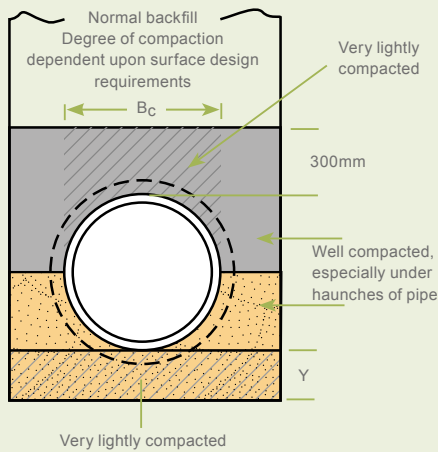
Lay pipes on a layer of granular bedding material on the
formation, (see Note1). Scoop out socket holes, lay and
joint pipes, place and well compact layers in the same
bedding material at each side of pipes, up to springing
level, taking care not to displace them.

Class S

360º Granular bedding & surround. Bedding factor = 2.2

Normal backfill
Degree of compaction
dependent upon surface design
requirements

Very lightly
compacted

B_C

300mm

Well compacted,
especially under
haunches of pipe

Y

Very lightly compacted
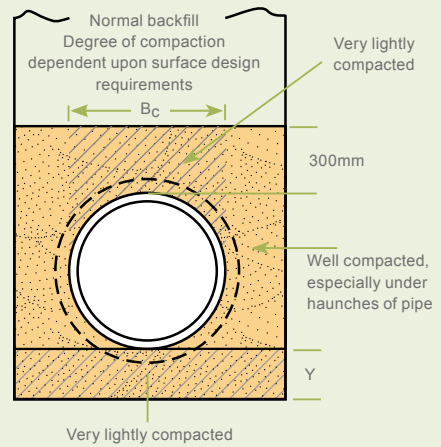
Lay, joint and bed pipes as for Class B then place and
well compact layers of the same bedding material at each
side, up to crown level, taking care not to displace the
pipes. This is followed by 300mm of granular bedding
material but lightly compacted directly over the pipe, after
which ordinary backfilling is commenced.

Normal
backfill

Granular
material

Selected
backfill
material

Grade
C20
concrete

Class A

Plain concrete cradle. Bedding factor = 2.6

Reinforced concrete cradle. Bedding factor = 3.4
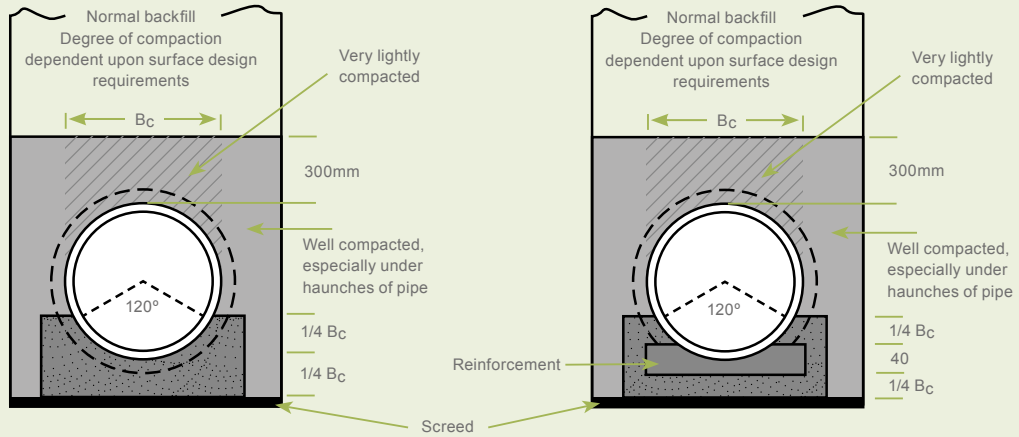
Class A concrete bedding, either plain or reinforced each 120° cradle. Screed the formation, place blocks on the screed to support pipes behind each socket. Lay pipes, using packers on blocks to achieve correct line and level. At pipe joints, form construction joints through concrete bed ensure flexibility of pipeline. Minimum width of cradle $1^{1}/_{4}$ B_C or B_C plus 200mm. Minimum thickness $1/_{4}$ B_C. Pour concrete carefully from one side to prevent voids. Backfill when concrete has attained required strength.

NOTES:
1. Generally thickness of bedding (Y), minimum of 100mm under barrels and 50mm under sockets. In rock 200mm under barrels and 150mm under sockets subject to maximum of 400mm. Minimal compaction directly beneath pipe.
2. Sidefills, whether of bedding material or of selected material, must be well compacted.
3. Backfill or bedding material to be highly compacted above sidefills to 300mm above the crown but lightly compacted directly over the pipe.
4. Normal backfill to be compacted as appropriate.
5. With reasonable workmanship and supervision these bedding factors are conservative.

1.2.5 Design Calculations

The calculated load "W_e", which is the total load a concrete pipe in a trench is required to sustain, is used in the design formula as follows:

$$F_n = \frac{W_e \times F_{se}}{F_m}$$

where
- F_n = required BS 5911-1 test strength (kN/m)
- W_e = load from Tables A3 or A4 (kN)
- F_{se} = factor of safety
- F_m = bedding factor chosen

Test strength of pipe (F_n)

The test strength of a concrete pipe may be referred to as F_c or F_n

In the UK, standard circular pipes to BS EN 1916 and BS 5911-1 are usually to Class 120. To calculate the test strength apply 120 x pipe nominal diameter in metres e.g. for DN450 pipe, Fn=120 x 0.45=54kN/m (see Table A1).

For a reinforced concrete pipe Fc is the load which the pipe will sustain without developing a crack exceeding 0.30mm in width over a length of 300mm and W_t is the load which the pipe will sustain without collapse, irrespective of crack width. However, to further simplify the procedure it is more straightforward to use the maximum test load F_n and applying the factor of safety of F_{se}.

Table A3. Total Design Loads - Main Roads. "H" = 0.9 metres to 8.0 metres

Total design load "W_e" in kN/m for cover depths "H" in metres

Nominal Diameter in mm	Outside Diameter in mm	Recommended Trench width in m	Waterload Included in kN/m	0.9	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.8	5.0	5.2	5.4	5.6	5.8	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.6	7.8	8.0
225	280	0.70		31.9	31.4	28.5	28.3	27.7	27.9	28.5	28.6	29.9	30.7	31.4	32.0	32.4	32.2	32.6	32.9	33.2	33.2	33.3	33.5	33.7	33.9	34.1	34.2	34.3	34.5	34.7	34.9	35.0	35.0	35.1	35.1	35.2	35.2	35.3	35.3	35.4
300	380	0.75		43.4	38.9	37.8	38.3	37.9	38.0	38.1	38.2	38.5	38.7	38.8	39.0	39.2	39.5	39.8	39.9	40.0	40.1	40.4	40.6	40.8	41.1	41.3	41.5	41.7	41.9	42.1	42.3	42.4	42.5	42.7	42.8	42.9	43.0	43.2	43.2	43.3
375	500	1.06		55.7	53.9	50.1	49.1	48.1	49.4	50.5	51.6	52.6	54.3	56.1	57.8	58.8	59.9	60.9	61.9	62.9	63.7	64.3	65.4	66.3	67.0	67.9	68.7	69.4	70.2	70.9	71.5	72.2	72.8	73.5	74.0	74.6	75.1	75.7	76.3	76.9
450	560	1.15		64.3	62.8	55.7	58.4	57.3	58.0	59.3	60.7	62.1	63.2	64.6	65.4	66.1	66.8	67.8	68.8	69.7	70.8	71.9	73.0	74.0	74.8	75.7	76.7	77.5	78.4	79.2	80.0	80.9	81.7	82.5	83.2	83.9	84.4	85.0	85.6	86.2
525	670	1.20		73.2	71.6	66.7	65.7	66.2	66.8	67.6	68.4	69.0	70.0	71.0	72.0	72.8	73.7	74.7	75.6	76.9	78.0	79.1	80.3	81.4	82.5	83.7	84.5	85.3	86.2	87.3	88.4	89.4	90.4	91.3	92.3	93.0	93.7	94.5	95.2	95.8
600	790	1.35	2.1	86.5	82.4	78.9	78.9	79.1	79.6	80.4	81.4	82.4	83.5	84.7	86.1	87.0	88.0	89.4	90.9	92.3	93.7	95.1	96.6	98.1	99.5	101	102	104	105	107	108	109	110	111	112	113	114	115	116	118
675	880	1.45	2.6	95.8	93.2	87.3	86.7	87.0	87.3	88.1	88.9	89.5	90.8	92.1	93.4	94.4	95.4	97.0	98.6	100	102	103	105	107	108	110	111	113	114	116	117	119	120	121	122	124	125	126	128	129
750	950	1.5	3.3	104	100	94.5	93.4	93.6	94.0	94.7	95.5	96.2	97.6	99.0	100	102	103	104	106	108	109	111	113	115	117	119	120	122	123	125	126	128	129	131	132	134	135	137	139	140
825	1040	1.60	3.9	113	109	103	102	101	102	103	104	105	107	108	109	110	112	114	116	118	119	121	123	125	127	129	131	133	135	136	138	140	142	143	145	147	148	150	150	151
900	1120	1.90	4.7	122	118	111	110	111	112	115	118	121	124	126	128	130	132	135	137	140	143	146	149	152	155	157	160	163	166	169	171	174	177	180	182	184	186	189	192	193
1050	1300	2.05	6.4	141	135	128	127	128	130	132	136	139	141	144	145	148	151	154	157	160	164	167	170	173	176	179	183	186	189	192	195	198	201	204	207	209	212	215	216	218
1200	1400	2.30	8.3	158	153	147	142	143	145	148	152	155	158	160	163	166	169	172	176	179	183	187	191	195	199	203	207	211	215	218	221	225	229	233	237	240	244	247	250	253
1350	1650	2.45	10.6	175	169	163	160	161	163	166	170	173	176	179	182	185	188	192	196	200	205	209	213	218	222	226	230	234	237	241	243	247	251	255	259	263	267	271	274	278
1500	1830	2.60	13.0	192	187	180	177	181	184	187	190	193	196	198	201	205	209	213	214	218	223	228	232	237	241	246	251	255	260	264	269	273	278	282	287	291	296	300	302	305
1800	2240	2.95	18.7	234	228	222	218	220	223	225	228	232	235	238	241	244	246	251	257	262	268	273	279	284	290	296	301	307	313	319	324	330	335	341	346	352	357	362	365	368
2100	2560	3.25	25.5	278	267	255	249	252	254	257	260	263	267	270	273	276	278	284	289	295	302	309	315	321	328	334	340	346	353	359	366	372	379	385	392	399	404	410	413	416
2400	2800	3.55	33.3	317	304	292	286	284	287	289	292	295	298	301	305	309	315	321	327	334	341	348	355	362	370	377	381	385	391	399	406	414	421	428	435	443	450	457	464	471

Table A4. Total Design Loads - Light Roads. "H" = 0.9 metres to 8.0 metres

Total design load "W_e" in kN/m for cover depths "H" in metres

Nominal Diameter in mm	Outside Diameter in mm	Recommended Trench width in m	Waterload Included in kN/m	0.9	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.8	5.0	5.2	5.4	5.6	5.8	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.6	7.8	8.0
225	280	0.70		27.1	25.0	23.1	22.0	21.8	21.9	22.5	23.3	24.2	25.3	26.2	27.2	27.6	28.0	28.4	28.9	29.3	29.7	30.1	30.4	31.0	31.1	31.4	31.7	32.0	32.3	32.6	32.8	33.1	33.2	33.4	33.5	33.5	33.6	33.7	33.8	33.9
300	380	0.75		36.9	34.3	31.5	30.0	29.4	28.8	29.9	30.1	30.5	31.0	31.6	32.2	32.6	33.0	33.5	34.1	34.7	35.2	35.7	36.3	36.8	37.3	37.8	38.1	38.4	38.7	39.0	39.3	39.6	39.9	40.2	40.4	40.7	41.0	41.2	41.4	41.6
375	500	1.06		47.3	44.1	40.6	38.8	38.3	38.7	39.7	41.2	42.7	44.8	46.9	48.9	50.5	52.1	53.5	54.8	56.1	57.4	58.6	59.9	61.1	62.2	63.4	64.3	65.3	66.3	67.2	68.0	68.8	69.6	70.4	71.1	71.8	72.5	73.3	74.0	74.5
450	560	1.15		55.4	51.0	47.6	45.2	44.8	45.5	46.6	48.4	50.3	52.0	53.5	55.2	56.4	57.5	59.0	60.5	62.0	63.5	64.9	66.4	67.7	68.9	70.3	71.5	72.7	73.8	74.7	75.9	77.0	77.5	78.8	79.6	80.4	81.3	82.1	82.9	83.7
525	670	1.20		61.9	58.3	54.5	52.0	51.5	52.2	53.5	54.4	55.5	57.4	58.8	60.3	61.6	62.9	64.5	66.2	68.0	69.6	71.3	72.9	74.3	75.8	77.3	78.1	80.0	81.4	82.6	83.8	84.9	86.0	87.1	88.3	89.2	90.2	91.1	92.0	92.9
600	790	1.35	2.1	72.9	68.2	63.8	62.3	62.9	63.7	64.7	66.3	68.7	70.4	72.2	73.3	74.4	75.4	77.6	79.6	81.7	83.7	85.6	87.7	89.6	91.6	93.7	95.4	97.2	100	101	102	104	105	106	108	109	110	111	112	114
675	880	1.45	2.6	80.4	75.5	70.1	68.7	68.4	69.1	70.1	71.4	73.6	75.8	78.1	79.8	81.5	83.8	86.4	88.4	90.7	93.1	95.3	97.4	99.0	99.9	102	103	106	107	109	111	113	114	116	117	119	120	122	123	125
750	950	1.5	3.3	87.5	81.0	75.7	73.5	72.8	73.5	74.6	75.8	77.0	79.0	81.4	83.8	85.5	87.5	90.0	92.6	95.0	97.4	99.9	102	105	107	110	112	114	116	118	119	121	123	125	127	129	130	132	134	136
825	1040	1.60	3.9	94.7	88.1	83.4	80.4	78.9	78.8	79.4	80.9	82.7	84.8	87.3	89.7	91.7	93.7	96.4	99.2	102	104	107	110	112	115	117	120	122	125	127	129	131	133	135	137	139	141	143	145	147
900	1120	1.90	4.7	101	95.1	88.1	84.8	85.3	87.4	91.3	95.2	99.1	102	105	109	112	114	118	122	125	129	133	136	140	143	147	150	154	157	160	163	166	169	173	176	178	181	183	185	188
1050	1300	2.05	6.4	116	110	101	97.1	98.9	102	106	110	112	115	117	122	124	127	131	135	140	144	148	153	156	160	164	168	172	176	179	183	186	189	193	196	199	203	206	209	212
1200	1400	2.30	8.3	130	123	115	110	112	117	122	126	130	134	138	142	145	150	155	159	164	168	172	175	179	184	189	194	198	203	207	211	215	219	224	228	232	235	239	243	246
1350	1650	2.45	10.6	143	135	127	122	124	128	132	137	141	146	150	155	159	164	169	172	175	179	184	190	196	201	204	207	213	219	225	230	235	241	246	249	254	258	262	266	270
1500	1830	2.60	13.0	156	149	140	133	136	140	145	150	155	159	164	169	172	175	179	184	190	196	201	207	213	219	225	230	235	241	246	251	257	262	267	272	277	282	287	292	297
1800	2240	2.95	18.7	185	177	167	161	164	169	173	178	184	190	196	201	206	212	216	220	227	234	242	249	255	262	269	276	283	290	296	303	309	316	322	328	334	340	346	352	359
2100	2560	3.25	25.5	209	201	191	185	186	191	197	202	209	215	222	227	232	236	240	246	254	262	272	279	287	295	303	311	319	327	334	342	349	355	363	371	378	385	391	398	404
2400	2800	3.55	33.3	236	228	217	212	213	219	223	229	236	243	250	256	263	272	281	285	289	298	308	317	326	334	342	352	360	367	377	386	394	402	411	419	427	434	442	450	458

Table A5. Total Design Loads - Fields, etc.. "H" = 0.6 metres to 8.0 metres

Total design load "W_e" in kN/m for cover depths "H" in metres

Nominal Diameter in mm	Outside Diameter in mm	Recommended Trench width in m	Waterload Included in kN/m	0.6	0.9	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.8	5.0	5.2	5.4	5.6	5.8	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.6	7.8	8.0
225	280	0.70		23.5	21.0	20.0	18.2	18.0	18.1	19.0	20.2	21.4	22.8	24.0	25.0	26.0	26.5	27.0	27.5	28.0	28.5	28.9	29.4	30.3	30.7	31.0	31.3	31.6	31.9	32.1	32.5	32.8	32.9	33.1	33.2	33.4	33.5	33.5	33.6	33.7	33.9
300	380	0.75		31.2	25.7	24.7	23.9	24.0	24.7	25.8	26.5	27.3	28.0	29.0	29.7	30.5	31.0	31.7	32.3	33.0	33.7	34.3	34.8	35.5	36.0	36.5	37.0	37.5	37.9	38.3	38.5	38.8	39.2	39.5	39.8	40.1	40.4	40.6	40.9	41.2	41.4
375	500	1.06		39.1	33.0	32.0	31.0	31.2	32.1	33.7	35.8	37.7	39.6	42.0	44.4	46.9	48.6	50.3	51.8	53.3	54.9	56.2	57.6	58.8	60.0	61.2	62.5	63.6	64.6	65.7	66.6	67.5	68.4	69.1	69.9	70.4	71.4	72.2	72.8	73.4	74.0
450	560	1.15		46.1	37.7	36.9	36.4	36.8	37.7	39.3	41.6	43.5	45.4	47.2	49.1	51.0	52.9	54.8	56.6	58.5	60.5	61.9	63.7	65.2	65.6	68.0	69.4	70.6	71.8	73.0	74.0	75.1	76.3	77.3	78.2	79.1	80.0	80.7	81.5	82.3	83.1
525	670	1.20		52.2	42.7	41.9	41.4	42.2	43.2	45.4	47.6	49.6	51.3	53.3	55.3	57.4	58.9	60.5	62.4	64.3	66.2	67.9	69.7	71.5	73.1	74.6	76.3	77.7	79.0	80.5	81.8	83.1	84.3	85.4	86.5	87.7	88.7	89.6	90.6	91.6	92.5
600	790	1.35	2.1	61.7	50.7	49.5	46.9	50.5	53.0	54.8	57.4	59.3	61.4	63.7	65.2	69.0	70.9	72.7	75.0	77.4	79.5	81.8	83.9	86.2	88.3	90.3	92.5	94.3	96.0	97.9	99.6	101	103	104	106	107	108	109	111	112	113
675	880	1.45	2.6	68.0	56.1	53.9	53.5	54.9	56.9	59.3	61.6	64.0	66.4	69.1	71.6	74.0	76.5	78.5	81.0	83.6	86.2	88.7	91.1	93.6	95.8	98.1	100	102	104	106	108	110	112	113	115	116	118	120	121	123	124
750	950	1.5	3.3	73.1	60.9	58.8	57.8	59.3	61.3	63.7	65.7	68.7	71.0	74.0	76.9	79.8	82.4	85.0	87.6	90.2	92.7	95.1	97.8	100	103	105	108	110	113	115	117	118	120	122	124	126	128	130	132	134	136
825	1040	1.60	3.9	78.2	66.2	64.7	62.8	64.2	66.1	68.4	70.6	73.6	76.1	79.4	82.4	85.4	87.8	90.1	93.2	96.2	99.2	102	105	108	111	113	116	119	121	124	126	128	130	132	134	136	138	140	142	144	146
900	1120	1.90	4.7	83.8	71.1	68.7	67.3	68.2	71.1	76.2	82.4	87.8	91.7	96.1	100	104	107	110	114	118	123	126	130	134	138	142	146	149	152	156	159	162	165	168	172	175	177	180	182	185	187
1050	1300	2.05	6.4	94.4	81.3	79	77	78.5	81.4	85.9	92.2	98.1	104	107	112	116	120	123	127	132	136	141	146	150	154	158	162	167	171	176	179	182	185	188	192	195	198	202	205	209	213
1200	1400	2.30	8.3	102	91.9	89.2	87.9	89.0	92.2	97.1	104	110	116	122	127	132	136	140	145	150	155	160	166	171	176	182	188	193	199	204	209	214	219	224	229	234	239	243	248	252	257
1350	1650	2.45	10.6	115	99.1	98	97.6	99	103	107	115	120	126	132	138	144	150	155	160	166	173	179	185	191	198	204	210	215	222	228	233	239	244	249	255	260	265	270	275	280	285
1500	1830	2.60	13.0	125	112	109	108	110	113	118	126	131	138	144	150	156	161	167	173	179	185	191	198	204	210	215	222	228	233	239	244	249	255	259	266	270	275	280	285	290	295
1800	2240	2.95	18.7	145	133	130	130	132	136	143	152	161	165	172	180	187	194	201	207	214	222	229	237	244	251	259	266	273	280	287	294	300	307	314	320	326	332	338	345	351	357
2100	2560	3.25	25.5	167	153	152	150	152	156	163	172	180	187	196	204	212	218	225	233	241	249	258	266	275	283	291	299	307	315	324	331	339	346	354	361	367	376	383	389	396	403
2400	2800	3.55	33.3	188	175	173	172	175	180	186	195	203	212	222	231	240	246	253	262	272	281	291	301	311	320	330	338	347	356	365	374	383	391	400	408	417	425	432	440	447	454

1.2.6 Worked examples

The symbols used in the examples are those referred to in Design Calculations (Section 1.2.5).

Example 1

Size of pipe: DN900 (reinforced)   Cover depth:3.00m   Design load: Main road

Nominal Diameter in mm	Outside Diameter in mm	Recommended Trench width in m	Waterload Included in kN/m	Total design load "We" in kN/m for cover depths "H" in metres																																				Nominal Diameter in mm
				0.9	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.8	5.0	5.2	5.4	5.6	5.8	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.6	7.8	8.0	
225	280	0.70		31.9	31.4	28.5	28.3	27.7	27.9	28.5	28.5	29.9	30.7	31.4	32.0	32.2	32.4	32.6	23.9	33.2	33.2	33.3	33.5	33.7	33.9	34.1	34.2	34.3	34.5	34.7	34.9	35.0	35.0	35.1	35.1	35.2	35.2	35.3	35.3	35.4	225
300	380	0.75		43.4	38.9	37.8	38.3	37.8	37.9	38.0	38.1	38.2	38.3	38.5	38.7	38.9	39.0	39.2	3.5	39.8	40.1	40.4	40.6	40.8	41.1	41.3	41.5	41.7	41.9	42.1	42.3	42.4	42.5	42.7	42.8	42.9	43.0	43.2	43.2	43.3	300
375	500	1.06		55.7	53.9	50.1	49.1	48.1	49.4	50.5	51.6	52.6	54.3	56.1	57.6	58.8	59.9	60.9	61.9	62.9	63.7	64.3	65.4	66.3	67.3	67.9	68.7	69.4	70.2	70.9	71.5	72.2	72.8	73.5	74.0	74.6	75.1	75.7	76.3	76.9	375
450	560	1.15		64.3	62.8	55.7	58.4	57.3	58.0	59.3	60.7	62.1	63.2	64.2	65.4	66.1	66.8	67.8	68.8	69.7	70.8	71.9	73.0	74.0	74.8	75.7	76.7	77.5	78.4	79.2	80.0	80.9	81.7	82.5	83.2	83.9	84.4	85.0	85.6	86.2	450
525	670	1.20		73.2	71.6	66.7	65.7	66.2	66.8	67.5	68.4	69.0	70.0	71.0	72.0	72.8	73.7	74.7	75.6	76.9	78.0	79.1	80.3	81.4	82.5	83.7	84.5	85.3	86.2	87.3	88.4	89.4	90.4	91.3	92.3	93.0	93.7	94.5	95.2	95.8	525
600	790	1.35	2.1	86.5	82.4	78.9	78.9	79.1	79.6	80.4	81.4	82.4	83.5	84.7	86.1	87.0	88.0	89.4	90.9	92.3	93.7	95.1	96.6	98.1	99.5	101	102	104	105	107	108	109	110	111	112	113	114	115	116	118	600
675	880	1.45	2.6	95.8	93.2	87.3	86.7	87.0	87.3	88.1	88.9	89.5	90.8	92.1	93.4	94.4	95.4	97.0	98.6	100	103	105	107	108	110	113	114	116	117	119	120	121	122	124	125	126	128	129			675
750	950	1.5	3.3	104	100	94.5	93.4	93.6	94.0	94.7	95.5	96.2	97.6	99.0	100	102	103	106	108	108	109	111	113	115	117	118	120	126	128	129	131	132	134	135	137	139	140				750
825	1040	1.60	3.9	113	109	103	102	101	101	102	103	104	105	107	108	109	110	112	114	116	118	119	123	125	127	129	131	133	135	136	140	142	143	145	147	148	150	151			825
900	1120	1.90	4.7	122	118	111	110	111	112	115	118	121	124	128	130	132	135	137	140	143	146	149	152	155	157	160	163	166	169	171	174	177	180	182	184	186	189	192	193		900
1050	1300	2.05	6.4	141	135	128	125	127	128	130	132	136	139	141	144	145	148	151	154	157	160	164	167	170	173	176	179	183	186	189	192	195	198	201	204	207	209	212	215	218	1050
1200	1400	2.30	8.3	158	153	147	142	143	145	148	152	155	158	160	163	166	169	172	176	179	183	187	191	195	199	203	207	211	215	218	221	225	229	233	237	240	244	247	250	253	1200
1350	1650	2.45	10.6	175	169	163	160	160	161	163	166	170	173	176	179	182	185	188	192	196	200																				1350
1500	1830	2.60	13.0	192	187	180	177	177	187	181	184	187	190	193	196	198	201	205	209	214	216																				1500
1800	2240	2.95	18.7	234	228	222	218	217	218	220	223	225	228	323	235	238	241	246	251	257	262																				1800
2100	2560	3.25	25.5	278	267	255	249	247	249	252	254	257	260	263	267	270	273	278	284	289	295																				2100
2400	2800	3.55	33.3	317	304	292	286	284	284	287	289	292	295	298	301	305	309	315	321	327	334																				2400

> From Table, W_e (design load) = 128kN/m
> F_{se} = 1.5 (reinforced pipe)
> F_n (pipe strength) = 120 x 0.9 = 108kN/m
> Required bedding factor, $F_m = (W_e \times F_{se}) / F_n$ = (128 x 1.5) / 108 = 1.78
> From Table A2, Bedding Class B (F_m=1.9) and Class S (F_m=2.2) are suitable.

Example 2

A 900mm diameter pipeline with Class B bedding is to be laid across fields.

What is the greatest cover depth that these pipes may be laid?

Nominal Diameter in mm	Outside Diameter in mm	Recommended Trench width in m	Waterload Included in kN/m	Total design load "We" in kN/m for cover depths "H" in metres																																				Nominal Diameter in mm
				0.9	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.8	5.0	5.2	5.4	5.6	5.8	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.6	7.8	8.0	
225	280	0.70		21.0	20.0	18.2	18.0	18.1	19.0	20.2	21.4	22.8	24.0	25.0	26.0	26.5	27.0	27.5	28.0	28.5	28.9	29.4	30.3	30.7	31.0	31.3	31.6	31.9	32.1	32.5	32.8	32.9	33.1	33.2	33.4	33.5	33.6	33.7	33.9		225
300	380	0.75		25.7	24.7	23.9	24.0	24.7	25.8	26.5	27.3	28.0	29.0	29.7	30.5	31.0	31.7	32.3	33.0	33.7	34.3	34.8	35.5	36.0	36.5	37.0	37.5	37.9	38.3	38.5	38.8	39.2	39.5	39.8	40.1	40.4	40.6	40.9	41.2	41.4	300
375	500	1.06		33.0	32.0	31.0	31.2	32.1	33.7	35.8	37.7	39.6	42.0	44.4	46.9	48.6	50.3	51.8	53.3	54.9	56.2	57.6	58.8	60.0	61.2	62.5	63.6	64.6	65.7	66.6	37.5	68.4	69.1	69.9	70.4	71.4	72.2	72.8	73.4	74.0	375
450	560	1.15		37.7	36.9	36.4	36.8	37.7	39.3	41.6	43.5	45.4	37.2	49.1	51.0	52.9	54.8	56.6	58.5	60.5	61.9	63.7	65.2	65.6	68.0	69.4	70.6	71.8	73.0	74.0	75.1	76.3	77.7	78.2	79.1	80.0	80.7	81.5	82.3	83.1	450
525	670	1.20		42.7	41.9	41.4	42.2	43.2	45.4	47.6	49.6	51.3	53.3	55.3	57.4	58.9	60.5	62.4	64.3	66.2	67.9	69.7	71.5	73.1	74.6	76.3	77.7	79.0	80.5	81.8	83.1	84.3	85.4	86.5	87.7	88.7	89.6	90.6	91.6	92.5	525
600	790	1.35	2.1	50.7	49.5	46.9	50.5	53.0	54.8	57.4	59.3	61.4	53.7	65.2	69.0	70.9	72.7	75.0	77.4	79.5	81.8	83.9	86.2	88.3	90.3	92.5	94.3	96.0	97.9	99.6	101	103	104	106	107	108	109	111	112	113	600
675	880	1.45	2.6	56.1	53.9	53.5	54.9	56.9	59.3	67.1	64.0	66.4	69.1	61.6	74.0	76.5	78.5	81.0	83.6	86.2	88.7	91.1	93.6	95.8	98.1	100	102	104	106	108	110	112	113	115	116	118	120	121	123	124	675
750	950	1.5	3.3	60.9	58.8	57.8	59.3	61.3	63.7	65.7	68.7	71.0	74.0	76.9	79.8	82.4	85.0	87.6	90.2	92.7	95.1	97.8	101	103	105	110	113	115	117	118	120	122	124	126	128	130	132	134	136		750
825	1040	1.60	3.9	66.2	54.7	62.8	64.2	66.1	68.4	70.6	73.6	76.1	79.4	82.4	85.4	87.8	90.1	93.2	96.2	99.2	102	105	108	111	113	116	119	121	124	126	128	130	132	134	136	138	140	142	144	146	825
900	1120	1.90	4.7	74.1	52.7	59.2	71.1	75.2	82.4	87.9	91.7	96.4	100	104	107	110	114	118	120	125	130	134	138	142	146	149	152	156	159	162	165	168	172	175	177	180	182	185	187		900
1050	1300	2.05	6.4	81.3	79	77	78.5	81.4	85.9	92.2	98.1	112	107	120	116	119	123	127	132	137	141	146	150	154	158	162	167	171	176	179	182	185	188	192	195	198	202	205	209	213	1050
1200	1400	2.30	8.3	91.9	89.2	87.9	89.0	92.2	97.1	104	110	116	122	127	132	136	140	145	150	156	161	167																			1200
1350	1650	2.45	10.6	99.1	98	98	99	103	107	115	120	127	132	138	144	150	155	160	166	171	176	182																			1350
1500	1830	2.60	13.0	112	109	108	110	113	18	126	131	138	144	152	156	151	167	173	179	185	191	198																			1500
1800	2240	2.95	18.7	133	130	130	132	136	143	152	161	165	172	180	187	194	201	207	214	222	229	237																			1800
2100	2560	3.25	25.5	153	152	150	152	156	163	172	180	187	196	204	212	218	225	233	241	249	258	266																			2100
2400	2800	3.55	33.3	175	173	172	175	180	186	195	203	212	222	231	240	246	253	262	272	281	291	301																			2400

> F_{se} = 1.5 (reinforced pipe)
> F_n = (pipe strength) = 120 x 0.9 = 108kN/m
> F_m = 1.9 for Class B bedding
> $F_m = (W_e \times F_{se}) / F_n \Rightarrow W_e = (F_m \times F_n) / F_{se}$ = (1.9 x 108) / 1.5 = 136.8kN/m
> From Table, Total load at 4.6m = 134kN/m.
> Total load at 4.8m = 138kN/m.
> Maximum cover under these conditions is 4.7m (approx.)

CPSA has developed online Structural and Material Cost calculators and a web App to help with the calculation and optimisation of the structural design and material cost of underground sewer pipeline systems.

The App offers a two-stage process:

Stage 1 Structural Design Calculator enables users to quickly establish acceptable structural bedding Classes for buried pipes based on the recommendations in BS EN 1295-1 "Structural design of buried pipelines".

Stage 2 Material Cost Calculator where users can compare the cost of materials required for each bedding Class option. The calculator takes into account the pipe cost (including connectors, gaskets, etc), imported granular bedding material and the disposal of surplus excavated material removed from the trench.

The App not only helps to improve pipeline construction cost efficiency by enabling users to minimise the amount of expensive imported granular bedding used during construction, it can also reduce the embodied carbon of the installation.

1.3 MANHOLE DESIGN

1.3.1 Manhole Positions

Manholes are recommended:

• At intervals of up to 90m, or 200m for man entry pipe runs.

• Whenever there is a significant change of direction in a sewer.

• Where another sewer is connecting with the main run of a sewer.

• Where there is a change of size or gradient of pipeline.

• Where there is a change of design loading or bedding design.

1.3.2 Precast Components

The following standard precast concrete components are manufactured in accordance with BS EN 1917 & BS 5911-3 for assembly into complete manholes;

• Adjusting units and corbel slabs
• Cover slabs
• Shaft sections
• Reducing slabs
• Chamber sections
• Landing slabs
• Base units

Fig. A4. Typical Manhole Layout

Fig. A4a. Typical Cast In-situ Manhole Base with Tongue and Groove Jointed Rings
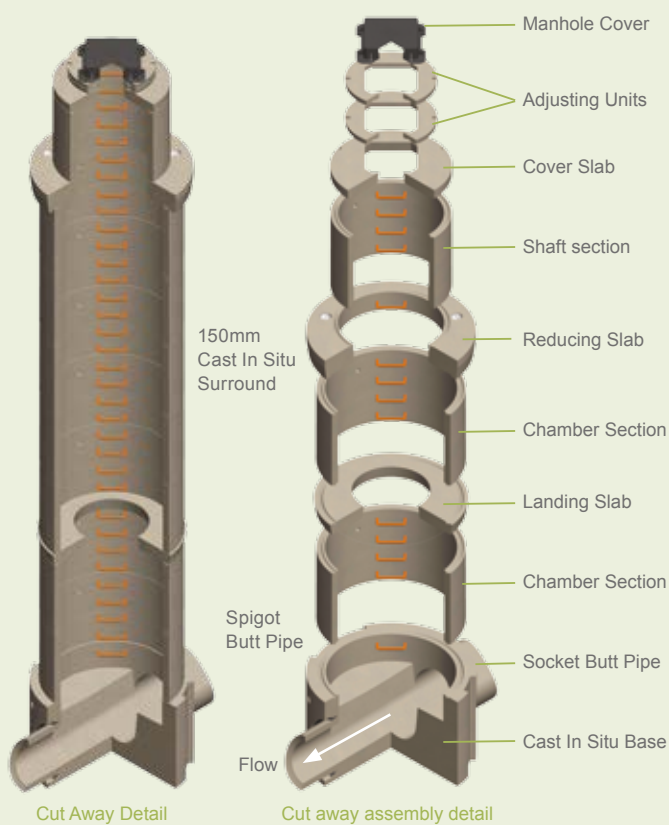
Fig. A4b. Typical Precast Manhole Base with Elastomeric Seal Jointed Rings

Fig. A4a labels: Manhole Cover, Adjusting Units, Cover Slab, Shaft section, 150mm Cast In Situ Surround, Reducing Slab, Chamber Section, Landing Slab, Chamber Section, Spigot Butt Pipe, Socket Butt Pipe, Flow, Cast In Situ Base, Cut Away Detail, Cut away assembly detail

Fig. A4b labels: Manhole Cover, Adjusting Units, Cover Slab, Seal, Shaft section, Seal, Reducing Slab, Seal, Landing Slab, Seal, Chamber Section, Seal, Socket Butt Pipe, Spigot Butt Pipe, Flow, Precast Base, Cut Away Detail, Cut away assembly detail

Base units can be supplied with circular or semicircular holes (cut-outs or dog kennels) cut in the chamber walls or with factory made flexible joints to incorporate a sealing ring to connect pipes to the chamber.

1.3.3 Advantages

The main advantages of manholes using precast concrete components are:

1. Reduced construction time and cost

2. Less operative risk exposure in trench during construction

3. Its self-weight provides natural resistance to flotation

4. Can accommodate new build and retro-fitting of new connections

5. Units are produced in a controlled factory environment to BS EN 1917 & BS 5911-3 to ensure consistent quality and performance.

6. All CPSA member factories are licensed to manufacture 'Kitemarked' standard units under BS EN ISO 9001 quality management systems.

7. They are manufactured in a range of standard sizes and depths.

8. They are simple to assemble requiring relatively unskilled labour on site.

9. Units are watertight structures without the need for a concrete surround. Soil backfill is normally sufficient.

10. They can be supplied ready fitted with double steps complying with BS EN 13101.

11. The structure is durable with its own inherent strength.

1.3.4 Types of Manholes

Manholes should be designed and constructed in accordance with BS EN 752. Table NA.22 provides recommendations for dimensions for manholes and manhole shafts for UK applications (with personnel entry) and Sewers for Adoption provides details of manholes suitable for adoption purposes.

Manholes are built on a run of sewer with or without side connections. Where conditions permit, the soffit level of sewers connecting to a manhole should be the same.

Manholes may be constructed with or without a shaft. It is recommended that reducing slabs and shafts are only used for DN1800 manholes and larger. Landing slabs are generally required for manholes 6 metres deep or greater.

Smaller diameter chambers should be constructed up to full height and use a cover slab. There are also inspection chambers which are constructed over a subsidiary drain or sewer of not more than DN 225 to permit inspection and access for rodding. Most manholes are sited symmetrically over the main sewer pipeline. Side-entry manholes which are formed integral to the crown of the pipe are also manufactured. These can be advantageous in terms of installation time and cost savings.

When contemplating the installation of rectangular or square manhole/s, reference should be made to Annex F of BS 5911-3+A1.

1) Conventional manholes

Concrete base, channel/s and benching installed in-situ. With the bottom section of the first manhole ring being built in to the base concrete by a minimum of 75mm. Distance between top of pipe and underside of first manhole ring to be minimum of 50mm to a maximum of 300mm. Generally and in accordance with 'Sewers For Adoption' a concrete surround is required with this type of manhole construction.

In-situ concrete to be GEN3 (designed to BRE Special Digest 1 Concrete in Aggressive Ground)

High-strength concrete topping to be brought up to a dense, smooth face, neatly shaped and finished to all branch connections (minimum thickness 20 mm)

Precast concrete manhole sections and cover slab to be bedded with mortar, plastomeric or elastomeric seal conforming to BS EN 1917 and BS 5911-3

Concrete surround 150 mm thick

The bottom precast section to be built into base concrete minimum 75 mm

Benching slope to be 1:10 to 1:30

Construction joint

Distance between top of pipe and underside of precast section to be minimum 50 mm to maximum 300 mm

225 mm to underside of channel

2) Precast base systems

Inlet(s) and outlet positions are configured to site requirements and delivered with all channels and benching complete. Watertight joints and thicker walls means units do not require a concrete surround, unless specified. A faster, safer, higher quality, lower installed cost and reduced carbon footprint alternative to conventional manholes. (The product's finish is not subject to the skills of site operatives)

Precast concrete manhole sections and cover slab to be bedded with mortar, plastomeric or elastomeric seal conforming to BS EN 1917 and BS 5911-3 Chamber wall to be minimum 125 mm

Benching slope to be 1:10 to 1:30

Surface of benching and channel formed monolithically with high-strength concrete base or a proprietary liner

150 mm to underside of channel
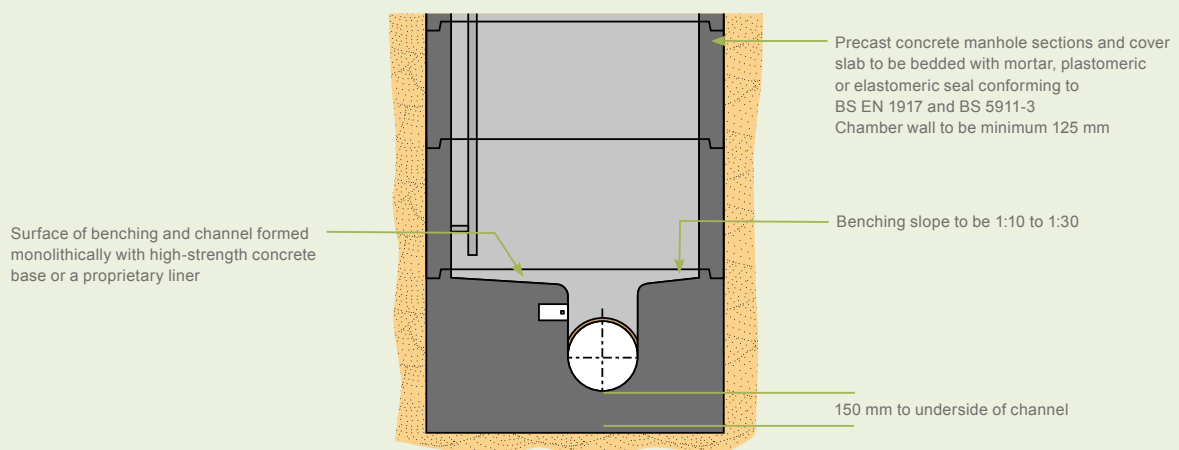
For more information on precast manhole base systems, refer to CPSA and member product information:

CPM Group Ltd http://www.cpm-group.com/products/drainage/sealed-manholes/the-perfect-manhole/

FP McCann Ltd http://fpmccann.co.uk/precast-concrete/drainage/easi-base-preformed-manhole/dn1200-easi-base

Milton Precast www.miltonprecast.co.uk/products/8/sealed manholes

Stanton Bonna Ltd http://www.stanton-bonna.co.uk/drainage-systems/perfect-manhole-system/

CPSA http://www.concretepipes.co.uk/page/innovation-concrete-manholes

3) Side-entry manholes

Side-entry can be provided for sewers larger than DN 1200. The side-entry shaft is fitted to the main sewer pipe by the manufacturer before delivery.

4) Backdrop manholes

Where one sewer connects with another at a substantially different level, the manhole is built on the lower sewer and incorporates a vertical or ramped drop pipe from the higher sewer. The drop pipe, which may be inside or outside the manhole chamber, has its lower end discharging into the main sewer, and at its upper end has a rodding eye for cleaning through the higher sewer.

Wherever possible, steeper gradients are preferred over the use of backdrops in 'Sewers For Adoption'.

5) Dual and crossing manholes

Where surface water and foul sewers are laid in the same trench, the surface water being normally above the foul, a normal manhole chamber is built for the foul sewer and the surface water is carried across the chamber in a separate pipe which may have a sealed inspection cover.

1.3.5 Sizes of Manholes

The diameter of the chamber is determined by the number and the diameter of the sewer pipes coming into the manhole and the working space required.

The chamber should be a minimum of DN 1050 and is the smallest size that may be fitted with steps, but are only permitted to be used to a depth of 1.5m. DN 1200 is the smallest size that can be used deeper than 1.5m and to which ladders may be fitted. It should have ample benching at least 225mm wide on one side of the channels. On the other side, the benching should be wide enough to stand on, at least 450mm.

For deep manholes, the chamber should be large enough to provide benching or a landing adequate for two persons to stand upon.

A guide for the minimum chamber diameters required for various sizes of sewer pipes entering the manhole is given in Table A6. When a manhole is sited on a curve, or where additional pipes enter at the sides a larger size may be required.

Table A6. Sizes of pipe and manhole chamber diameters

Maximum size of pipe (DN) through chamber	Minimum Chamber diameter (DN)
Less than 375	1200
375 – 450	1350
500 –700	1500
750 – 900	1800
Greater than 900	Pipe diameter + 900

1.3.6 Pipes Adjacent to Manholes

There may be differential settlement between a structure and the pipeline resulting in angular deflection of the joint. This creates no problem for the joint itself but when this movement is "excessive" there is a shear force that can cause structural failure on the pipe, either shear behind the collar or from beam fracture of the pipe barrel.

To prevent this, the first pipe in the line can be restricted in length. This is known as a "rocker pipe". The likelihood of differential settlement should be assessed and rocker pipes used as appropriate.

Guidance on rocker pipes may be found in "Civil Engineering Specification for the Water Industry" and "Sewers for Adoption".

Fig. A5. Typical Rocker Pipe

Acceptable angular deflection

Full length pipe

Short pipe length
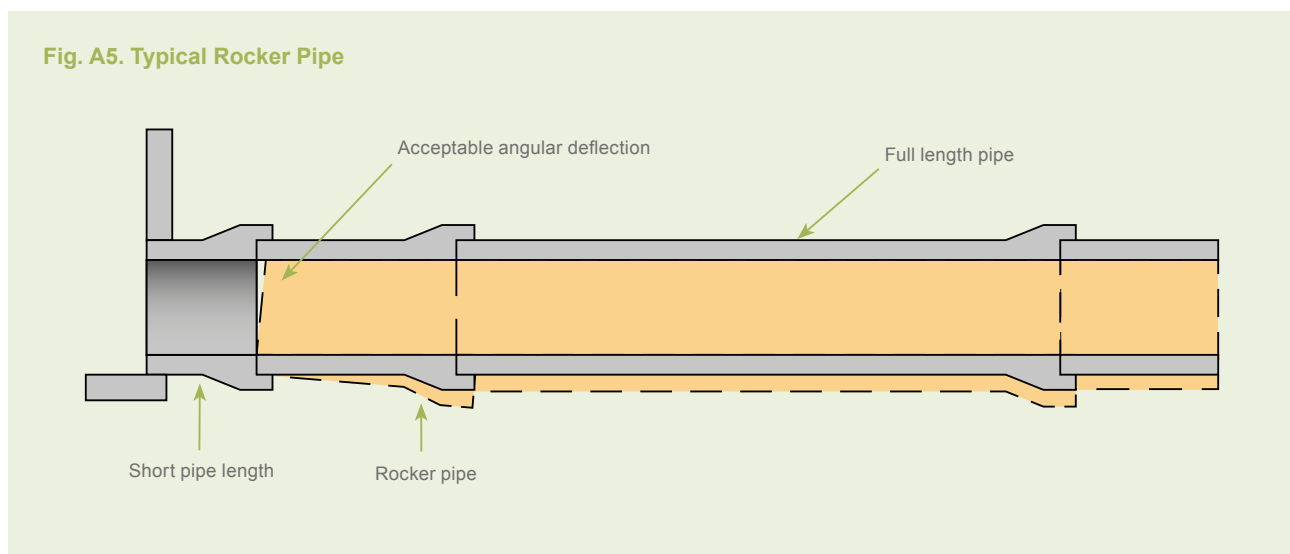
Rocker pipe

In certain conditions where excessive differential movement is possible, for pipes ≥ DN750, it may be advisable to use multiple rocker pipes to avoid unacceptable angular deflection or shear force at the joint.

1.3.7 Cover, landing and reducing slabs

1) Cover slabs

The minimum clear opening through a cover slab should be 600mm x 600mm.

Slabs with other sized accesses/multiple accesses or rebated accesses are quite often required in cases of split wall chambers, pumping stations, where flow control devices are fitted within the chamber etc. (these would be made to order products).

The access is normally located in an eccentric position i.e. usually 150mm - measured from edge of access (mid-point of side) to face of chamber wall below. This allows for safe and clear access to steps or ladder system below (where fitted).

Cover slabs are generally suitable for installation below highways (some small units are available for use in non-trafficked areas and hence should not be installed in a highway).

2) Landing slabs

Landing slabs are generally required on manholes greater than 6m depth (landing slabs should be installed at minimum of 2 metres and maximum of 6 metres spacing for the depth of the manhole).

It is usual for the access in the landing slab to be 900mm circular and is usually positioned offset on site so that there is a break in the steps/ladders vertically (alternatively a hinged safety grill may be fitted over the access).

3) Reducing slabs

On large, deep chambers (usually DN1800 or greater), it is common practice to reduce the upper access shaft to a smaller, more economic solution of typically DN1200 size.

Where double steps are fitted in the main chamber, the steps alignment is maintained through the reduced shaft section.

4) Corbel units and adjusting units

The access in the concrete cover slab may be reduced in size (typically from 750 mm x 600 mm to 600 mm x 600 mm) via the use of corbel units.

Adjusting units can be installed between the concrete cover slab and the access cover and frame (can be used in replacement of engineering brickwork in most situations).

1.3.8 Access into manholes

Manhole rings can be pre-fitted with double steps or supplied plain for post fitting of ladder system or where winch access only is permitted.

1.3.9 Soakaways

Manhole rings can also be supplied with perforations for the use in the construction of soakaway chambers.

1.3.10 Specialist manholes

Special chambers are widely being precast that can include flow control and treatment devices, weir walls and manifold units (multiple pipelines entering parallel into connecting chamber) etc.

Where manholes are required to be constructed and normal construction methods would not be suitable (e.g. large depth, poor ground or high water table), suppliers are also available to offer units for sinking top down via a caisson sinking system.

1.3.11 Spillway headwalls

Where a pipeline discharges into a watercourse such as rivers, ditches, ponds or swales, spillway headwalls are commonly installed.

The spillway headwall not only anchors the end of the pipeline, but also helps to control erosion and scour and the units can be fitted with grills to help prevent materials (or animals/people) entering the pipeline.

2 - INSTALLATION: PIPES

This section describes the recommended procedure for the installation of concrete pipelines in trenches for non-pressure (gravity) applications or when occasional periods of hydraulic surcharge may occur. It covers the types of laying conditions most commonly encountered in practice. In situations beyond these general conditions, the pipeline designer and the site engineer should give suitable instructions to supplement this guidance.

Pipelines laid under embankments require special consideration whilst those installed by pipe jacking require the use of specialised techniques.

2.1 Planning

General

Prior to constructing the pipeline, the contractor will need to organise the work from the contract documents, specification, drawings and bill of quantities.

The line and level of the sewer, any side connections and the positions of the manholes will have been determined at the design stage but some flexibility in construction should be permitted to cater for circumstances such as foundations or buried services not shown on the drawings. An agreed re-siting of a manhole may save time and additional expense.

Sequence of operations

a) Plan and set out the work including location of manholes.

b) Receive, check against specification and store deliveries of materials on site.

c) Excavate trench and install trench support system.

d) Lay bedding material forming socket holes as appropriate.

e) Check for damage, lay and joint pipes, air testing every third or fourth pipe as laying proceeds. Check line and level.

f) Place and compact sidefills with bedding or selected materials.

g) Continue placing and compacting sidefills withdrawing trench sheeting in stages.

h) Place initial backfill above pipe continuing withdrawal of sheeting.

i) Air and/or water test or inspect visually prior to final backfill.

j) Complete backfill, compacting as appropriate.

k) Final acceptance, air and/or water test or inspection.

l) Reinstatement of surface as appropriate

2.2 Handling and storage

Lifting equipment

Time and place of off-loading should be agreed before units arrive on site. The contractor should have suitable equipment for off-loading, stacking and stringing out pipes and other units on site.

All lifting tackle must be of good sound construction and should be regularly tested and certificated.

Off-loading

Whenever possible, pipes and other units should be off-loaded in the reverse order that they were loaded. The vehicle must not be moved if any part of the load is unsecured. Off-loading

should take place at the nearest hard standing to the point of installation; all units must be left in a stable position well clear of the edge of the trench.

For further information, refer to the CPSA Health & Safety Off-loading Guide
http://www.concretepipes.co.uk/page/pipe-laying-lifting

CPSA member companies are also available to advise on general handling of products and appropriate lifting equipment. Member companies contact details can be found here:
http://www.concretepipes.co.uk/suppliers

Use of tackle

Where provided, lifting holes, anchors etc. must be used with the correct equipment to lift the units (note - installed lifting points may not necessarily be suitable for the transportation of a product across a site).

Pipes

Pipes should be handled individually using a properly designed "C" hook, beam sling or other purpose-designed system. Small diameter pipes may be slung through the bore providing the sling is sleeved and protected around the joint. This is important in order to avoid damage to jointing surfaces and consequent leakage of the laid pipe. 'Pipe hooks' must not be used. Slings may be made of cordage, canvas, or man-made fibres, but not unprotected chains.

Many manufacturers offer a combined lifting and jointing system using a three-legged chain and cast-in facilities (larger pipe sizes only). A special concrete pipe lifter is also available providing improved site safety, reduced installation time, labour and cost savings. Further details relating to the concrete pipe lifter and other proprietary lifting devices can be found in the CPSA Site Guide, available at www.concretepipes.co.uk and directly from CPSA members.

The Concrete Pipe Lifter is designed to improve site safety and increase efficiency during the lifting and installation of precast concrete pipes. It is connected to an excavator via a quick hitch attachment.
www.concretepipelifter.co.uk

How to Use

• Perform appropriate pre-work checks to ensure all equipment is working properly and has valid operating certificates, where required.

• Connect Pipe Lifter to excavator via quick hitch coupling, ensuring correctly attached and locked in position.

• Fully insert the long lifting arm horizontally into the barrel of the pipe and carefully raise to make contact with the internal crown. When installing pipes, ensure it is lifted from the socket end.

• The clamp arm will slowly press down onto the top of the pipe and hold it in position.

• The pipe may now be lifted and transferred to a suitable storage location or placed into the prepared trench and jointed following the application of an approved joint lubricant to the pipe

spigot. Care should be taken to avoid lubricant coming into contact with the lifting area as this can cause the pipe to slip.

- Depending on the weight of pipe, depth of installation and lifting capacity of site plant, the pipe may be tilted up to 30 degrees from horizontal and maneuvered between struts on trench support systems. It can also be used to push the pipe home to ensure formation of the correct joint gap.

- Check limits of use before operation including lifting capacity and the compatibility of trench support system with the Pipe Lifter to ensure that struts do not interfere with the removal of the lifter from the pipe.

- When installing a pipe, no personnel should be in the working area or come into contact with the Pipe Lifter, excavator or any pipe in transit.

Other units

Where lifting eyes or lifting holes are provided they should be used. Extra care should be taken when lifting bends and junctions (pipes with inlet).

Chocks

When pipes are loaded, transported or stacked, sufficient timber chocks should be provided. Chocks or packing between individual units should not be removed until lifting tackle is secured.

Care in handling

Pipes and other units must never be dropped. Pipes which have to be moved should be lifted and never dragged. When pipes have to be rolled, beware of rocks or boulders. Care should be taken to avoid damage especially to jointing profiles.

Stacking on site

Ideally, pipes should be strung out and secured beside the trench where they are to be used. Where stacking is necessary this should be on level ground and the bottom layer of pipes securely chocked to prevent the stack from collapsing. Pipes should be supported under the barrel so that the socket is free of load and so that the jointing faces are not damaged. They should be stacked barrel to barrel with sockets overhanging, or with spigots protruding as preferred.

Fig. B1. Typical stacking arrangement

2.0 M Max

Chocks

Socket clear of the Ground
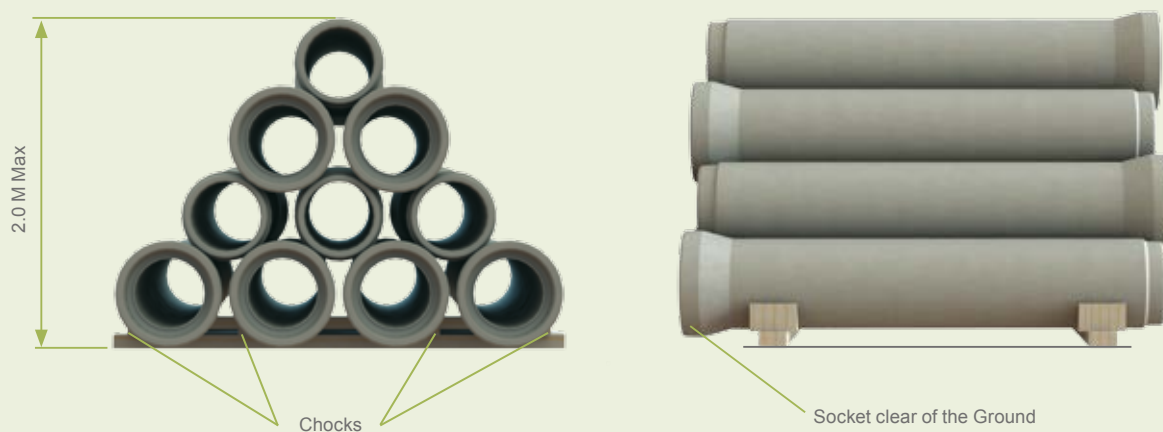
For safety reasons and to prevent damage to the lower layers of pipes in the stack, pipes should not be loaded or stacked in a greater number of layers than shown in Table B1 overleaf.

Table B1. Pipe stacking layers

Nominal size (DN)	Number of layers
150-225	6
300-375	4
450-600	3
675-975	2
above 975	1

Storage of loose jointing materials

Precast concrete pipes are normally supplied with an elastomeric sealing gasket integrally-cast into the socket of the pipe. For other forms of joint seal, the quantity, type and diameter of jointing rings or other jointing materials should be checked with the delivery note at the time of off-loading. Elastomeric rings should be carefully stored and protected from sunlight, oils, greases and heat. If the rings have been tied they should be separated a few days before use in order to eliminate minor impressions which the ties may have caused. Rings should not be stored hanging from a hook.

2.3 Excavation and laying

Trench excavation

The trench should be dug to the line, gradient and width indicated on the drawings or in the specification or as agreed with the Engineer. The safety of the public and site personnel is of paramount importance.

Trench width

Any increase in trench width above that specified could increase the load on the pipe and increase the quantity of the excavation and of bedding material.

A trench narrower than that specified may impede the proper placing and compaction of the bedding material and restrict working conditions in the trench during pipe laying.

A trench adjacent to a manhole may need to be wider but this should be taken into account at the design stage.

The trench width should allow for safe working alongside the pipeline. For recommended trench widths see load tables in section 1.2.5, pages 26-29.

Formation

Uniform support along the pipeline is essential.

Rock outcrops and soft zones such as peat or boggy material which can cause differential settlement should be dug out and replaced with well tamped selected material.

Ground water should be kept below the bottom of the trench during pipe laying operations by the use of temporary drains, sumps or a designed well-point system. The water level should not be allowed to rise before backfilling is completed.

If the trench bottom is likely to be disturbed by trampling during pipe laying, selected material should be placed to protect it.

Where the trench bottom is unstable, for example in marshy ground or running sands, special measures are necessary to ensure proper embedment.

A trench excavated in clay should not be kept open any longer than necessary to avoid instability due to change in moisture content.

Pipe laying

Before lowering into the trench, each unit should be inspected carefully for any damage which may have occurred in transit or during handling and storage on site. Pay special attention to jointing surfaces. Units should be lowered carefully into the trench with tackle suitable for their weight and for the depth of the trench.

The contractor should have available, at the required time, all material and equipment necessary for carrying out the work in accordance with the specification and statutory safety requirements.

The contractor must ensure that the size and strength class of pipes or other units conform to the contract specifications and manufacturer's recommendations. In the case of integrated gaskets, the joint must be prepared i.e. the application of the correct lubricant and the removal of the gasket positioning strip (where present).

Normal gradients

Pipes should be supported by the bedding over the length of their barrels and their weight must never be carried by the sockets or by bricks and rocks in the trench bottom. Bedding under the pipe should be scooped out to accommodate pipe sockets at each joint. The pipes should be laid and assembled in correct alignment.

If, in order to curve the pipeline it is necessary to deflect the pipes at the joints, the deflection should be applied only after the joint has been made in the normal manner and should be limited to 75% of the manufacturer's recommended limits to allow for any subsequent movement.

Mechanical plant must not be used to press pipes down to their correct level.

Changing direction

Change in direction, either horizontal or vertical, should be made at a manhole or by means of a precast bend unit.

Passing through rigid structures

For a pipeline connection to a manhole or passing through a wall it is essential that the pipeline joint retains its flexibility. This may be achieved by casting a short length of pipe into the wall of the structure and providing a flexible joint adjacent to the wall. Depending on ground conditions, short length pipes (rockers) should be used (see Section 1.3.6).

Unstable ground

In unstable ground an appropriate installation method should be determined. The following possibilities should be taken into account:

• Use of short lengths of pipe.

• Use of continuous support on pile caps/beams.

• Special preparation of trench bottom.

• Trenchless methods of construction such as pipe jacking or heading.

Passing under highways or railways

If disruption of traffic is to be avoided, pipes should be installed by jacking or in heading.

2.4 Jointing

A number of different joint designs are manufactured, all of which comply with the performance requirements of BS EN 1916 and BS 5911-1.

The pipe manufacturer's jointing instructions should be complied with but the basic requirements for jointing concrete pipes are:

• Pipes should always be handled in a way to avoid damage, especially the spigot and socket ends and joint surfaces.

• Prior to jointing, the socket and spigot should be cleaned and inspected to ensure they are in good condition.

• Most standard concrete pipes are supplied with an elastomeric seal integrally cast into the socket of the pipe

For Integrated Seal Joints

• Remove the protective polystyrene strip (where present) by using the tape provided. Grip the tab of the tape and pull firmly towards the centre of the pipe.

• Lubricant should be applied to the spigot end of the pipe, ensuring the radius area and entire length of the spigot is covered. Additional lubrication may be also applied to the seal face to assist jointing.

• Only use lubricant as recommended/supplied by the manufacturer.

• Enter the spigot carefully into the socket, ensuring that the pipes are correctly aligned.

• Always follow the manufacturer's instructions.

For Spigot Seal Joints (Rolling and Sliding Seals)

• Stretch and position the seal onto the spigot of the pipe ensuring it is not twisted. Even out the stretch by lifting and releasing at several points around the spigot.

• The seal should be located on the spigot in accordance with the manufacturer's instructions.

• Rolling seal joints do not require lubrication. Most sliding seal are internally pre-lubricated and do not require additional lubrication. If the joint design does require lubrication then follow the manufacturer's instructions.

• With rolling ring joints, offer up the pipe spigot to the socket, but keep clear of engagement by 25mm so that the joint ring is not disturbed. With sliding ring joints, the joint ring should be just in contact with the socket.

• Enter the spigot carefully into the socket, ensuring that the gasket is correctly positioned and that the pipes are correctly aligned.

• Always follow the manufacturer's instructions.

• Jointing tackle or chain systems should be used in accordance with the pipe manufacturer's instructions.

• Fully support the pipe so that it does not exert undue weight on the seal whilst closing the joint to the recommended joint gap.

• Joint the pipes in accordance with the manufacturer's recommendations, making sure that the pipe moves without excessive slew or misalignment, that extraneous matter does not enter the joint and that the joint is not damaged and correctly positioned. For jointing bends, special procedures may be appropriate.

- After adjusting for line and level, release the tackle. Care should be taken not to disturb the pipe or bedding material when removing slings.

- The finished internal pipe joint gaps should be within the tolerances as specified by the manufacturer.

- It is advisable to carry out an air test on the installed pipeline after the laying of at least every 3-4 pipes to ensure satisfactory installation has been achieved.

Back laying

In special circumstances, such as at manhole connections, it may be necessary to joint a pipe socket onto the spigot of a pipe already laid.

When this is done, additional care is necessary to ensure that the joint is properly made with the joint ring correctly positioned and that bedding material is not scooped into the joint.

Fig. B2. Integral sealing ring - standard for most UK concrete pipes

Fig. B3. Pre-lubricated Sliding Ring

Fig. B4. Rolling Ring – circular / tear drop / 'G' ring

NOTES:
1. Each joint type is diagrammatic and typical.
2. Rolling and fixed rings may be one of a variety of different profiles / cross sections / designs.
3. Tolerances of joint profiles shall be determined by the pipe manufacturer and described in factory documents.
4. Joint assembly shall be watertight / airtight when constructed in strict accordance with the manufacturer's recommendations.
5. Pipes with integral seals offer some protection to the seal, however the same precautions should still apply to protect the seal.

2.5 Reinstatement

Trench reinstatement

After inspection and testing, backfilling should proceed whilst withdrawing trench sheeting in stages where practicable.

The sidefill is of great importance and close attention to its selection, placing and compaction will protect a new pipeline.

Good trenching practice including controlled removal of temporary supports and compaction of backfilling as described above not only protects the pipeline but will also reduce settlement and the risk of damage to adjacent underground services or structures.

The trench should be backfilled as soon as possible after the pipes are laid bearing in mind any specified test and inspection requirements. Compaction of the envelope of material immediately around the pipe is extremely important. In trench installations, as space is limited, mechanical compactors are commonly used but caution should be exercised so as not to damage or displace the pipe. The material should be compacted at near optimum moisture content and should be brought up evenly in layers on both sides of the pipe, withdrawing trench sheeting as backfill proceeds. Backfill material should not be pushed into the trench from the surface nor dropped in bulk directly onto the pipe.

Heavy mechanical equipment should not be allowed to traverse pipelines with limited cover except at prepared crossing places.

Fill material

Material for sidefill, initial and final backfill should be similar in character to the surrounding soil; for example, the use of single size granular material in clay soil will create a natural drainage channel that could cause subsequent settlement.

Sidefill and initial backfill should be free from large stones, heavy lumps of clay, frozen soil, tree roots and other rubbish, and should be readily compactable.

Sidefill

The sidefill should be placed and compacted as soon as possible after laying, or as soon as it is safe to do so without damaging concrete beddings. Compaction should be carried out evenly on each side of the pipe to prevent lateral or vertical displacement.

Initial backfill

This should also be placed as soon as possible in order to provide protective cover of not less than 300mm compacted depth. This should consist of bedding or selected material placed carefully and evenly over the top of the pipe and lightly compacted by hand.

Removal of trench supports

Trench sheeting should be removed as backfilling proceeds, where practicable as soon as it is safe to do so.

Remaining backfill

This should be placed evenly in layers and compacted as appropriate.

2.6 Testing

Acceptance tests on the completed pipeline give an indication of the level of control of workmanship and materials during construction.

Visual inspection

Check for: -

a) Obstructions and debris.

b) Structural soundness of pipes.

c) Joints properly sealed.

d) Line and level within tolerance.

Man entry sized pipelines can be physically inspected whilst smaller diameters can be visually inspected from manholes or by means of CCTV cameras.

Air and water tests

All lengths of drain and sewer up to DN 750 should be tested for leakage by means of air or water tests.

These tests should be carried out after laying and before backfilling. Some backfill may be placed at the centre of each pipe to prevent movement during testing. Short branch drains connected to a main sewer between manholes should be tested as one system with the main sewer. Long branches should be separately tested.

Air Test

The air test is more convenient than the water test, but the leakage rate cannot be measured accurately. An excessive drop in pressure in the air test may indicate a fault in the line such as a displaced sealing ring or it may be due to faults in the testing apparatus. Therefore, the first check must be on the apparatus, especially the seals of the stop ends and all connections.

The point of a leakage may be difficult to detect but spraying with soap solution could indicate such leakage by the presence of bubbles.

Failure to pass this test is not conclusive. When marginal failure does occur, a water test should be performed and the leakage rate determined before a decision on rejection is made.

Air test requirements are specified in 'Civil Engineering Specification for the Water Industry'.

It is strongly recommended that inflatable stoppers are used for air testing.

A successful test is achieved if the equipment shows a fall in pressure of no more than 25mm after 5 minutes, having allowed a suitable period for stabilisation.

If the pressure falls sharply and the pipes appear to have failed, check the test equipment is in good condition, that the stoppers are not leaking (use industrial soap around the edge of the stopper to provide an effective seal if necessary) and check the joint rings are correctly located or re-test after allowing temperature to settle.

A video on how to air test concrete pipelines is available at the CPSA channel in Youtube:
Link: https://www.youtube.com/watch?v=UdohjdbKP0o

Water Test

A water test is the more conclusive method of testing a completed pipeline but problems of availability and disposal of the quantity of water involved may cause difficulty. Before backfilling, leakage can be clearly located, its amount assessed and where necessary, appropriate remedies applied.

To test the pipeline:

a) Insert plugs in both ends of the drain or sewer and in connections if necessary. Precautions should be taken by strutting or otherwise, to prevent any movement of the drain or sewer during testing.

b) Fill the system with water ensuring all the air has been expelled.

c) Allow at least two hours before test readings are taken to permit conditions to stabilize, adding water to maintain test head.

It may be necessary to extend this period for large diameter pipes, up to twenty-four hours or more before a stable condition is reached.

d) Apply required test head at the upper end by means of a flexible pipe leading from a graduated container or stand pipe.

e) Apply the test pressure of 1.2m head of water above the soffit of the drain or sewer at the high end with a maximum of 6m head at the low end. If this exceeds 6m test the drain or sewer in stages.

f) Measure the loss of water over a period of 30 minutes by adding and metering quantities of water at intervals of 5 minutes to maintain original water level in the standpipe.

Over this 30 minute period, the quantity of water added should not exceed 0.05 litre per 100 linear metres per millimetre of nominal size of the drain or sewer.

For example:

For a 150m length of DN 800 pipe the allowable leakage would be:

$$0.05 \times \frac{150}{100} \times 800 = 60 \text{ litres}$$

Should the pipeline not comply with these requirements it will probably be attributable to one of the following:-

a) Leakage from test equipment.

b) Trapped air.

c) Leakage from joints, e.g. displaced ring.

d) Leakage from damaged or defective pipe.

3: INSTALLATION - JACKING PIPES

3.1 Introduction

The installation of pipelines for drainage purposes has traditionally been carried out using open-cut trenches in both urban and rural locations. However, in recent years an increasing proportion of pipeline construction projects have utilized pipe jacking or the form of the miniaturized tunneling technique known as microtunneling.

The basic pipe jacking method has been used in various forms for centuries but only in the past decades have we seen significant advances in equipment and technology.

This has raised confidence in the technique and numerous successful pipeline engineering schemes have used pipe jacking and microtunneling.

Normally, for pipelines constructed in this manner up to DN 900 the technique is referred to as microtunneling and above this as pipe jacking, but the principle remains the same.

3.2 Technique and equipment

The pipe jacking or microtunneling method consists of the construction of a number of excavated shafts from which a tunneling shield is launched and behind which a succession of smooth-walled concrete pipes are jacked. When the shield reaches the destination or reception shaft, it is either re-launched in a different direction or removed to another location and the process repeated. The excavated drive and reception shafts are usually converted to finished manholes once pipeline installation is complete.

Spoil excavated by the rotating cutting head in the front of the shield is removed by an auger flight or by mixing with water and pumping to the ground surface for treatment and disposal. Some progress has been made with the development of machines which can compact soil to the sides of the shield as it advances. Other equipment types use vacuum systems for the removal of excavated material to the surface.

Particularly high levels of installation accuracy can be achieved with these systems since they use sophisticated steering and guidance methods based on laser technology and optional automatic computer control. Finished bores have frequently been described "like rifle barrels". Equipment has been developed which can install pipes in small diameters down to DN150 for house connections and lateral drains without the need for a trench.

3.3 Advantages

The advantage of using a trenchless method can be substantial. Any attempt to dig up long trenches within an urban area often results in severe disruption, delays and diversions to traffic, environmental pollution through noise, dust and dirt, loss of profit for local businesses, damage to properties or other buried pipes and cables and so on. These items are usually referred to as social costs and are nearly always absorbed by the community rather than paid as direct engineering costs.

However, when one considers further, other equally serious problems become apparent. Sometimes, the as-dug material excavated from the trench is not suitable for re-use as backfill. This waste spoil must be transported away from the area and disposed at a suitable landfill site. Such sites are becoming more difficult to find and the cost of using them is increasing. Also, new backfill material such as crushed stone has to be imported to the site and these operations usually involve heavy wagons inflicting damage to roads and using fuel which in turn produces more pollution. These environmental costs are compounded by the damage and visual impact to the countryside from landfill and quarrying sites.

Pipe jacking and microtunneling can dramatically reduce many of these social and environmental problems. The technique offers significant benefits in reduced excavation since they only require relatively small launch and reception shafts for the tunneling equipment. Streets and roadways can often be kept open to traffic with little hindrance or disruption. The environment in general benefits from a no-dig approach because far less transportation of trench reinstatement materials is required, normally limited to only the displaced spoil from the pipes and manholes.

Reduced levels of reinstatement lead to cost savings, as much of the cost of a pipeline scheme is in the excavation and subsequent reinstatement. Installation depths of up to 35m have successfully been achieved which would not have been possible with open cut methods.

3.4 Products

The UK concrete pipe manufacturing industry is playing a leading role in the advancement of trenchless techniques. Several CPSA member companies produce jacking and microtunnelling pipes in a range of sizes. These pipes are manufactured to produce accurate joint surfaces with square faces and a strong high density concrete with a smooth surface finish to assist in reducing jacking forces.

Jacking and microtunneling pipes are available in sizes from DN 450 up to DN 2500 and utilise elastomeric seals in a steel banded joint. These pipes are manufactured to comply with the requirements of European Standard EN 1916:2002 and the UK complementary standard BS 5911-1:2002. The external surface of the pipeline is smooth for easy insertion through the ground during installation. For steel banded joints, both mild and stainless steel are available. Jacking pipes can be supplied with grout holes and cast-in lifting sockets as required.

Other products for use with this trenchless method include caisson sections in sizes from DN 2000 to DN4000 complete with base sections fitted with cutting shoe. Also produced are lead pipes which are rebated to accommodate the tunneling shield and interjack pipes (leading and trailing pipes in pairs) for use with intermediate jacking stations.

3.5 Further information

More information on the pipe jacking and microtunnelling method can be found in the publications of the Pipe Jacking Association (PJA) http://www.pipejacking.org/publications.

The United Kingdom Society for Trenchless Technology (UKSTT) is another useful source of information on trenchless techniques including pipe jacking.

4: INSTALLATION - MANHOLES

Manholes may be installed using fresh concrete to construct the base, channels and benching in-situ or by using a precast base system where units are manufactured and delivered to site with predetermined positions for connecting pipework using flexible, watertight elastomeric joints.

4.1 Planning

Sequence of operations

a) Place the bottom unit with either integral precast or in-situ concrete base.

b) Erect the required number of standard components and seal the joints as appropriate in accordance with the design/chosen method of construction.

c) Place a precast reinforced concrete cover slab on top.

d) If required, place a corbel slab then add the appropriate number of adjusting units.

e) Fit the access cover and frame.

4.2 Handling and storage

1) Chamber rings may be supplied with lifting holes for the use with specialist lifting pins and chain/sling sets. Alternatively they may have pins cast into them for use with universal head-links and chain/sling sets.

2) Cover, landing and reducing slabs are usually cast with anchors allowing the use of hook and chain/sling sets.

Note: Apparatus used for lifting, may not necessary be suitable for the transporting of products across a site.

Other lifting methods may be available or available to order – check with manufacture for full details.

All products should be lifted individually.

Chamber rings must not be lifted by attaching lifting equipment to steps.

Chamber rings should be stored 'chimney' fashion i.e. not on their side, or rolled.

Chamber rings and all types of slabs should be stacked on level and stable ground and on timbers wherever possible.

4.3 Construction

To ensure that the manhole structure is vertical, accurate levelling of the formation for the precast base unit or the in-situ concrete foundation is essential.

Shaft and chamber sections with tongued and grooved joints should be installed with the socket / groove facing upwards, whereas units with ogee joints should have the spigot upwards.

Precast cover slabs can be installed onto the shaft or chamber rings (with appropriate mastic, mortar or seal). Suitable cover and frame can then be bedded on adjusting units to achieve the finished level required.

Note that the distance from ground level to the first step in the manhole is usually specified as not to exceed 675mm (where units are fitted with step or ladder system).

Jointing to pipeline

To allow for differential settlement between manhole and pipeline, short "butt" pipes, either

spigot or socket, should be built into the wall of manholes constructed with an in-situ concrete base and a flexible joint incorporated as close as possible to the outside of the manhole wall or concrete surround, if used.

Depending on ground conditions, short length pipes (rockers) then connect the butt pipes to the incoming pipe runs. Additional care must be taken to ensure that the joints are properly made.

4.4 Jointing

Precast manhole components are provided with joints formed within the wall section. These are rebated or tongued and grooved and are sealed with proprietary mastic seals, sand / cement mortar, or with elastomeric joints. Precast concrete manhole units, well jointed, provide an adequate seal under normal conditions. Any lifting holes will need to be sealed with sand / cement mortar or a proprietary non-shrink mortar.

Joint strips typically have a thickness of 12mm and are offered in one or two layers as demonstrated in the table below.

Fig. D1 Examples of Manhole Joints

a) Cover, Landing and reducing slab joints

(DN675-1200)   (DN 1350-3000)

1 or 2 strips
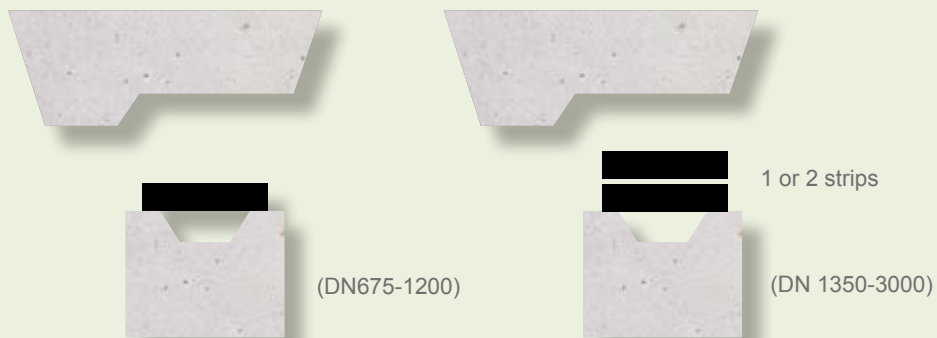
Reducing slab, shaft and chamber joint

b) Tongue and groove   c) Ogee

Other joints

d) Landing platform joint

1 or 2 strips
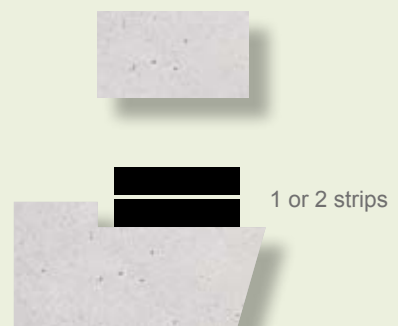
Fig. D2 Example of Manhole Joint with Elastomeric Seal

Load Distribution Seal

Joint
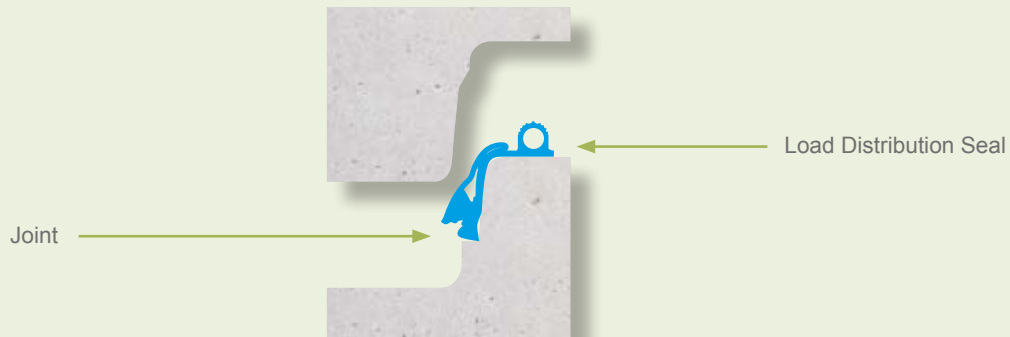
4.5 Reinstatement

In-situ concrete surround

In-situ concrete surround to precast concrete manholes, except for side-entry manholes, is unnecessary other than for exceptional structural reasons such as embankments, in sloping or unstable ground, where there is a large opening into the manhole, where it is a requirement due to a permanent head of water or where an individual specification requires it i.e. as in some types of adoptable manholes specified in Sewers For Adoption.

Note: Sewers For Adoption includes for the use of thicker walled (minimum 125mm thick) manhole rings without the requirement for a concrete surround.

Side entry manholes should be provided with a suitably designed GEN 3 concrete surround of at least 150mm thick extending the whole length of the pipe in which the manhole is placed.

Backfilling

As each precast manhole section is placed, backfill should be returned in layers and compacted as for pipelines. Backfill must be brought up evenly around the manhole to prevent displacement. Additionally, care should be taken to avoid damaging the connecting pipelines.

Special consideration should be given where construction plant is working in the vicinity of manholes. Where possible, traffic should be routed away from such structures and may require temporary protection with heavy steel plates or temporary additional cover material.

4.6 Testing

It is generally unnecessary to apply water tests to manholes. In working conditions manholes are not normally full of water. This only happens under rare conditions of surcharge. Prevention of infiltration is of more relevance than exfiltration and where this occurs, it can be remedied by sealing using an appropriate method.

Where testing of manholes is required, see Sewers For Adoption or Civil Engineering Specification for the Water Industry for suitable method.

5: REFERENCES AND FURTHER READING

	5.1 British Standards		
1	BS EN 197-1:2011 Cement. Composition, specifications and conformity criteria for common cements.	2011	BSI
2	BS EN 206:2013 Concrete. Specification, performance, production and conformity.	2013	BSI
3	BS EN 450 (various parts) Fly ash for concrete.	2005-2015	BSI
4	BS EN 681-1:1996 – Elastomeric seals. Material requirements for pipe joint seals used in water and drainage applications. Vulcanised rubber.	1996	BSI
5	BS EN 752:2008 Drain and sewer systems outside buildings.	2008	BSI
6	BS EN 1295-1 Structural design of buried pipelines under various conditions of loading – Part 1: General requirements.	1996	BSI
7	BS 1881 (various parts) Testing Concrete.	1983-2015	BSI
8	BS EN 1916 – Concrete pipes and fittings, unreinforced, steel fibre and reinforced.	2002	BSI
9	BS EN 1917 – concrete manholes and inspection chambers, unreinforced, steel fibre and reinforced.	2002	BSI
10	BS 4449: 2005+A3:2016 Steel for the reinforcement of concrete. Weldable reinforcing steel, Bar, coil and decoiled product. Specification.	2016	BSI
11	BS 4482:2005 Steel wire for the reinforcement of concrete products. Specification.	2005	BSI
12	BS 4483:2005 Steel fabric for the reinforcement of concrete. Specification.	2005	BSI
13	BS 5911 – 1 : 2002 + A2 : 2010 - Specification for unreinforced and reinforced pipes	2002	BSI
14	BS 5911 – 3 : 2010 + A1:2014 - Specification for unreinforced and reinforced manholes and soakaways.	2010	BSI
15	BS 5911 – 4 : 2002 +A2 : 2010 - Specification for unreinforced and reinforced inspection chambers.	2010	BSI
16	BS 5911 – 6 : 2004 + A1 : 2010 - Specification for road gulley and gulley cover slabs.	2010	BSI
17	BS 6031:2009 Code of Practice for earthworks.	2009	BSI
18	BS 8500-1: 2015+A1 Concrete. Complementary British Standard to BS EN 206. Method of specifying and guidance for the specifier.	2016	BSI
19	BS 8500-2: 2015+A1 Concrete. Complementary British Standard to BS EN 206. Specification for constituent materials and concrete.	2016	BSI
20	BS EN ISO 9001:2015 - Quality management systems: Requirements.	2015	BSI
21	BS 9295:2010 Guide to the structural design of buried pipelines.	2010	BSI
22	BS EN 13101:2002 Steps for underground man entry chambers. Requirements, marking, testing and evaluation of conformity.	2002	BSI
	- BS EN 16933-2 Drain and sewer systems outside buildings — Design. Part 2: — Hydraulic design (expected in 2017) - Also see SuDS references on page 16		

5.2 Industry References			
1	Sewers for Adoption 6th and 7th Editions	March 2006 & August 2012	Water UK / WRc
2	Sewers for Adoption 6th Edition – Combined Addendum	March 2006	Water UK / WRc
3	Civil Engineering Specification for the Water Industry (CESWI) 7th edition	March 2011	WRc
4	Simplified Tables of External Loads on Buried Pipelines	1986	
5	Guide to Design-Loadings for Buried Pipelines (Out of print)	1983	TRL HMSO
6	Tables for the Hydraulic Design of Pipes, Sewers and Channels 8th edition	2005	HR Wallingford and D H Barr
7	Specification for Highway Works	2001	Department of Transport HMSO
8	An introduction to pipe jacking and microtunnelling design	1995	Pipe Jacking Association PJA
9	Guide to Best Practice for the Installation of Pipe Jacks and Microtunnels	1995	Pipe Jacking Association (PJA)
10	Concrete in Aggressive Ground - BRE Special Digest 1	2005	BRE
11	Imported Granular and Selected As-dug Bedding and Side Fill Materials for Buried Pipelines Water Industry Specification 4-08-01	1994	WRc
12	Precast Concrete Pipes - Unreinforced and Reinforced, with Flexible Joints - Water Industry Specification 4-12-01	1991	WRc
13	Specification for Polypropylene Encapsulated Steps for Use in Manholes and Access Chambers - Water Industry Specification 4-33-01	1990	WRc
14	Specification for Flexible Couplings for Gravity Sewage and Drainage Pipes - Water Industry Specification 4-41-01	1993	WRc

5.3 Relevant Organisations

British Precast The Old Rectory Main Street Glenfield LE3 8DG	• Telephone: +44 (0) 116 232 5170 • Fax: +44 (0)116 232 5197 • info@britishprecast.org • www.britishprecast.org
British Water Vox Studios Unit V03 1-45 1 Durham Street London SE11 5JH	• Telephone: 02035670950 • info@britishwater.co.uk • www.britishwater.co.uk
BRE Building Research Establishment Garston, Watford WD25 9XX	• Telephone: +44 (0)1923 664000 • Fax: +44 (0)1923 664010 • enquiries@bre.co.uk • www.bre.co.uk
BSI British Standards Institution 389 Chiswick High Road London W4 4AL	• Telephone: +44 (0)20 8996 9000 • Fax: +44 (0)20 8996 7001 • cservices@bsi-global.com • www.bsi-global.com
CIRIA Griffin Court 15 Long Lane London EC1A 9PN	• Telephone: +44 (0) 20 7549 3300 • Fax: +44 (0) 20 7549 3349 • enquiries@ciria.org • www.ciria.org.uk
EA Environment Agency Head Office Horizon House Deanery Road Bristol BS1 5AH	• Telephone: 03708 506 506 • enquiries@environment-agency.gov.uk • www.environment-agency.gov.uk
Highways England Bridge House, 1 Walnut Tree Close, Guildford GU1 4LZ	• Telephone: 0300 123 5000 • info@highwaysengland.co.uk • www.highwaysengland.co.uk
Office of Public Sector Information / The Stationery Office (Previously HMSO) TSO Orders/Post Cash Dept PO Box 29 Norwich NR3 1GN	• Telephone: +44 (0)870 600 5522 • Fax: +44 (0)870 600 5533 • customer.services@tso.co.uk • www.tso.co.uk
HR Wallingford (Formerly HRS) HR Wallingford Ltd, Howbery Park Wallingford Oxfordshire OX10 8BA	• Telephone: +44 (0) 1491 835381 • Fax: +44 (0) 1491 832233 • info@hrwallingford.co.uk • www.hrwallingford.co.uk
PJA Pipe Jacking Association 10 Greycoat Place London SW1P 1SB	• Telephone: +44 (0)845 0705201 • Fax: +44 (0)845 0705202 • secretary@pipejacking.org • www.pipejacking.org

TRL Transport Research Laboratory Crowthorne House Nine Mile Ride Wokingham Berkshire RG40 3GA	• Telephone: +44 (0)1344 773131 • Fax: +44 (0)1344 770356 • enquiries@trl.co.uk • www.trl.co.uk
UKSTT United Kingdom Society for Trench- less Technology 38 Holly Walk Leamington Spa Warwickshire CV32 4LY United Kingdom	• Telephone: +44 (0)1926 330 935 • Fax: +44 (0)1926 330 935 • admin@ukstt.org.uk • www.ukstt.org.uk
UK Water Industry Research Ltd BCSC 8th Floor 50 Broadway, London SW1H 0RG	• Telephone: +44(0)20 7152 4537 • mail@ukwir.org.uk • www.ukwir.org/
Water UK 3rd Floor 36 Broadway London SW1H 0BH	• Telephone: +44 (0)20 7344 1844 • info@water.org.uk • www.water.org.uk
WRc plc Frankland Road Blagrove Swindon Wiltshire SN5 8YF	• Telephone: 01793 865000 • Fax: 01793 865001 • solutions@wrcplc.co.uk • www.wrcplc.co.uk

For further information contact:

Concrete Pipeline Systems Association

The Old Rectory, Main Street
Glenfield, Leicester
LE3 8DG
Tel: 0116 232 5170
Fax: 0116 232 5197
email@concretepipes.co.uk
concretepipes.co.uk