Clay Pipe Development Association Ltd

(TN12) The specification, design and construction of drainage and sewerage systems using vitrified clay pipes

Contents

Advice on the design of drains and sewers in vitrified clay may be obtained from the Association

Clay Pipe Development Association Ltd.,
Copsham House,
53 Broad Street,
Chesham,
Bucks.,
HP5 3EA

Tel: 01494 791456 **Fax: 01494 792378** **email: cpda@aol.com**

Price £5.00 / 7.00 EURO

The specification, design and construction of drainage and sewerage systems using vitrified clay pipes

Foreword

Using updated material previously published within a range of smaller CPDA booklets, this guide provides a one-stop source for the bulk of information needed for the specification, design and construction of drains and sewers using vitrified clay pipes.

Where a greater depth of information is required from structural design or flow tables [1] or on the subject of hydrogen sulphide in sewers [2], copies of the original booklets are currently still available.

Introduction

On 1st November 1991 a new British and European standard, BS EN 295 [3], was published to replace BS 65:1988 for flexibly jointed vitrified clay pipes and fittings, with or without sockets, for the construction of drainage and sewerage systems. The same European standard, EN 295, is used in all the 18 countries of CEN, the European Committee for Standardisation, prefixed by the appropriate National standards organisation identifier, such as BS in Britain, DIN in Germany, or AE in Spain. EN 295 was the first European pipe standard.

The design and construction of sewers and drains in the United Kingdom has been largely controlled over recent years by the provisions of BS 8005 [5], the Guide to new sewerage construction, and BS 8301 [6], the Code of practice for building drainage. The other principal reference documents in these fields are the Civil Engineering Specification for the Water Industry [7], Sewers for Adoption [8], the Scottish Standard Specification for Water and Sewerage Schemes [9] and Approved Document H to the Building Regulations [10], together with the equivalent building regulations documents for Scotland [11] and Northern Ireland [12]. These documents are generally based on the material in BS 8005 [5] and BS 8301 [6].

The publication during 1997 and 1998 of new European standards covering the design and construction of drains and sewers has changed this picture. The standards are BS EN 752 - Drain and sewer systems outside buildings [13], BS EN 1295-1 - Structural design of buried pipelines under various conditions of loading [14] and BS EN 1610 - Construction and testing of drains and sewers [15]. They have become the references to be used in specification documents and with this, some of the procedures to be adopted have been changed, although not as many as might be imagined.

Each standard sets out basic provisions, common to all user countries, and provides annexes giving additional information by referencing for each country existing National standards, codes and guides, such as those referred to earlier, together with other relevant technical information.

In areas where existing National methods needed to be retained, specific National annexes are provided to the standards. For British standards, these National annexes largely contain the familiar information from BS 8005 and BS 8301, brought up to date where necessary. In this way, most pre-existing design and construction practices will not need to change with the advent of the European standards. Two exceptions to this are in revised design methods for flow prediction in BS EN 752-4 and pipeline testing procedures in BS EN 1610.

Scope of this document

In the following pages, the way in which the normal range of planning, design and construction issues for drains and sewers are dealt with by the current European standards is outlined.

Bracketed references are given throughout the text to the relevant standard and clause number. Each National annex clause is designated by the letter N and a main subject letter, followed by a sub-clause number. Thus, BS EN 752-3 NB.3 is the unique reference for the National annex section on rodding eyes in BS EN 752 part 3.

This document is not designed to replace the advice given in the standards, to which reference should be made for detailed guidance.

Materials

General (BS EN 752-3 NA.1)
Materials for pipes, pipe joints, pipe bedding, fittings, inspection chambers, manholes and associated works should be selected to ensure satisfactory service for the life of the drainage or sewerage system. Factors to be taken into account include:-

(a) The nature of the effluent and the possibility of chemical attack.
(b) The possibility of mechanical attack from cleansing processes such as jetting, or rodents.
(c) The nature of the ground and the possibility of subsidence or chemical attack.
(d) The physical and chemical characteristics of the materials.
(e) The expected quality of workmanship.
(f) The degree of supervision to be provided.

Resistance to chemical attack (BS EN 752-3 NA.2)
Pipes and joints in the materials shown in the following list are generally considered to be suitable for sewers and drains conveying effluents that may

legally be discharged to public sewers. Specific material limitations need to be considered if they are to be laid in ground that may be corrosive or used to carry corrosive effluents, particularly at elevated temperatures, or where septicity may develop.

Clay as a material

Clay pipes are resistant to chemicals within the pH range 3-11. They are not subject to attack by sulphuric acid produced where septic sewage conditions give rise to the production of hydrogen sulphide and can carry a wide range of aggressive effluents. They can be laid in aggressive ground conditions without damage, such as where sulphates are present. Selected products can cover the wider pH range of 2-12. Extra chemically resistant pipes and joints are also available.

Clay pipes resist mechanical cleaning methods, such as rodding and winching because of their high strength and durability. They are also impervious to rodent attack.

Recent research conducted by WRc recognised that high jetting pressures are used by pipeline cleaning contractors, especially when clearing blockages. Clay pipes are resistant to pressures in excess of the 5,000 psi subsequently shown as the highest acceptable pressure in the WRc code of practice on jetting[16], produced after the research programme.

British and European Standards for pipe materials and associated items

Vitrified Clay	BS EN 295 & BS 65
Concrete	BS 5911 (prEN 1916)
Polyethylene	BS 6437, CP 312
Polypropylene	BS EN 1852-1
Cast Iron	ISO 694 (prEN 877)
PVC-U	BS EN 1401
Ductile Iron	BS EN 598
GRP	BS 5480
Plastic manholes	BS 7158
Manhole covers and gully gratings for roads	BS EN 124
Bedding materials for pipes	BS EN 1610,

The specification of clay pipes to BS EN 295 1-7

BS EN 295 Part 1 specifies the requirements for appropriate dimensions, tolerances and performance of flexibly jointed pipes, fittings and joints for drains and sewers. Two amendments to this part of the standard have so far been published, which have principally increased the available range of pipe strengths and jointing systems.

It is supported by BS EN 295 Part 2, which specifies the quality control and sampling requirements for the manufacturer's internal quality control procedures, third party assessment and inspection. BS EN 295 Part 3 specifies the test methods used to verify compliance with the requirements specified in BS EN 295 Part 1.

BS EN 295 Part 4 was published in September 1995 and covers the requirements for special fittings, adaptors and compatible accessories. These include repair couplings, which are used to repair existing pipelines, to make post connections to pipelines by inserting purpose made junctions or to connect pipes of different materials or outside diameters. They are required to have the same joint performance as the joints specified in BS EN 295-1 for internal pressure, angular deflection and shear resistance.

The requirements for perforated pipes are covered in BS EN 295 Part 5, published in August 1994. Perforated pipes are used for the construction of french drains, land drains and the drainage of waste tips. The same basic specification requirements apply as for pipes to BS EN 295 Part 1, except that joints are not required to be watertight and the size and distribution of the perforations are specified.

The requirements for vitrified clay manholes and inspection chambers are specified in BS EN 295 Part 6, published in April 1996.

The last part of the standard, BS EN 295 Part 7, also published in April 1996, gives the requirements for pipes used for pipe jacking. The dimensional requirements are more stringent than those in BS EN 295 Part 1, particularly in respect of squareness of pipe ends, straightness of pipe barrel and tolerances on outside diameter. The method for obtaining the compressive strength and the maximum jacking force are given.

A revised version of BS 65[4] was also published in 1991, covering the specification of items which were not within the scope of the European standard. These are pipes, fittings and flexible joints for surface water applications, extra chemically resistant pipes and ducts.

Definitions

Important definitions provided by the standard (BS EN 295-1 1.3) include:- Nominal size (DN) - A numerical designation of size which is a convenient round number equal to or approximately equal to the bore in millimetres; Curvature - The angle subtended by the length of a curved fitting at the centre of a circle of nominal radius through the centreline of the fitting; Joint assembly - The adjacent ends of pipes, fittings or adaptors and the means of joining them.

Materials

Pipes and fittings are required to be made from suitable clays and be properly fired to vitrification (BS EN 295-1 2.1). Visual imperfections are permitted, provided that the major performance characteristics of pipes, such as durability, impermeability and flow, are unaffected. Pipes and fittings may be unglazed or glazed and the glaze may be on either their interior or exterior surfaces, or on both.

Pipes

Minimum bore

The minimum permissible bore of pipes is given in the standard (BS EN 295-1 2.2) and the values for current UK pipe sizes are shown in Table 1.

Table 1 - Minimum bore of UK pipe sizes

Nominal size (DN)	100	150	225	300	400	450	500	600
Minimum bore (mm)	96	146	219	293	390	439	487	585

Length

The limits of tolerance on the nominal length of pipes (BS EN 295-1 2.3) are required to be – 1 % + 4 %, measured to the nearest whole mm, with minimum limits of tolerance of ±10 mm. The same tolerance applies to the nominal length of straight fittings.

Squareness of ends

To ensure good joints, pipe ends should be as square as possible to the longitudinal axis of the pipe. Any deviation from squareness must not be greater than 6 mm for pipes of up to and including 300 mm nominal diameter and not greater than 2 % of the nominal size for larger pipes. (BS EN 295-1 2.4)

Straightness

The maximum permissible deviation from straightness of pipe barrels is specified (BS EN 295-1 2.5). It decreases with increasing pipe diameter and is measured to the nearest whole millimetre per metre of nominal length.

Table 2 - Permissible deviation from straightness

DN <150	DN ≥150 ≤250	DN >250
5.0	4.5	4.0

Strength testing

Pipes are preconditioned prior to crushing strength, bending moment resistance, fatigue or bending tensile tests. This is carried out in the UK by completely immersing the pipes in water for the minimum period of time shown in Table 3 (BS EN 295-3 4.1.1).

Table 3 - Minimum preconditioning times

Pipe wall thickness	All pipes other than ceramic glazed pipes	Ceramic glazed pipes
mm	hours	hours
Up to 20	18	42
>20 ≤35	42	66
>35	66	90

Crushing strength (FN)

Minimum crushing strength values for pipes or pipe sections are specified in two ways (BS EN 295-1 2.9).

For 100 and 150 mm diameter pipes specific values are given of 22, 28, 34 and 40 kN/m, with higher strengths permitted in steps of 6 kN/m.

For larger pipes, crushing strengths are given according to class numbers, as shown in table 4 below for UK pipe sizes.

Table 4 - Currently available crushing strengths (FN) in kN/m - for UK pipe sizes greater than DN200

Nominal Size (DN)	Class Number				
	95	120	160	200	240
225		28	36	45	54
300		36	48	60	72
375		45	60		
400		48	64	80	
450	43	54	72		
500		60			
600	57	72			

A formula is provided so that the crushing strengths of other nominal sizes and higher crushing strengths may be calculated.

$$\text{Crushing strength} = \frac{\text{Class number} \times \text{DN}}{1000} \quad \text{in kN/m}$$

The class numbers to be used are 95, 120, 160 and 200, or higher numbers in further increments of 40.

Bending moment resistance

Extensive research in the UK established the bending moments that occur in clay pipelines.

Minimum bending moment resistance values for pipes of sizes DN100 to DN225 and nominal lengths greater than 1.1 m are given in the standard (BS EN 295-1 2.9), shown in table 5 for UK pipe sizes.

Higher values may be required if higher crushing strengths are declared.

Table 5 - Bending moment resistance (BMR) kN.m for crushing strength values (FN) in kN/m

Pipe size (DN)	FN	BMR	FN	BMR	FN	BMR	FN	BMR
100	22	1.0	28	1.3	34	1.7	40	2.0
150	22	2.8	28	3.4	34	4.0	40	4.6
225	28	6.5	36	7.4	45	9.0	54	10.6

Fittings

The dimensional and performance requirements to be applied to each group of fittings are defined in part 2 of the standard (BS EN 295-2 Table 2).

Table 6 - Requirements for fittings

Fittings	Minimum bore *	Length	Water seal	Angle of curvature	Branch angle	Imperm-eability
Taper & splay pipes	√	√				√
Access & inspection pipes & chambers Channels & taper channels	√	√				
Bends, taper bends & rest bends	√			√		√
Channel bends, access & inspection bends, saddles and oblique saddles.	√			√		
Junctions	√	√			√	√
Channel junctions, access junctions, taper channel bends	√	√		√	√	
Trapped gullies,low back traps, syphons and interceptors	√		√			
Trapless gullies, hoppers and raising pieces	√					

The symbol "√" shows where the BS EN 295-1 requirement is applicable. * Applies to pipeline connections only.

Water seal of fittings
Trapped fittings have a minimum water seal depth of 50 mm (BS EN 295-1 2.6).

Bends
Bends may be made to a range of preferred nominal curvatures on which tolerances are specified (BS EN 295-1 2.7). Other values of curvature are acceptable as long as the necessary performance requirements are met and the bend is properly marked.

Table 7 - Tolerance on curvature of bends

Angle of curvature	Tolerance
11.25° and 15°	± 3°
22.5° and 30°	± 4°
45° and 90°	± 5°

The radius of bends, measured to the neutral axis, is not less than the nominal size in mm, except for knuckle bends which are only allowed for the smaller sizes of pipes up to DN150.

Angle of junction arms
Junction arms (BS EN 295-1 2.8) are usually fixed at an angle of 45° or 90° to the main pipe, with a tolerance of ± 5°. Other angles are acceptable as long as the necessary performance requirements are met and the junction is properly marked.

Strength of adhesive
The adhesive used for fixing fired clay parts together is tested by means of a bending tensile strength test (BS EN 295-1 2.12). Both the adhesive and the adhesive/clay interface should stay intact under a bending tensile force of 5 N/mm^2 either dry or after immersion in a range of test solutions.

Watertightness of pipes, bends and junctions
Pipes, bends, junctions and pipe sections are tested for watertightness (BS EN 295-1 2.14) at a pressure of 50 kPa (0.5 bar or approx. 5 m head of water).

Airtightness
Pipes, bends, junctions and pipe sections are tested for impermeability using an air test (BS EN 295-1 2.18). Barrels are subjected to an initial air pressure of 100 mm water gauge, which may not drop below 75 mm water gauge, in 5 minutes for pipes up to and including DN 225, 7 minutes for larger pipes up to and including DN 300, 10 minutes up to and including DN 400 and 14 minutes up to and including DN 600.

Optional requirements
A number of optional requirements, needed for special applications, are specified, with test methods given in BS EN 295-3. These are Bending tensile strength; Fatigue strength under pulsating load; Chemical resistance; Hydraulic roughness and Abrasion resistance.

Joint assemblies

Jointing material
Rubber sealing elements and are specified to be in accordance with BS EN 681-1 [17] (BS EN 295-1 3.1.1) Requirements for polypropylene sleeve couplings are also specified.

Internal and external pressure
Joint assemblies remain watertight during angular deflection and shear resistance tests under both internal (BS EN 295-1 3.2.1) and external (BS EN 295-1 3.2.2) pressures of 5 kPa (0.05 bar) and 50 kPa (0.5 bar).

Angular deflection
For the angular deflection test, one pipe in a joint assembly is deflected with respect to the other by a specified amount (BS EN 295-1 table 9) and the assembly subjected to the internal and external test pressures specified for 5 minutes. There should be no visible leakage.

Shear resistance
An external shear load is applied to one pipe in a joint assembly which is then required to withstand the internal and external pressures specified (BS EN 295-1 3.4) for 15 minutes without visible leakage.

Joints which pass this shear load test are considered to be resistant to root penetration.

Invert conformity
A limit to the difference in invert levels between adjacent socketted pipes is specified (BS EN 295-1 3.5). For pipes up to and including DN300 this limit is 5mm, rising to 1 % of DN for the largest pipes.

Joint interchangeability
Tables 11 and 12 in BS EN 295-1 specify the interchangeability of joints by means of specified control dimensions and tolerances for a range of different jointing systems.

For socketted pipes, the internal diameter of the socket or socket fairing is the controlling dimension, whereas for sleeve-jointed pipes, the mean value of the outside diameter of the spigot is the controlling dimension.

Within a given dimensional jointing system, pipes and fittings of the same nominal size and the same strength are directly interchangeable.

There is no interchangeability between pipes and fittings of the same size and different strengths.

Other dimensional jointing systems with different controlling dimensions are permitted, under a range of specified conditions (BS EN 295-1 3.6).

Manufacturers of such jointing systems are required to offer, where necessary, adaptors to connect to the dimensional requirements of the systems given in tables 11 and 12.

Chemical and physical resistance to effluent
Joint assemblies withstand constant internal pressures of 5 kPa (0.05 bar) and 50 kPa (0.5 bar) without visible leakage, after exposure to specified test solutions (BS EN 295-1 3.7).

Thermal cycling and long term thermal stability
Joint assemblies remain watertight under internal pressures of 5 kPa (0.05 bar) and 50 kPa (0.5 bar), after withstanding both specified cyclic temperature changes (BS EN 295-1 3.8), without visible impairment, and a long-term thermal stability test (BS EN 295-1 3.9).

Sampling for tests
Sampling procedures and rates of sampling are given in BS EN 295-2, which specifies the requirements for manufacturer's internal quality control, third party assessment and inspection. Details are provided for all the sampling necessary for pipes, fittings and joints for routine, regular and optional tests.

Designation
The standard details a system of designation for the description of pipes and fittings (BS EN 295-1 5), which sets out in a standard format the name of the item, the standard reference, the nominal size, the strength and the jointing system. Examples are:-

PIPE EN 295-1 - DN300 - FN48 - D, which is a 300 mm diameter socketed pipe to BS EN 295 Part 1, of 48 kN/m strength and jointing system D.

BEND 45 EN 295-1 - DN225 - FN45 - E, which is a 225 mm diameter sleeve jointed bend to BS EN 295 Part 1, of 45 kN/m strength and jointing system E.

Marking
Marking should preferably be impressed before firing or be indelibly marked after firing (BS EN 295-1 6.1) and should cover the following information:-

The standard reference, the identification symbol of the third party certification body (BSI Kitemark), the manufacturers identification, the date of manufacture, the nominal size and the dimensional jointing system.

Crushing strength in kN/m and bending moment resistance in kN.m are mrked on pipes, if applicable.

Flexible mechanical joints, connectors and adaptors are also appropriately marked.

Products can only be marked with the standard number, EN 295-1 if they have been certified in accordance with the quality assurance requirements of BS EN 295-2 by a third party certification body.

Quality Assurance
The quality assurance requirements for all products manufactured to BS EN 295-1 are given in BS EN 295-2, which requires the manufacturer to have a quality system to EN ISO 9002 [18]. This provides third party assessment to ensure compliance with the requirements of the standard and also the assessors must be accredited as complying with EN 45011 [19] and 45012 [20], the general criteria for certification bodies operating product certification & quality system certification respectively.

Performance requirements (BS EN 752-2)

General

Drain and sewer systems need to convey and discharge their contents without causing unacceptable environmental nuisance and risk to public health or workers (BS EN 752-2 clause 5). The basic performance requirements for drains and sewers (BS EN 752-2 clause 6) are:-

(a) Pipes should not block and both sewer surcharge and flooding frequencies should be limited to prescribed values.
(b) Access is needed for maintenance purposes.
(c) Pipelines have to be watertight and structurally sound for their design life and they should not endanger adjacent structures and services.
(d) Public health and life, health and safety of operator personnel have to be safeguarded.
(e) Receiving waters have to be protected from pollution, odour nuisance and toxicity.

The hydraulic design performance of surface water or combined sewers is governed by the chosen design storm frequency. A range of these is given (BS EN 752-2 clause 6, table 1) to provide a simple but safe approach for smaller schemes, for use with rainfall intensity and duration figures for the area and indicating predicted design flooding frequencies and is shown in table 8 below.

Table 8 - Design Storm Frequencies

Design storm frequency, no surcharge to occur (return period in years)	Location (type of area)	Design flooding frequency (once in 'n' years)
1	Rural area	1 in 10
2	Residential area	1 in 20
2 (with model flood check) 5 (without model flood check)	City centre/ industrial/ commercial areas	1 in 30
10	Underground railway/ underpass	1 in 50

Testing and assessment of the performance of drain and sewer systems is required during construction, on completion and during their operational life. This includes air, water and infiltration tests, visual and CCTV inspection, dry weather flow assessment and monitoring of inputs, effluent quality, toxic or explosive gases and the discharge to treatment works (BS EN 752-2 clause 7).

A wide range of records (BS EN 752-2 clause 8) can be used to provide the data to properly assess system performance, for example of the incidence of blockages, collapses, flooding and surcharge, compliance with discharge consents and health related issues.

Many of these records will be held by the relevant authorities and all appropriate records should be retained.

Access to Drains & Sewers (BS EN 752-3)

Access is required to drainage and sewerage installations for testing, inspection, maintenance and removal of debris (BS EN 752-3 NB.1). The guiding principle is that each pipeline length should be accessible for maintenance and rodding without the need to enter buildings (BS EN 752-3 NB.1).

BS EN 752-3 Table NB.1 indicates the recommended maximum distance between rodding eyes, access fittings, inspection chambers and manholes. These are based on standard manual rodding techniques and the need for removing debris and are shown in table 9.

Table 9 - Maximum distance between access points (m)

Distance in metres from:	To access fitting type 1 *	To access fitting type 2 **	To junction or branch	To inspection chamber	To man-hole
Start of external drain	12	12	-	22	45
Rodding eye	22	22	22	45	45
Access fitting type 1 (min 150x100)	-	-	12	22	22
Access fitting type 2 (min 225x100)	-	-	22	45	45
Inspection chamber	22	45	22	45	45
Manhole	-	-	-	45	See NB. 2.2 & 2.3

Access fittings are pipework fittings having a small opening in the crown of the pipe, forming a chamber. Access is available for inspection, testing and cleaning in both directions. Type 2 ** fittings are larger than Type 1 *.

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

Minimum internal dimensions and cover sizes for all types of access fittings, inspection chambers and manholes are shown in Table NB.2, with associated permissible depths to invert of the drain or sewer.

In the case of clay and plastic inspection chambers the minimum 'clear' cover opening may be reduced to provide proper support for the cover and frame.

General guidance is provided in the standard for the construction of inspection chambers and manholes (BS EN 752-3 NB.4.4.1). This includes a requirement to use rocker pipes at inspection chambers, manholes and other fixed points.

Specific guidance is also given on the use of brick, pre-cast concrete and in-situ concrete chambers (BS EN 752-3 NB.4.4.2 to NB.4.4.4). Channels and benching, deep manholes, backdrop manholes and access to manholes are also dealt with (BS EN 752-3 NB.4.5 to 4.10.3).

Hydraulic Design - Wastewater flows

Methods

The hydraulic design of wastewater flows in drains and sewers outside buildings (BS EN 752-4 NC.1) is based on either the probability method or on the population method. The probability method is normally used for drainage design.

The methods give different results and generally the population method should be used if the probability method gives a pipe size larger than DN 150.

Pipeline roughness (BS EN 752-4 NB.2)

For wastewater and combined flows, BS EN 752-4 Table NB.1 shows a value of 0.6 mm where the peak dwf velocity typically exceeds 1.0 m/s and a value of 1.5 mm where the peak dwf velocity is between 0.76 m/s & 1.0 m/s.

The same hydraulic roughness value is used for all pipe materials, based on extensive research into the behaviour of drains and sewers in service.

Drains and sewers up to DN 150 (BS EN 752-4 NC.2)

The probability method has been used for the design of above ground drainage since 1978 (BS 5572[21]) and below ground drainage since 1985 (BS 8301[6]). It is based on the assignment of discharge units to each appliance under consideration which take into account their relative hydraulic load-producing effect in terms of both flow rate and frequency. These are added together to give the peak flow rate in discharge units for the drain.

The European standard EN 12056-2[22] updates this method. Different discharge unit values are allotted to appliances in relation to the particular form of internal drainage system in use.

The values appropriate to the UK system of using a single stack system with full-bore discharge pipes (System III) are given in Table 3 of the standard. Annex C to BS EN 752-4 provided a solution to the values to be chosen in the form of ranges until EN 12056-2 was published (BS EN 752-4 NC.2.2).

The discharge units for each appliance under consideration are added together to give the peak flow rate in discharge units.

It can be seen from table 10 that the values given in EN 12056-2 fall within the limits of the published ranges in EN 752-4.

BS EN 752-4 NC.2.2 states that 3.0 discharge units per dwelling should be used where several are connected to a length of drain or sewer, subject to a minimum flow of 1.6 l/s.

Table 10 - Discharge units for sanitary appliances

Appliance	Discharge units (DU) (EN12056-2)	Discharge units (DU) (EN752-4)
Wash basin, bidet	0.3	0.3 – 0.6
Shower without plug	0.4	0.3 – 0.6
Shower with plug	1.3	-
Single urinal with cistern	0.4	0.3 – 0.8
Slab urinal	0.2*	-
Bath	1.3	0.8 – 1.3
Kitchen sink	1.3	0.8 – 1.3
Dishwasher (household)	0.2	0.2 – 0.8
Washing machine up to 6 kg	0.6	0.5 – 0.8
Washing machine up to 12 kg	1.2	1.0 – 1.5
WC 6.0 litre cistern	1.2 - 1.7**	1.2 – 2.5
WC 7.5 litre cistern	1.4 - 1.8**	
WC 9.0 litre cistern	1.6 – 2.1**	

* per person
** depending on type (valid for WC's with siphon flush)

The total number of discharge units may then be converted into a flow rate in litres per second using the following equation:-

$$Q_{ww} = K \sqrt{\sum DU} \qquad (1)$$

where:- Q_{ww} = waste water flow rate in l/s
K = frequency factor (see table 11)
$\sum DU$ = sum of discharge units

Table 11 - Typical frequency factors (K)
(BS EN 752-4 annex C and EN 12056-2 clause 7.3.2)

Usage of appliances	K
Intermittent use, e.g. in dwelling, guesthouse, office	0.5
Frequent use, e.g. in hospital, school, restaurant, hotel	0.7
Congested use, e.g. in toilets and/or showers open to the public	1.0
Special use, e.g. in a laboratory	1.2

The informative annex B in EN 12056-2 gives a table of waste water flow rates for a range of discharge unit totals calculated in accordance with equation (1), as shown in table 12.

Table 12 - Waste water flow rates

Sum of discharge units $\sum$ DU	Flow Q_{ww} in l/s			
	K = 0.5	K = 0.7	K = 1.0	K = 1.2
10	1.6	2.2	3.2	3.8
12	1.7	2.4	3.5	4.2
14	1.9	2.6	3.7	4.5
16	2.0	2.8	4.0	4.8
18	2.1	3.0	4.2	5.1
20	2.2	3.1	4.5	5.4
25	2.5	3.5	5.0	6.0
30	2.7	3.8	5.5	6.6
35	3.0	4.1	5.9	7.1
40	3.2	4.4	6.3	7.6
45	3.4	4.7	6.7	8.0
50	3.5	4.9	7.1	8.5
60	3.9	5.4	7.7	9.3
70	4.2	5.9	8.4	10.0
80	4.5	6.3	8.9	10.7
90	4.7	6.6	9.5	11.4
100	5.0	7.0	10.0	12.0
110	5.2	7.3	10.5	12.6
120	5.5	7.7	11.0	13.1
130	5.7	8.0	11.4	13.7
140	5.9	8.3	11.8	14.2
150	6.1	8.6	12.2	14.7
160	6.3	8.9	12.6	15.2
170	6.5	9.1	13.0	15.6
180	6.7	9.4	13.4	16.1
190	6.9	9.6	13.8	16.5
200	7.4	9.9	14.1	17.0
220	7.6	10.4	14.8	17.8
240	7.7	10.8	15.5	18.6
260	8.1	11.3	16.1	19.3
280	8.4	11.7	16.7	20.1
300	8.7	12.1	17.3	20.8
320	8.9	12.5	17.9	21.5
340	9.2	12.9	18.4	22.1
360	9.5	13.3	19.0	22.8
380	9.7	13.6	19.5	23.4
400	10.0	14.0	20.0	24.0

A total flow rate may then be obtained by adding continuous flows and pumped flows. With this flow rate a pipe diameter and suitable gradient can be selected from appropriate tables or charts such as those referred to in Appendix A.

Drains and sewers larger than DN 150

The method of design generally adopted for sewers and drains larger than DN150 is based on population and a rate of flow per head per day (BS EN 752-4 NC.1). The rate of flow is identified in BS EN 752-4 Annex B as between 150 and 300 l/head/day and the peak design flow as up to 6 times domestic flow rate. The values chosen for use in design will vary according to the characteristics of the area being designed for and the needs of the sewer owner. The diameter and gradient selected should be adequate for the maximum flow and to maintain self-cleansing velocity under normal discharge conditions.

A minimum velocity of 0.7 m/s is required for drains and sewers up to DN300. Higher velocities may be needed for larger sewers and information is available in CIRIA Report 141 [23].

Pipeline gradients (BS EN 752-4 NA.2.2)

The following guidelines on gradients are accepted as normally providing self cleansing conditions:

(a) For flows of less than 1 litre per second, pipes not exceeding DN100 need to be laid at gradients not flatter than 1:40.

(b) Where the peak flow is more than 1 litre per second, a DN100 pipe may be laid at a gradient no flatter than 1:80, provided that at least one W.C is connected.

(c) DN150 pipe may be laid at a gradient not flatter than 1:150, provided that at least five WC's are connected.

For gradients flatter than those given in above, high standards of design and workmanship are necessary and are most effective where buildings are close together, so that the lengths of drains or sewers are short. Exceptionally, where runs are long, gradients may have to be steepened. (BS EN 752-4 NA.2.2)

Research has shown that steep gradients do not cause increased erosion of pipes or deposition of solids and drains should be laid at gradients which are most economical in terms of excavation and cost.

Hydraulic design – Surface water flows (BS EN 752-4 11.3.2)

Methods

Flow rates for surface water drains for areas requiring a main surface water drain of up to 200 m length are normally calculated using a flat rate of rainfall (typically 50 mm/hr).

The peak flow rate is given by $Q = \Psi\, i\, A$ (2)

where: Q = peak flow rate in l/s
Ψ = dimensionless runoff coefficient
(Approximate values for Ψ are given in Table 13)
i = rainfall intensity in l/s.ha
A = horizontal area receiving rainfall in ha

Table 13 - Runoff coefficient values

Nature of connected area	Runoff coefficient Ψ	Comments
Impermeable areas & steeply sloping roofs*	0.9 to 1.0	Depending on depression storage
Large flat roofs	0.5	Over 10,000 m^2
Small flat roofs	1.0	Less than 100 m^2
Permeable areas	0.0 to 0.3	Depending on ground slope & cover

* Impermeable areas may be increased by 30 % for large vertical surfaces

For larger areas flow simulation methods are used (BS EN 752-4 Annex D). These may be simple empirical methods, where the flow is regarded as uniform and steady; kinematic wave methods, which can simulate uniform unsteady flow; or dynamic wave methods, in which non-uniform unsteady flow can be simulated, even under surcharge and backwater conditions. Further details of their use are given in BS EN 752-4 Table D.1.

The necessary rainfall information is explained in BS EN 752-4 ND and may be of either a constant rate or time varying profile, depending on the particular design method to be used. Detailed design of the drainage of paved areas is covered in BS EN 752-4 NE. The design of flow detention facilities has become important with the need to maximise the use of surface water sewers and other outfall facilities and their design is covered in (BS EN 752-4 NF). Soakaway design is covered in BS EN 752-4 NG.

Pipeline roughness (BS EN 752-4 NB.2)
For surface water flows, where sliming is not a major factor, a roughness value of 0.6 mm is used in design to reflect the effect of grit in the pipeline (BS EN 752-4 NB.2.2). The same hydraulic roughness value is used for all pipe materials, based on extensive research into the behaviour of drains and sewers in service.

Structural Design (BS EN 1295-1)

The structural design of buried pipelines is specified in BS EN 1295-1 [14], which gives general requirements. These demand (BS EN 1295-1 5.1 & 5.2) that all significant loads are taken into account, including backfill, surface surcharge and traffic. Longitudinal effects including bending moments need to be considered (BS EN 1295-1 5.4), using information from the product standards. For clay pipes these are covered by the requirements specified in BS EN 295-1 for bending moment resistance, which ensure that they will not fail in bending before reaching their design crushing load.

The structural design is required to ensure that an adequate level of safety is provided against the appropriate ultimate limit state being exceeded, that is where the pipe ceases to behave in the manner intended in the structural design. For a clay pipe this means structural failure. In addition, the design loading must not cause any appropriate serviceability limit state to be exceeded. Examples of such serviceability limits are buckling and deformation of flexible pipes.

Clay pipes have high inherent structural strength and can better accommodate poor standards of workmanship or supervision during construction than plastics pipes which have little intrinsic physical strength and demand high quality bedding and sidefill to avoid deformation. The acceptable limit for this deformation is specified in WRc External Report ER201E [24] and restated in the Materials Selection Manual for Sewers, Pumping Mains and Manholes [25] as 6 %, for the long term deformation of the pipe. The flexible joints of a clay pipe system allow its use in areas where subsidence may be expected, using the appropriate design details.

The various national methods of design are identified in annex B of the standard so that they can continue to be applied in their respective countries. The National Annex contains full details of the calculation procedure for the UK established method of design, including design formulae, procedural flowcharts, recommended values for variables in the formulae, graphical surcharge vehicle load information and rigid pipe bedding factors. In this method, for rigid pipes, soil loads are calculated from the geostatic earth pressure using Marston's theory and surcharge loads, such as traffic, using Boussinesq's theory (BS EN 1295-1 B.2.12.1.3).

Figure 1 shows the precise terminology for various parts of a pipe trench installation used in European standards (BS EN 1295-1 Figure 1)

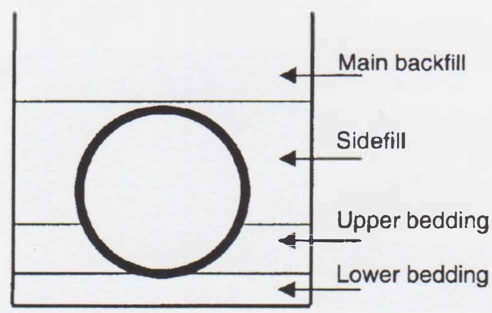


Figure 1 - Pipe trench installation

The design of bedding for pipelines is based on the principle that the ability of a rigid pipe, such as a clay pipe, to carry a load may be increased by a factor determined by the provision of suitable bedding (the bedding factor). Bedding factor values have been established by research and accepted for various standard types of installation (BS EN 1295-1 B.2.12.1.6).

In 1988 the water industry published Information and Guidance Note 4-11-02 [26] giving revised bedding factors for clay pipes (BS EN 1295-1 B.1.12) and these are illustrated in figure 2, together with class D and N beddings (BS EN 1295-1 NA.7).

Flexible pipes deform under the application of load and require support from surrounding material, and thus from the sides of the pipe trench, in order to avoid excessive deformation of the pipe.

The load on a pipeline depends on the diameter of the pipe, the depth at which it is laid, the trench width, and the traffic, or other superimposed loading (BS EN 1295-1 7.1 & 7.2).

It should be noted that wide trench conditions give the maximum load for any width of trench.

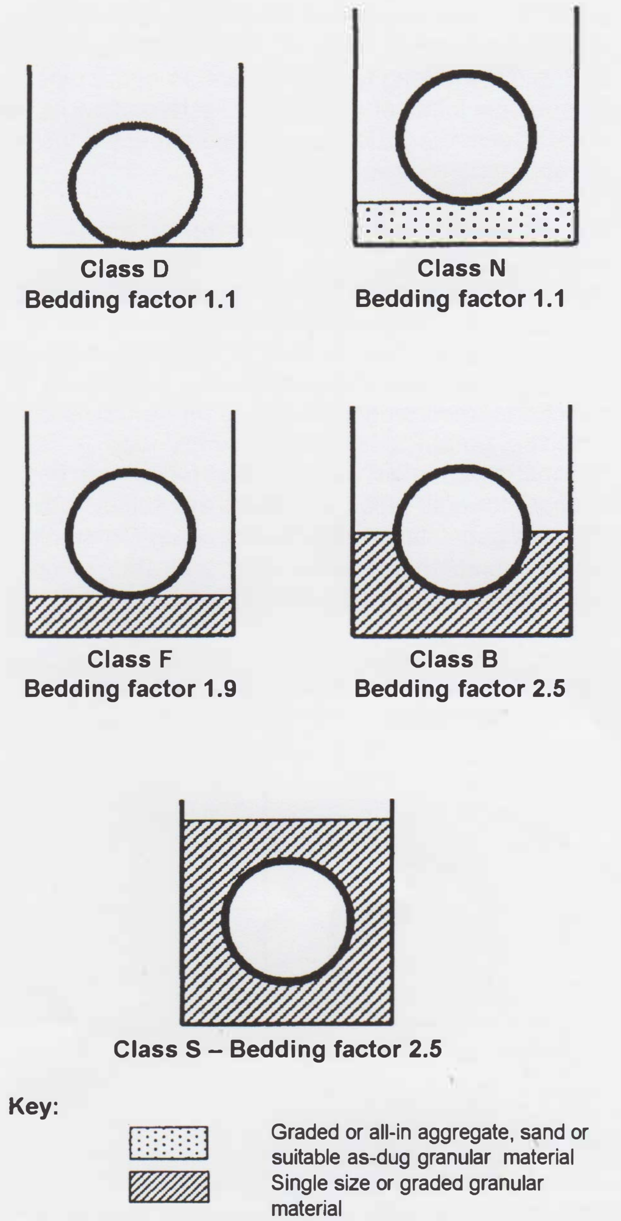


Figure 2 - Bedding factors for pipe bedding classes

Design guides and tables are referenced in BS EN 1295-1 B.1.12, including the CPDA Bedding Tables[1]. Design tables for backfill and traffic loads taken from the CPDA Tables are given in Appendix B and these are used to calculate the total load on a pipeline which, together with the pipe strength, will allow the required bedding factor to be calculated.

Table 14 shows the limits of cover between which vitrified clay pipes with commonly available strengths from BS EN 295 Part 1 can be laid in any width of trench under Fields and Gardens & Main Road loading.

It should be noted that laying pipes with less than 1.0 m of cover requires precautions to be taken besides those needed to resist the calculated loads upon them. Special note should be taken of the effects of construction traffic and the loads due to construction processes, such as compaction of trench backfill and shallow overlying layers such as road sub-base material.

Table 14 - Strengths, beddings and depths of cover

Nominal diameter mm	Bedding construction Class	Crushing strength kN/m	Main roads m	Fields & gardens m
100	D or N	28	0.4 - 5.7	0.4 - 6.0
		40	0.4 - 8.5	0.4 - 8.6
	F	28	0.4 - 10.0+	0.4 - 10.0+
		40	0.4 - 10.0+	0.4 - 10.0+
	B or S	28	0.4 - 10.0+	0.4 - 10.0+
		40	0.4 - 10.0+	0.4 - 10.0+
150	D or N	28	0.7 - 3.4	0.6 - 4.0
		40	0.6 - 5.5	0.6 - 5.8
	F	28	0.6 - 6.9	0.6 - 7.1
		40	0.6 - 10.0+	0.6 - 10.0+
	B or S	28	0.6 - 9.3	0.6 - 9.4
		40	0.6 - 10.0+	0.6 - 10.0+
225	D or N	36	0.9 - 2.6	0.6 - 3.5
	F	36	0.6 - 5.9	0.6 - 6.2
	B or S	36	0.6 - 8.0	0.6 - 8.2
300	D or N	36	-	0.6 - 2.5
		48	0.8 - 2.7	0.6 - 3.5
	F	36	0.6 - 4.2	0.6 - 4.6
		48	0.6 - 6.0	0.6 - 6.2
	B or S	36	0.6 - 5.9	0.6 - 6.2
		48	0.6 - 8.1	0.6 - 8.3
375	D or N	36	-	0.9 - 1.9
		45	-	0.6 - 2.7
	F	36	0.7 - 3.2	0.6 - 3.9
		45	0.6 - 4.5	0.6 - 5.0
	B or S	36	0.6 - 4.8	0.6 - 5.2
		45	0.6 - 6.3	0.6 - 6.6
400	D or N	38	-	0.9 - 1.8
		48	-	0.6 - 2.6
		64	0.8 - 2.9	0.6 - 3.7
	F	38	0.8 - 3.0	0.6 - 3.8
		48	0.6 - 4.4	0.6 - 4.9
		64	0.6 - 6.3	0.6 - 6.5
	B or S	38	0.6 - 4.6	0.6 - 5.1
		48	0.6 - 6.2	0.6 - 6.5
		64	0.6 - 8.5	0.6 - 8.6
450	D or N	43	-	0.8 - 1.9
		54	-	0.6 - 2.7
	F	43	0.7 - 3.2	0.6 - 3.9
		54	0.6 - 4.5	0.6 - 5.0
	B or S	43	0.6 - 4.8	0.6 - 5.2
		54	0.6 - 6.3	0.6 - 6.6
500	D or N	48	-	0.8 - 1.9
		60	-	0.6 - 2.7
	F	48	0.7 - 3.2	0.6 - 3.9
		60	0.6 - 4.5	0.6 - 4.9
	B or S	48	0.6 - 4.8	0.6 - 5.2
		60	0.6 - 6.3	0.6 - 6.6
600	D or N	48	-	-
		57	-	0.8 - 1.9
	F	48	1.0 - 2.1	0.6 - 3.2
		57	0.7 - 3.2	0.6 - 3.9
	B or S	48	0.6 - 3.8	0.6 - 4.4
		57	0.6 - 4.8	0.6 - 5.2

As evidence of the strength of clay pipes, Table 14 shows that, under main traffic roads, DN100 clay pipes of 40 kN/m strength can be laid at up to 8.5 m cover on a trimmed trench bottom and at over 10.0 m cover on a flat bed (Class F) of granular material. DN 600 clay pipes of 57 kN/m strength can be laid at up to 3.2 m depth on a flat bed (Class F) of granular material. It is evident that the majority of clay pipe drains and sewers do not structurally require large amounts of granular bedding material, unlike flexible pipes, which need appropriate surrounding material in order to limit deformation and prevent buckling (BS EN 1295-1 B.2.12.1.4)

Construction

Excavation and preparation of trench (BS EN 1610 clause 6)

General
The construction and testing of drains and sewers is specified in BS EN 1610 [15]. This begins with trench excavation and the provision of adequate trench support where necessary to ensure stability and safety (BS EN 1610 6.3). Care should be taken to limit loads close to the edge of the trench, such as excavated material, which should be no closer than 1.5 m to any trench. Particular ground conditions may require detailed consideration as described in subsequent sections. For example, in the case of unstable ground such as running sand or silt, additional measures such as dewatering operations (BS EN 1610 6.5) or consolidation by freezing or chemical means may be necessary.

In wet, fine grain soil such as soft clays, silts or fine sands, suitable blinding or other stabilising material should be placed on the virgin soil immediately after the last cut and before any traffic is permitted on the trench bottom to prevent disturbance and softening of the foundation. The use of a filter fabric is also effective in preventing movement of fine material, both on the trench bottom and around pipe bedding, as described in the section on waterlogged ground.

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

Soft spots
Pockets of peat, chalk slurry or unconsolidated ground occurring below formation level should be removed if practicable and replaced with suitable well-compacted material (EN 1610 clause 7.1).

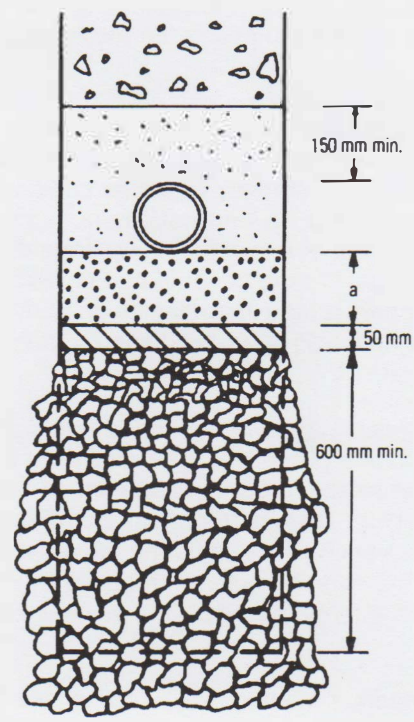
In mixed non-uniform soil containing soft spots, rock bands or boulders, the foundation should be tested at suitable intervals and soft spots hardened by tamping in suitable material. Hard spots should be generously undercut and large boulders removed. The resulting holes should be filled with suitable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

Rock
In rock, the bottom should be trimmed and screeded either with concrete or with not less than 200 mm of bedding material so that there is no rock projection that could damage the pipes. Where first class workmanship and supervision can be guaranteed and where the variation in depth of bed does not exceed 25 mm and the socket depression 25 mm, the minimum depth of granular bed may be 100 mm.

Soft ground
Where the trench formation has little bearing strength and will not support pipe bedding material effectively, it is necessary to provide a stable formation before pipelaying. Such conditions most commonly occur in peat, silty ground, soft to very soft alluvial clays, running sand, or in artificially filled ground and running sand. (BS EN 1610 7.1 & 7.3)

Although trench formations are sometimes stabilised with concrete, this is unlikely to assure long-term stability in all cases, and a form of flexible bedding construction is the preferred method of dealing with this situation. (BS EN 1610 7.1 & 7.3)

The trench formation and manhole base should be over-excavated by 600-800mm, depending on the bearing strength of the ground. Gravel reject material or small hardcore, less than 75 mm, is then compacted in layers to form a firm trench bottom. A 50 mm thickness of lean-mix concrete is then placed as blinding. The pipe is then laid on granular bedding material. These details are shown in Figure 3.



Note: Dimension a, the depth of the bedding material below the pipe, is 150 mm for sleeve jointed pipes and 200 mm for socketed pipes.

Key:

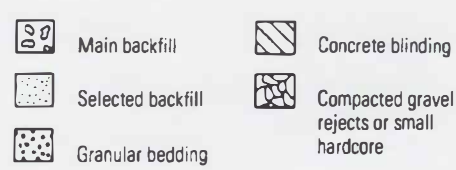


Figure 3 - Class F bedding construction in soft ground

The pipe bedding construction requirements are calculated in the normal way, for example by using the Association's Bedding Tables [1], Appendix B or table 7. It is important that "wide trench" design criteria are used because "narrow trench" conditions cannot be guaranteed in this situation. The extra depths of granular bedding material shown in Figure 3, 150 mm for sleeve-jointed pipes and 200 mm for socketted pipes, rather than the usual 50mm and 100 mm respectively, are required because of the hard nature of the constructed trench bottom.

For a class F bedding, selected backfill material is then placed to 150 mm above the pipe and compacted before the main backfill is placed. Where class B or class S beddings are required, additional bedding material will either partially or wholly replace the selected backfill material.

Where groundwater exists at a level above the interface between the rejects and the new trench bottom, the procedure detailed for waterlogged ground should also be applied (Ref. 28 4.3.2). The geotextile should surround both the material in the base of the trench as well as the pipe bedding material. The use of a geotextile around the compacted material in the base of the trench will also assist compaction in exceptionally soft ground conditions, as well as limiting the movement of fines.

Waterlogged ground
Moving groundwater at a level above trench formation in fine grained soils can reduce the strength of pipe beddings. Granular bedding material encourages water movement and this washes fines out of the surrounding ground, causing a loss of support to the bedding and pipeline. This may occur particularly in peat, silty ground, soft to very soft alluvial clays, running sand or artificially filled ground.

The traditional method of dealing with this problem was to include a proportion of coarse sand in the bedding material in order to fill the interstices that might otherwise take up the fine material from around the trench. This limits the movement of fines, but the bedding material requires much more compaction energy than if it were single sized or graded.

A more effective method is to wrap the whole of the bedding construction, including any additional compacted material in the trench bottom as detailed for soft ground, in a geotextile as shown in Figure 4.

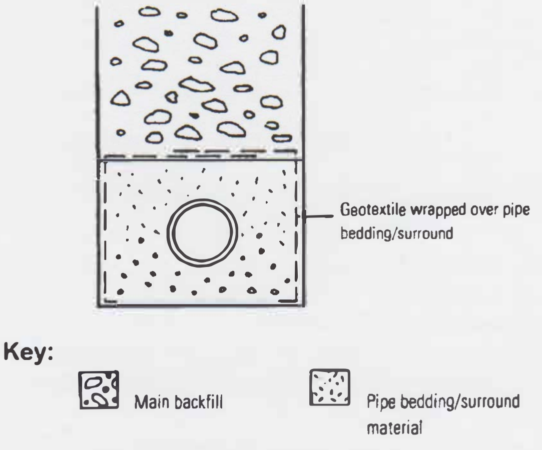


Figure 4 - Use of geotextile around pipe bedding

This will allow the movement of water through the bedding material, but will tend to prevent the movement of fine material, and retain it in the ground around the trench (BS EN 1610 11.2, Ref. 28 fig. 7 & 4.3.2, Ref. 29 fig. 2). In such conditions measures are also needed to prevent similar movement of fines under manholes. The geotextile construction should be continued around the outside of the manhole excavation and under any manhole bedding material. The specification for the geotextile, particularly the pore size, should be related to the nature of the fines in the ground, and specialist advice may need to be sought on this.

Prior to commencing pipelaying it is essential to satisfactorily dewater the trench formation. Any well point dewatering must also be suitably filtered to prevent continuous removal of fine sands and silts. Sump pumping from the end of the trench is not recommended even when filtered, as instability of the formation can arise.

'Drag-box' or similar trench support systems should not be used in waterlogged fine grained soils because the pipe and bedding are likely to be disturbed when the support is removed. Steel or timber sheet trench support systems are recommended. They should not be driven or extracted with vibratory hammers and backfilling should proceed progressively as the support system is removed.

Laying pipes

Laying pipes on the trimmed trench bottom - (BS EN 1610 clauses 7.2.2 and 7.2.3)
Where the design permits and the nature of the ground is such as to allow it to be trimmed to provide a uniform bearing, pipes may be laid direct on the trench formation so that their barrels make reasonable contact with the formation. The bottom will be suitable if the formation can be hand trimmed with a spade and is not puddled when walked upon.

Socket and joint holes should be as short as practicable, scraped or cut into the formation, and deep enough to give a minimum clearance of 50 mm between the socket and the formation. For clay sleeve jointed pipes only shallow scraped joint holes are required to accommodate the coupling. This type of bedding is defined as Bedding construction type 3 (BS EN 1610 7.2.3) and is shown in figure 5 as Class D bedding (BS EN 1295-1 NA.7).

Laying pipes on granular beds (BS EN 1610 clause 7 and 8)
Defined as Bedding construction type 1, the granular bedding material should be placed to invert level and should usually extend to the full width of the trench (BS EN 1610 7.2.1). Gradings for the granular materials to be used for pipe bedding are specified in tables B.15 to B.17 of Appendix B to BS EN 1610, which also specifies the standards that define the materials themselves. These are BS 882 [34], BS 1047 [35] and BS 3797 [36].

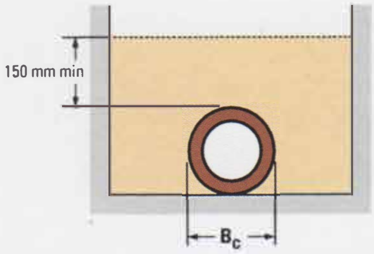


Figure 5 - Class D - Trimmed trench bottom
Bedding factor 1.1 (Ref. 14)

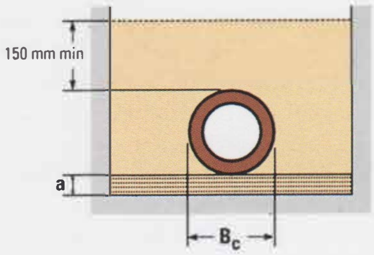


Figure 6 - Class N - Granular or "as-dug" material
Bedding factor 1.1 (Ref. 14)

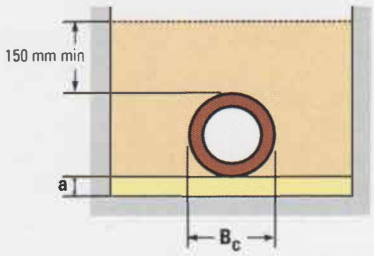


Figure 7 - Class F - Granular material
Bedding factor 1.9 (Refs. 14 & 46)

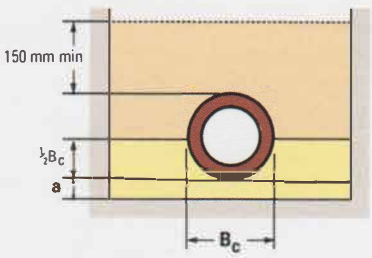


Figure 8 - Class B - Granular material
Bedding factor 2.5 (Refs. 14 & 46)

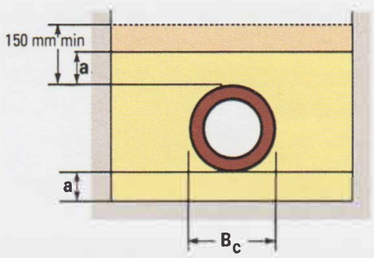


Figure 9 - Class S - Granular material
Bedding factor 2.5 (Refs. 14 & 46)

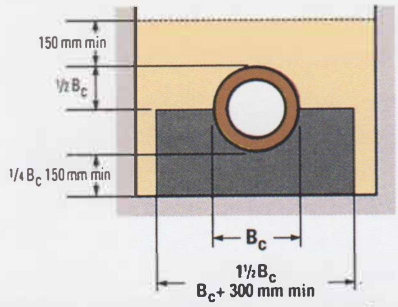


Figure 10 - Unreinforced concrete bed
Bedding factor 2.6 (Refs. 27 & 28)

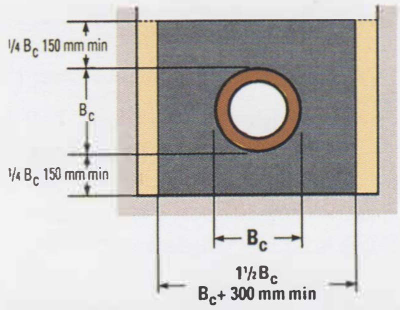


Figure 11 - Unreinforced concrete surround
Bedding factor 4.5 (Ref. 30)

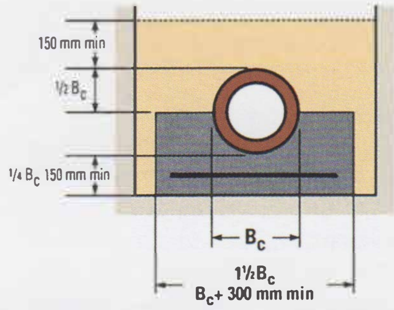


Figure 12 - Reinforced concrete bed
Bedding factor 3.4 (0.4 % steel) (Refs. 27 & 28)

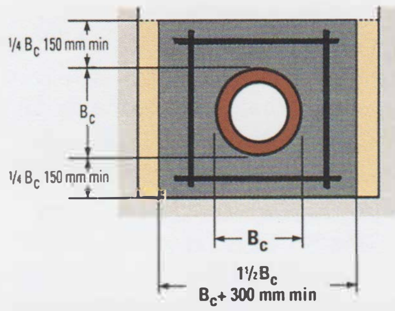


Figure 13 - Reinforced concrete surround
Bedding factor 4.8 (2x 1.0 % steel) (Refs. 27, 28 & 30)

Key

- Vitrified clay pipe
- Graded or all-in aggregate or compacted sand or suitable as-dug material
- Fill selected from excavated material and lightly compacted by hand
- Concrete with 28 day cube strength
- Single size or graded granular material
- Undisturbed natural soil

Class N bedding – Figure 6
For Class N bedding these materials may be used:-

All-in aggregate
All-in aggregate should conform to the grading requirements of table B.17 from BS EN 1610 [15] and can be of 20 mm nominal size for all pipe sizes.

Sand
Sand may be coarse, medium or fine and should conform to the gradings of BS EN 1610 [15]table B.16.

As dug material or recycled construction waste
As dug material or recycled construction waste is suitable where it has a compaction fraction of up to 0.3 (Ref. 38) and does not exceed 20 mm nominal size, or 40 mm for 600 mm or larger diameter pipes.

Classes F, B and S beddings – Figures 7, 8 & 9
It should be noted that the bedding factors for classes F, B and S beddings illustrated in figure 2 and figures 7, 8 and 9 are normally achieved using the following single sized or graded aggregates:-

Single size granular material
Single size granular material should conform to the appropriate grading requirements of table B.15 from BS EN 1610[15]. Nominal single sizes of 10 mm, 14 mm or 20 mm may be used for pipe sizes from 100 mm to 500 mm diameter and 14 mm, 20 mm or 40 mm may be used for pipe sizes larger than 500 mm.

Graded granular material
Graded granular material should also conform to the appropriate grading requirements of table B.15 from BS EN 1610[15]. 14 to 5 mm or 20 to 5 mm may be used for all pipe sizes and in addition 40 to 5 mm may be used for pipes of larger than 500 mm.

Recycled material
Recent research into the structural performance of clay pipes laid on a variety of types of recycled materials, published in Ceram Research Paper 815 [47] has shown that these may be safely used for bedding clay pipes with normal bedding factors achieved over both graded and "all-in" materials, with a range of compositions ranging from all concrete to "as-received" general construction and demolition waste.

Recycled material is applicable to all bedding classes, N, F, B and S. To achieve the normal bedding factors of 1.1, 1.5, 1.9 and 2.2 respectively the compaction fraction of the recycled material should not exceed 0.3. For the enhanced bedding factors applied to clay pipes (see IGN 4-11-02 [26]) this should not exceed 0.2. The material is specified for use as either RCA(II) concrete or RCA(III) concrete and brick to the requirements of BRE Digest 433, Recycled material [48]. Additional information is available in the CPDA Technical Note No. 9 [49].

Depth of bedding material (See IGN 4-08-01 [46])
The depth of bedding material below the pipe is dimensioned as "a" in figures 5, 6, 7 and 8 and is:-

In machine-dug uniform soils: a = for sleeve jointed pipes, a minimum of 50 mm or $^1/_6$ B_c, whichever is the greater, for socketed pipes a minimum of 100 mm or $^1/_6$ B_c, whichever is the greater under barrels but not less than 50 mm under sockets.

In rock or mixed soils containing rock bands, boulders, large flints or stones or other irregular hard spots: a = for sleeve jointed pipes, a minimum of 150 mm or $^1/_4$ B_c, whichever is the greater, for socketed pipes a minimum of 200 mm or $^1/_4$ B_c, whichever is the greater under barrels but not less than 150 mm under sockets.

Placing bedding material
The bedding material for the specified bedding class is placed as required in the lower bedding, upper bedding, sidefill and initial backfill areas, as defined in figure 1 (BS EN 1295-1 NA.7).

Socket holes should be formed at each joint position (BS EN 1610 8.5.4). These should be deep enough to prevent the weight of the pipe and the load upon it bearing on the socket or coupling and should be a minimum of 50 mm deep, leaving a minimum depth of 50 mm of bedding material beneath the joint. For clay sleeve jointed pipes and couplings (not socketed) this permits a minimum bedding depth construction of 50 mm under couplings and pipes to be specified (BS EN 1610 7.2.1).

Placing side fill material
Side fill of either granular or selected backfill material, depending on the class of bedding, should be placed evenly on either side of a rigid pipe taking care not disturb the line and level. Bedding material should not be compacted in the socket holes. The side fill should be placed to the top of the pipe and hand compacted in 150 mm layers, ensuring that the line of laid pipeline is not disturbed. The initial backfill should be placed to 150 mm above the crown of the pipe and this layer also hand compacted.

Selected fill, whether selected from locally excavated material or imported, should consist of uniform, readily compactible materials, free from vegetable matter, building rubbish, frozen material, materials susceptible to spontaneous combustion. It should also exclude clay of liquid limit greater than 80 and/or plastic limit greater than 55 and materials of excessively high moisture content. Clay lumps and stones retained on 75 and 37.5 mm sieves respectively should be excluded from the fill material.

It should be noted that the side support for flexible pipes depends upon the extent and the degree of compaction of the bedding and the nature of the surrounding soil. For this reason, flexible pipes should be installed with specified bedding materials which allow appropriate compaction.

Placing backfill material
As soon as pipes are jointed, bedded, tested and approved, selected material and backfill should be placed. The minimum thickness of the initial backfill over the pipe barrel shall be 150 mm (BS EN 1610 7.1) with a minimum of 100 mm over the joint.

For clay pipes with class D, N, F or B beds, selected material from the trench excavation can be used as sidefill above the bedding, or for the layer directly above the pipes, provided it is readily compactible and excludes stones retained on a 14 mm sieve, hard lumps of clay retained on a 100 mm sieve, timber, frozen material, vegetable and foreign matter. For class D, N or F bedding selected material should be placed under the haunches of the pipe, care being taken not to displace the pipe from its correct line and level.

Mechanical compaction equipment should not be used until there is a minimum of 450 mm of compacted material above the crown of the pipe. The need for effective compaction is important at all stages to minimise subsequent settlement.

Laying pipes with concrete beds or surrounds
Bedding or surrounding a pipe in concrete may be required in some cases. The indiscriminate use of concrete for pipe beddings can cause problems unless carefully specified procedures are adopted. (BS EN 1295-1 Table NA.7, Ref. 5 12.6.6 & Ref. 6 20.4, Ref. 27 11.1, Ref. 28 9.6)

The trench formation should provide a firm foundation for the concrete bed or its value in strengthening the pipeline will be lost.

It may therefore be necessary to seal or firm up the trench bottom before laying the concrete bedding using a blinding layer of weak concrete or granular material. It may also be necessary to excavate soft spots and compact in some more suitable material, such as granular bedding material or small hardcore.

It is important that the following minimum dimensions for concrete bedding or surround are used in order to ensure that the specified bedding factors are realised. Any concrete bed or surround should extend at least 150 mm either side of the pipe. The depth of concrete below the pipe, and above the pipe for a surround, should be at least 150 mm or one quarter of the outside diameter, whichever in the greater.

Where pipes are laid on blocks, at least two layers of bitumen damp-proof sheeting complying with BS 743 [29] should be placed between the blocks and the pipes. This allows the pipes to be uniformly supported by the concrete after normal setting shrinkage has occured. Rigid supports under the pipes must be removed as concrete is placed.

The flexibility of a pipeline bedded on or surrounded with concrete should normally be maintained by the provision of flexible construction joints through the concrete at each pipe joint. These should be made from bitumen impregnated insulating board complying with BS EN 622-4 [31] or other equally compressible material such as expanded polystyrene. The board should be cut to fit the pipes, and placed at the face of sockets or at one end of sleeve joints. Where more uniform support of the pipeline is found, the construction joints may be less frequent.

Where large shear forces may be expected to occur at construction joints because of heavy imposed loads, it is preferable to omit flexible construction joints and to longitudinally reinforce the concrete bed to obviate possible excess shear forces causing pipeline failure. Examples are on shallow pipelines under main roads or on very deep pipelines. However, it is necessary to introduce one flexible construction joint at least every 5 m length, keeping the longitudinal reinforcement continuous, so as to avoid problems due to the expansion and shrinkage of the concrete. This construction joint should be positioned at the face of a pipe joint.

All concrete for pipe bedding should be of structural quality, with a minimum 28 day cube strength of 20 N/mm (Ref. 27, 11.1), and should be thoroughly compacted into place. Care should be taken in placing concrete so as not to move pipes or construction joints.

No load shall be applied within the 24 hour period immediately after the completion of placing the concrete, except for an uncompacted protective layer of selected backfill material. Mechanical compaction should not be used and traffic loads should not be imposed until at least 72 hours after completion of concreting (Ref. 6 18.3.2, Ref. 27 fig 6 & 11.1, Ref. 29 fig 3). This is to allow the concrete to reach a high enough strength to resist backfill and compaction loads, usually quoted as 14 N/mm^2 (Ref. 5 12.9.3, Ref. 6 18.3.4).

Plain and reinforced concrete beddings and surround are illustrated in Figures 10 to 13. The use of concrete arches is not recommended because it is difficult to ensure adequate support at the sides of the pipes. Additionally, the width of the top of the concrete, rather than the outside diameter of the pipe, is used to calculate the load on the pipe/bed construction. This higher load can counterbalance the higher bedding strength of an arch or surround.

For reinforced concrete beds, the minimum transverse steel area should not be less than 0.4% of the area of the concrete in longitudinal section. (Ref. 27 fig 6 & Ref. 28 fig 3)

If the area of transverse steel is increased to 1.0% of the concrete area in longitudinal section in a concrete bed or surround both above and below the pipe, the bedding factor may be increased up to 4.8. This bedding factor has been derived from the 4.8 for a 1.0 % reinforced concrete arch (Ref. 27, fig 6; Ref. 28, fig 3; Ref. 30, Ch. 9 F.4a & F.5)

Pipelines at shallow depths
Most specifications for drainage or sewerage pipelines contain similar general recommendations on minimum depths of cover, together with warnings that shallower pipelines require special protective measures to be taken. The guidance given in the two principal British Standard codes of practice (Ref. 5 10.1 and Ref. 6 11.1.2) and in the water industry guide (Ref. 8 2.7) is very similar. It is not directly specified in current European standards.

Normal minimum depths of cover
Sewers laid under highways should have a minimum cover of 1.2 m, primarily to avoid interference with

other underground utility pipes and cables, and secondarily to provide protection to the pipeline during construction, where the actual cover may only be to the formation level of the road.

Sewers laid under fields and gardens should have a cover of at least 0.9 m so as not to interfere with land drainage or cultivation. This depth also gives a measure of protection before finished levels are achieved in these areas.

Since it is often difficult to maintain these ideal minimum depths of cover, particularly at the higher end of drainage and sewerage systems, precautions have to be taken where cover depths are shallower.

Protection to shallow pipelines

Shallow pipelines may need to be protected by more than normal bedding and backfill materials, especially when laid at an early stage of a contract where the cover is less than that specified. Two clear examples of this are:-

(a) When a sewer or drain is laid in a road which has only been brought up to formation level, where the pipe bedding has been designed assuming full depth of cover to finished road level.

(b) Where building works are taking place close to a drain run previously laid to a specification suitable for "fields and gardens" and the pipeline is subjected to unexpected loading due to delivery lorries, dumpers, fork lift trucks etc.

Wherever possible, pipelaying should be the last construction activity, so as to be within the design conditions, otherwise the pipelines must either be isolated from site traffic by directing this away from pipe runs or temporarily bridging the trenches, or be protected by stronger bedding constructions.

Taking into account the warnings given in various design tables for bedding construction, including those published by CPDA [1] and other recommendations in Ref.6, clause 11.1.2, pipes can be safely laid using granular bedding without the need for a concrete bed or surround, provided that the effective depth of cover is at least 0.6 m, the required bedding factors are achieved and there are no additional imposed loads.

Table 14 provides information on cover depths down to 0.4 m for DN 100 pipes, with an appropriate warning on their use.

Where the depth of cover is less than 0.6 m, it is normally recommended (Ref. 5 11.1.2 & table 1 & Ref. 7 5.3) that the pipeline is completely surrounded with well rammed good quality concrete, with a design strength of 20 N/mm at 28 days - grade C20P or C20.

The flexibility of a pipeline bedded on or surrounded with concrete should normally be maintained by the provision of flexible construction joints through the concrete at pipe joints. These should be made from

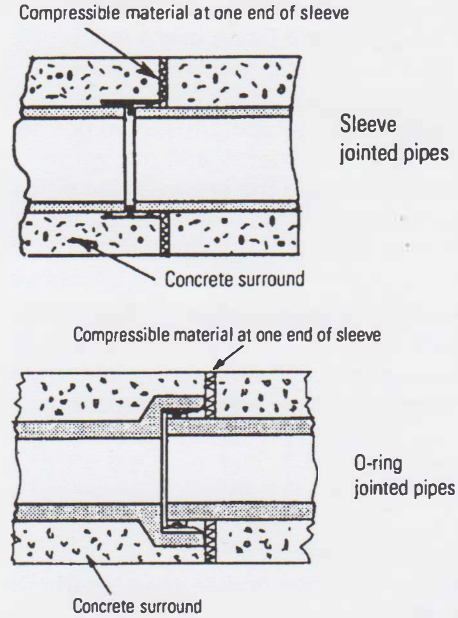


Figure 14 - Protection of a shallow pipeline using concrete surround

bitumen impregnated insulating board complying with BS EN 622-4 [31], or other equally compressible material such as expanded polystyrene. The board should be cut to fit the pipes, and placed at the face of the pipe sockets or at one end of sleeve joints. The joint material should be at least 18 mm thick (Ref.7 2.52).

This procedure allows for flexible movement of the pipe joints, while retaining the strength given by the concrete surround and should normally be carried out at every joint as shown in figure 14, particularly in building drainage applications (Ref. 6 20.2, Ref. 7 5.3).

Further details in respect of concrete surrounds are given in the earlier section on laying pipes with concrete beds or surrounds.

An alternative method of protection is recommended in the code of practice for Building Drainage (Ref. 6 11.1.2) using concrete slabs of sufficient strength to span the trench, as shown in figure 15.

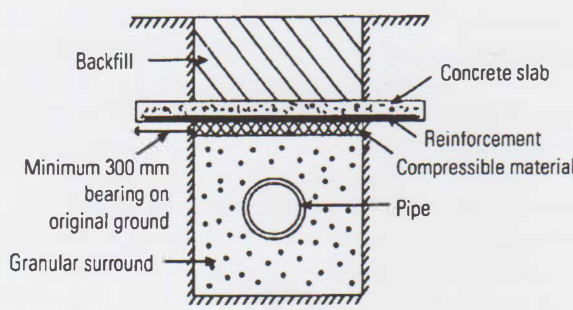


Figure 15 - Protection of shallow pipeline with a slab

The intention of this method of protection is to isolate the pipeline from imposed loading, particularly traffic loading, which is critical at shallow depths. In order to do this, the slab must be structurally capable of carrying the imposed load. In roads with a reinforced concrete slab construction, this may be easily accomplished by continuing the slab over the trench. Separate slabs may also need to be reinforced, except for example in gardens, where no wheel load is anticipated.

It is important that in all cases the slab spans the trench completely, bearing on the original ground on both sides, and does not simply rest within the trench. The width of bearing required will vary with the pipe diameter, trench width and ground conditions, but should not be less than 300 mm.

It is advisable to make sure that any movement or deflection of the slabs does not load the pipeline by introducing a layer of compressible material, such as expanded polystyrene, immediately below the slab. The pipe should be bedded and surrounded in appropriate granular material in the normal way as shown in figure 15.

In all cases, backfilling should be carefully carried out as recommended in BS EN 1610 clause 11 [15]

Where concrete backfill to trenches is demanded for early permanent reinstatement, either using lean mix or foam concrete, care should be taken that this is not allowed to generate a high concentrated load on the pipes. It is therefore necessary to ensure that the concrete backfill is well supported by the trench sides. This can be achieved by the use of a stepped or battered trench. Concrete should not be placed between trench sheets which are subsequently removed which would eliminate the friction between the concrete and the trench walls.

Pipes passing through structures

Where a pipeline is built into any structure differential settlement will take place. This occurs at any manhole, inspection chamber, groundbeam or concrete surround and must be allowed for in detail design (Ref. 7 5.2, Ref. 8 4.66, Ref. 10 A10, Ref. 15 8.6.4).

The risk of a pipe failure occurring at this point may be obviated by providing a flexible joint as close as possible to the face of the structure, allowing for the joint to be properly made and to move freely. A short length 'rocker' pipe should be laid next before any full length pipes are used, as illustrated in figure 16.

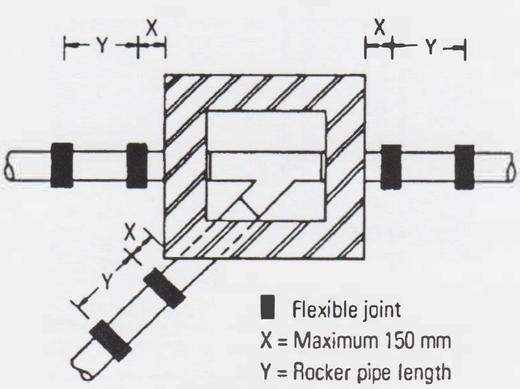


Figure 16 - Pipeline flexibility at a structure

The first joint should be within 150 mm of the face of the structure. The length of the rocker pipe should be no longer than shown in Table 15.

Table 15 - Maximum Length of Rocker Pipes

Pipe Diameter (mm)	Rocker Pipe Length (m)
≤ 300	0.6
> 300 ≤ 450	0.75
> 450	1.0

Where very large differential settlements may be anticipated, the number of short length pipes should be increased. Shallow gradients should be avoided in this situation, in order to minimise the possibility of deposition of solids (Ref. 5 10.6.1).

The effects of differential settlement may also be overcome by the provision of a relieving arch or lintel over the pipeline as it passes through a structure as shown in Fig 17 (Ref. 6 6.7 & Ref. 10 A10). A gap of not less than 50mm must be left around the pipe and effectively sealed to prevent the entry of gas, bedding material or rodents (Ref. 6 6.7). This is not an easy requirement to fulfill. Flexible joints should be incorporated close to the structure, even where this procedure is adopted.

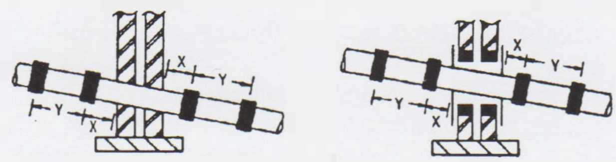


Figure 17 - Diagrammatic sections showing pipes passing through structures

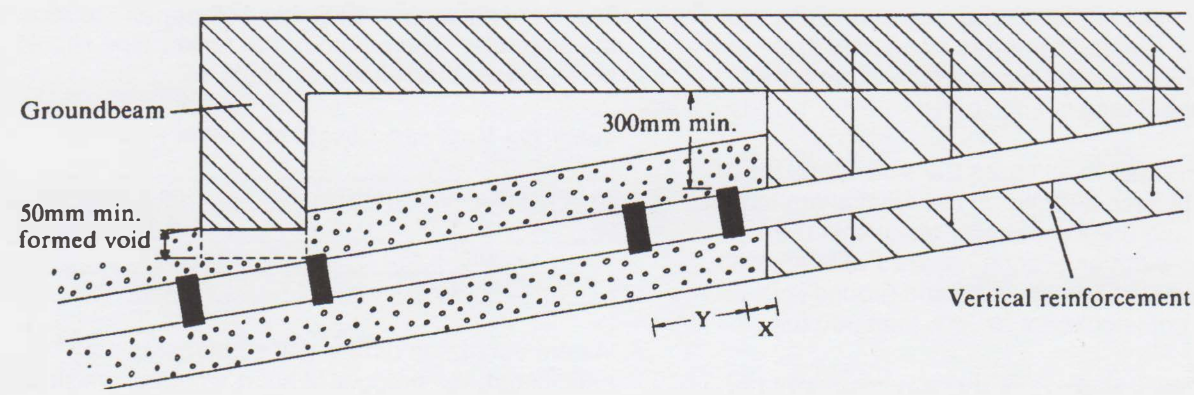
Where a pipeline is to pass close under a groundbeam, the groundbeam may be treated as a lintel. The pipeline should be isolated from the load by, for example, a slab of expanded polystyrene or "clayboard" of at least 50 mm thickness placed under the groundbeam, as shown in figure 9.

Alternatively, where ground conditions are suitable, the beam may be lowered to incorporate the pipeline as a built-in structure. In both cases, flexible joints should be provided close to both sides of the beam, with the appropriate associated rocker pipes.

Laying pipes under buildings

Where a pipeline passes under a building, it is necessary to both protect it from imposed loadings and ensure that the building stability is not impaired.

Where a pipeline has less than 300 mm cover under a load-bearing floor slab, it should be surrounded with concrete integral with the slab. Ideally this should be poured at the same time as the floor slab. The concrete surround should be tied to the slab with nominal steel reinforcement placed vertically with turned over ends. If it is not possible to pour the concrete surround at the same time as the slab, the steel reinforcement should be included and used to tie the two pours together. No provision for flexibility



Key: Flexible joint | Granular bedding | Concrete slab/beam | Concrete surround

X = Maximum 150 mm   Y = Rocker pipe length (see Table 15)

Figure 18 - Vitrified clay pipeline under a typical building slab

within the concrete surround should be made, unless an expansion joint is included in the slab, when a flexible construction joint as described for concrete bed or surround should be included at that point. This must also be coincident with a pipe joint. Additional flexibility should be incorporated into the pipeline as it leaves any concrete surround, as described for pipes passing through structures.

In normal stable ground conditions, and with 300 mm or more cover to the pipeline beneath the slab, a total granular surround can be used as the pipe bedding.

Where the pipeline subsequently passes under or through the edge of the building, it should again be treated as described for pipes passing through structures (BS EN 1610 8.6.4).

It may be practicable to lower an edge-beam to incorporate the pipeline as a built-in structure, or it may be preferred to pass under the beam with minimum cover, treating it as a lintel (Ref. 10 appendix A9).

The use of flexible couplings with clay pipes

Description

A range of purpose made repair and adaptor couplings has been developed by clay pipe manufacturers which provide easy to use, immediate, permanent and flexible joints for pipe repair or replacement situations and connection to other pipeline materials.

Repair couplings are used to satisfactorily connect two pipes of equal or slightly different outside diameters, within a specified range, as shown in figure 19.

The couplings are available to fit pipes with outside diameters from 75 mm upwards. As appropriate, couplings may be certified to either the requirements of the water industry Specification 4-41-01 [32], BS EN 295-4 [33], or a BBA Certificate.

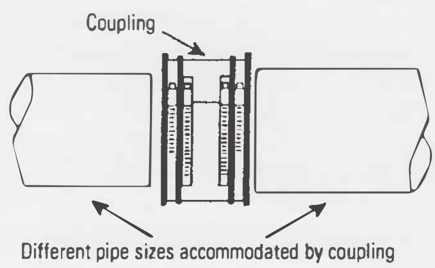


Figure 19 - Application of repair coupling

Couplings consist of elastomeric sleeves, secured to the pipe with outer stainless steel clamping bands and with an optional central stainless steel shear band, as shown in figure 20. The shear band provides resistance to shear forces and imposed loads, whilst still allowing joint flexibility, and also also aids alignment of pipe inverts when jointing.

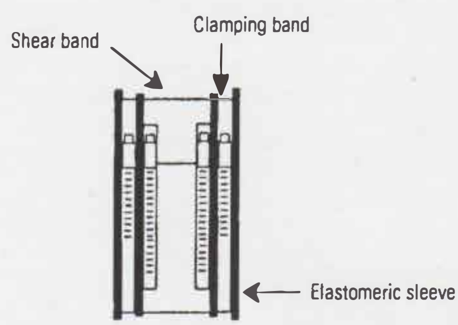


Figure 20 - Typical repair coupling

Uses

The couplings are used to repair existing pipelines, to make post connections to pipelines by means of inserting purpose made junctions or to connect pipes of different materials or outside diameters.

Repairing existing pipelines

The damaged section of pipeline should first be removed, by cutting the damaged ends cleanly using either a chain or disc cutter. A repair coupling should then be fitted over each pipe clear of the ends, and the replacement section laid between them. The replacement pipe or pipes should have a total length of 20 mm less than that between the cut ends of the existing pipeline to allow for clearance when laying and flexibility. The replacement length should end with plain or cut ends. Each coupling should be centred over its joint and the outer clamping bands tightened first, followed by the central shear band, as shown in figure 21.

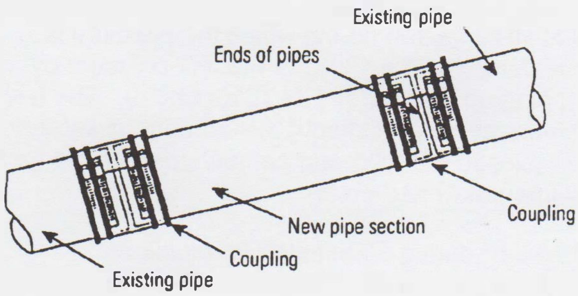


Figure 21 - Repairing existing pipelines

Inserting junctions for post-connection of laterals

A lateral connection can be made by the insertion of a factory made junction into an existing pipeline. This is achieved by removing a section of pipeline and using repair couplings to connect the new junction in the same way as for the replacement of a section of damaged pipeline, as shown in figure 22. The piece being removed from the pipeline should be cut 20 mm longer than the junction which is to be inserted into the line to allow for clearance when laying and flexibility.

A major advantage of employing this method of construction is that when a junction has been inserted the lateral pipeline may be connected immediately without the need to wait for any concrete surround or mortar joint to set. Also, the joints to the existing pipeline and the lateral are flexible. If a new lateral is to be laid, a system compatible with the junction arm can be used, or an existing lateral can be connected using another repair coupling.

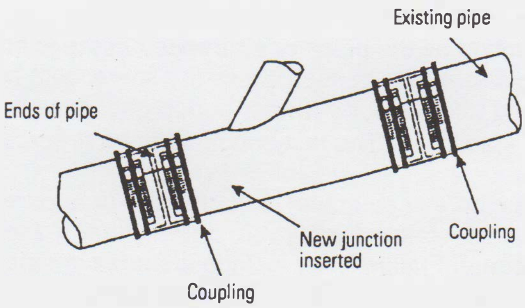


Figure 22 - Insertion of junction

Connecting pipes of different materials or outside diameters

Repair couplings are ideal for jointing pipes of different materials or outside diameters, or where incompatible jointing systems are employed by the two pipelines involved. Where the difference in outside diameter is excessive, a bush will usually be required to take this up, as shown in figure 23.

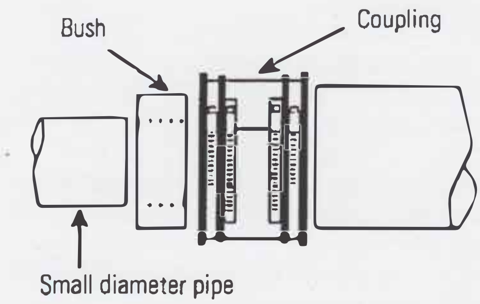


Figure 23 - Use of elastomeric bush

Adaptor couplings

For 35 to 420 mm diameter pipes, adaptor couplings are available. Adaptor couplings are often used to connect pvc and vitrified clay pipes. The couplings themselves are stepped to accommodate the difference in outside diameter and so no bush is required, as shown in figure 24.

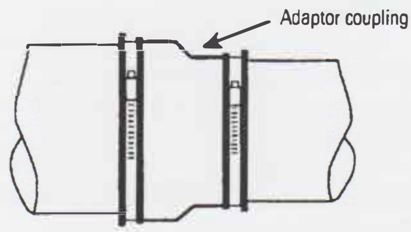


Figure 24 - Adaptor coupling

Performance

When correctly installed, couplings for pipe sizes up to DN1200 will meet the performance requirements of joints to BS EN295 Part 1 Clause 3.

External Protection

External protection to the couplings is rarely required, except where they are used in particularly aggressive ground or ground containing chlorides. In these situations, a suitable proprietary tape protection or wrapping system is advised.

Site Testing

Pipelines which contain joints made with the couplings should be tested with the air or water pressure tests specified in BS EN 1610. These are of similar form to the tests previously specified in UK codes of practice and specifications, although there are some changes of detail. In particular, the duration of the air test is extended beyond 5 minutes for pipe sizes larger than DN300.

Inspection and testing (EN 1610 clauses 10, 12 and 13)

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

First stage inspection and testing
Before any test, check for any damage and clear out any debris. Ensure that plugs are clean and in good condition before they are fitted.

Tests should be carried out to locate and remedy any defects in the soundness that may exist during construction. Such tests should take place immediately before sidefill is applied and the work is covered up so as to facilitate replacement of any faulty pipe or fitting or to rectify any joint defect.

Tests may include visual inspection (EN 1610 12.1) for line and level, joints, damage or deformation, connections, linings and coatings. The standard specifies that the vertical change in diameter of flexible pipes shall be checked (EN 1610 12.3.2) for compliance with the design. Inspection of the pipeline will also reveal any defects in the support and bedding. Testing for leaktightness (EN 1610 12.2) includes the testing of connections, manholes and inspection chambers

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

A water test is generally preferred since it relates very closely to the conditions found in practice. It does however suffer from the disadvantage of providing and disposing of large quantities of water.

An air test is easier to apply but the results can be affected by small changes in temperature. A change in temperature of 1 °C will result in a corresponding change in air pressure of about 38 mm water gauge. Therefore, if the pressure drop is above that recommended, the pipeline should not be deemed unsatisfactory on the air test alone.

The number of air tests allowed to be carried out is not restricted but where recourse is made to the water test, it shall alone be decisive (EN 1610 13.1).

Water test (EN 1610 13.3)

The water test is applied as an internal pressure-head of water above the pipe at the high end of the line to be tested. A maximum limit is placed on the head at the lower end to prevent damage to the pipeline. Steep drains and sewers may need to be tested in short sections in order to avoid too great a head at their lower end. The test is carried out to a maximum pressure of 50 kPa (≈ 5 m head at the lower end of the pipeline) and a minimum pressure of 10 kPA (≈ 1 m head) measured at the top of the section of pipeline under test. The pressure is applied by filling the test section up to the ground level of the upstream or downstream manhole or inspection chamber as appropriate (EN 1610 13.3.1). Pipes are strutted as necessary to prevent movement.

After the test section has been pressurised, the pipeline should be conditioned by allowing to stand full for at least one hour (EN 1610 13.3.2). A longer time may be needed in dry climatic conditions.

The test is carried out over a period of 30 minutes (EN 1610 13.3.3) during which the pressure is maintained within 1 kPa of the test pressure by topping up with water (EN 1610 13.3.4). The test requirement is satisfied if this amount of water does not exceed the following amounts per square metre of internal wetted area:-

0.15 l/m^2 during 30 minutes for pipelines
0.20 l/m^2 during 30 minutes for pipelines including manholes
0.40 l/m^2 during 30 minutes for manholes and inspection chambers

For various pipe diameters this rate of top-up over the test period may be expressed as shown in Table 16.

Table 16 - Water test - allowable rate of loss in litres per metre over 30 minute test period

Pipe Size	Pipe-lines	Pipelines & MH's	MH's & IC's
DN100	0.047	0.063	0.126
DN150	0.071	0.094	0.189
DN225	0.106	0.141	0.377
DN300	0.141	0.189	0.377
DN400	0.189	0.251	0.503
DN500	0.236	0.314	0.629
DN600	0.283	0.377	0.754

The volume of water added may be measured directly or calculated by measuring the drop in level in a standpipe or chamber.

Even though there may be no visible leakage, an apparent loss of water may exceed the permitted figure at first, due to the effect of continued absorption by the pipes or air trapped in the joints being dissolved. In such cases the line should be allowed to stand for a further period until conditions have stabilised. The test should then be repeated.

Unless there is an actual leak, the rate of apparent loss will decrease rapidly with time. Other reasons for apparent failure may include changes in ambient temperature, trapped air or leakage past plugs or stoppers.

Air test (EN 1610 13.2)

The air test is carried out by inserting plugs or inflatable bags in the upper and lower ends of the pipeline and pumping in air under pressure. A glass U tube gauge (manometer) and the air pressure source are connected. Air pressure is then applied by mouth or hand pump to achieve the required test pressure.

The test time for the air test varies according to the pipe size as defined in Table 17. The test method (LA) is the same as that previously specified in the UK, except that the test period is increased for pipe sizes above DN200.

It is expected that this will remain the preferred UK method for the future, avoiding the additional safety precautions needed when using the higher test pressures favoured by parts of continental Europe.

Table 17 – Test pressures, allowable pressure drop and test periods for the air test for clay pipes

Test method	Test press mbar (kPa)	Allowable drop mbar (kPa)	Test period in minutes				
			100	200	300	400	600
LA	10 (1)	2.5 (0.25)	5	5	7	10	14

The pressure is first brought up to approximately 10 % more than the test pressure and held for 5 minutes. It is then adjusted to the test pressure and the drop in pressure measured at the end of the specified test period. If the measured drop is less than the allowable drop, then the pipeline passes the test. The test equipment is required to measure with an accuracy of 10 % of the allowable pressure drop.

As with the water test there are possible contributing factors that could cause an apparent failure in the air test. These are: temperature changes of the air in the pipe due to direct sunlight or cold wind acting on the pipe barrel, these may show up during the 5 minute stabilisation period; dryness of the pipe wall and leaking plugs or faulty testing apparatus.

Operations and maintenance (BS EN 752-7)

Operation and maintenance activities are designed to ensure that the performance requirements for drains and sewers which are defined in BS EN 752-2 in respect of freedom from blockage, access, health and safety, watertightness, structural soundness and the protection of receiving waters from pollution are maintained.

A wide range of references is provided in BS EN 752-7 that detail operational and maintenance procedures, including British standards, codes of practice and water industry publications.

Carrying out maintenance can involve dealing with both functional and structural problems and methods of dealing with them include a wide range of repair, renovation and replacement options.

Functional problems can include sedimentation, encrustation, grease, tree roots and infiltration or exfiltration. Methods of dealing with them include jetting, winching, rodding, cleaning balls, remote controlled equipment, flushing, excavation and repair.

Clay pipes have been proven to withstand all normal cleaning methods, including jetting operations at high pressures. The WRc Sewer jetting code of practice provides for a maximum pressure of 340 bar (5,000 psi) for clay pipes, whereas only 180 bar (2,600 psi) is allowed for plastics pipes.

Structural problems include collapse, cracking or fracturing, chemical attack or corrosion, ground erosion outside the pipe, defective connections, pipe deformation and open or displaced joints.

Many structural problems are related to connections. To alleviate these, the following procedure should be adopted.

a) The drain or sewer should be inspected before and after connection is made and a check should be made that the connection is to the correct pipeline.

b) The connection should be made using a pre-formed junction. The use of repair couplings when making post connections ensures watertight, flexible joints.

c) The system should be checked for watertightness after the connecton is made.

d) It is necessary to ensure that the drain or sewer is not weakened or damaged by the connection and that no operational problems are caused by the connection.

The appropriate pre-formed junctions and repair couplings are available for all clay pipe systems.

Further information

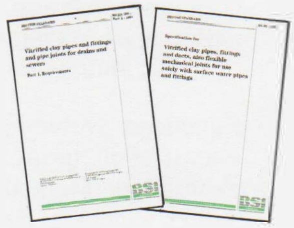
Detailed information on structural and hydraulic design is given in appendices A and B on pages 25 to 44. A wider range of structural design and flow tables is provided in reference number 1 and a detailed consideration of the problems of hydrogen sulphide in sewers can be found in reference number 2.

Details of all the references used in this booklet are given on pages 51 and 52. Information on other areas of pipeline design and construction is contained in many of those references.

Illustrations of laying practice for vitrified clay pipe drainage and sewerage systems

STANDARDS

Vitrified clay pipes and fittings are specified to BS EN 295: Part 1: 1991.



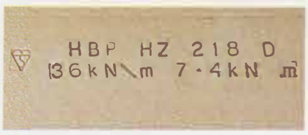
BS 65:1991 covers pipes and fittings without flexible joints; pipes, fittings and flexible joints for surface water applications; extra chemically resistant pipes and ducts.

TRANSPORT

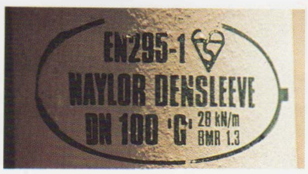
Mechanical off loading should be used when available and pipes and fittings handled with care.

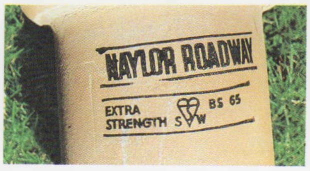
MARKING

Pipes and fittings show clear marking of third party inspection marks, size, strength and jointing system.



The marking can be checked on arrival.





STORAGE

Pipes are kept in packs until needed, stored on a clean level area, safe from damage.

Loose pipes are stacked, strongly pegged to prevent rolling, with barrels of socketted pipes on sockets to prevent joint damage.

Fittings are stored to keep them safe from damage, with protective caps, shrink wrap or other packaging in place. Sleeve couplings are kept in bags.

EXCAVATION

Spoil should be dumped clear of trench sides.

Any pegs needed for levels are placed at the side of the trench.

Suitable excavated material is used as sidefill and initial backfill to pipes.

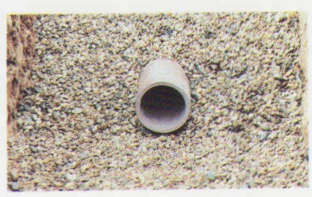
BEDDING CLASSES

Pipes can be laid on flat beds of granular materials such as sand - Class N.

Pipes can be laid on a flat bed of specified granular material such as single sized or graded aggregate - Class F.

Pipes can be laid with specified granular material to half-pipe height - Class B.

Pipes can be laid with specified granular material as a complete surround - Class S



BEDDING MATERIALS

Selected as-dug granular material can be used for Class N bedding.

Sand is suitable for Class N bedding.

Graded aggregate (20-5 or 14-5mm) is usable for all bedding classes.

10mm single size aggregate (pea-shingle) can be used for all bedding classes.

CUTTING

Small diameter pipes are easily cut with a chain or ring cutter.

A masonry saw is normally used for larger diameter pipes.

To avoid damaging joint rings an appropriate tool or small hammer is used to dress the cut pipe ends.

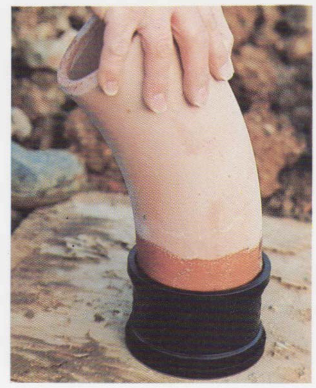
JOINTING

The jointing surfaces of pipes, joint rings and couplings are cleaned.

After the pipe end is lubricated, a coupling is put on before laying the pipe in the trench.

JOINTING (continued)

The same operation is carried out for fittings by pushing a plain end into a sleeve on a flat surface.



PIPELAYING

The bedding should be checked to ensure that it supports pipes along their whole barrel length and socket holes are dug where necessary.

Pipe laying starts, conventionally, at the downstream end with a short "rocker" pipe next to the manhole or inspection chamber.

The plain end of a pipe is lubricated and pushed into the coupling of the previous pipe in the trench.

Line and level are checked and, if necessary, more bedding material is placed under the whole barrel length.

The specified sidefill and initial backfill is placed and compacted by hand.

The backfill is placed as soon as practicable, compacting in layers, so that there is a protective layer over the pipes before leaving site.

CONSTRUCTION DETAILS

In waterlogged ground, bedding material and trench construction is stabilised by wrapping with a geotextile fabric.

Construction joints are positioned at the face of sleeve joints when using concrete surrounds

The first pipe joint is kept within 150 mm of the face of any structureand short "rocker" pipes are used if significant settlement is expected.

Where a lintel is used, the first joint should still be kept close to the structure.

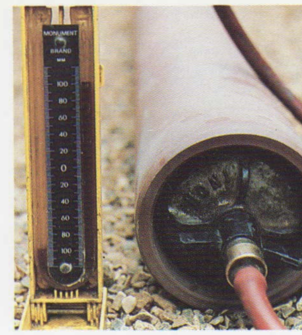
Repair couplings are used to provide flexible joints to an inserted junction or for a repair length inserted into a pipeline.

TESTING

Before testing, the pipeline should be checked for damage and cleared of debris and plugs should be cleaned and in good condition before being fitted.

TESTING (continued)

The air test measures the loss of air pressure in the pipeline from an initial pressure of 100 mm water gauge (0.25 kPa).



The water test pressure is applied by filling the test section up to the ground level of its highest manhole or inspection chamber.

Pipes are strutted as necessary to prevent movement and the filled line allowed to stabilise for at least one hour.

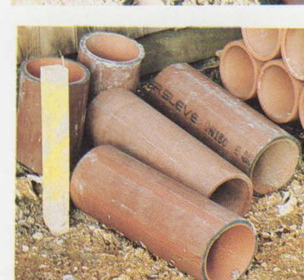
The water added is measured directly or calculated from the drop in level.

COST SAVING

Using a total granular surround is rarely necessary and a flat bed of appropriate granular material can be used in most bedding situations for clay pipes.

Brickwork chambers are expensive to construct and clay or polypropylene chambers are used where possible.

Discarded lengths of sleeve jointed clay pipes can be used as rocker pipes to avoid cutting precise lengths from new pipes.



Appendix A - Determining the bedding construction of vitrified clay pipelines

Introduction

In October 1967, the Ministry of Housing and Local Government Working Party on the Design and Construction of Underground Pipe Sewers issued its Second Report [37] which gave design methods and criteria to be used where rational structural design of underground pipelines was to be applied.

The Department of the Environment subsequently set up a new Working Party with the title "Sewers and Water Mains" which produced its First Report in 1975 [42]. This report confirmed the design criteria of the Second Report and gave recommendations with regard to various types of minimum bedding.

Revised Bedding Factors

After a research programme carried out for the Clay Pipe Development Association Limited at the Water Research Centre and British Ceramic Research Limited, revised bedding factors for Classes F, B and S granular beddings were proposed as:-

Class F - 1.9 Class B - 2.5 Class S - 2.5

The Water Authorities Association's Sewers and Water Mains Committee recommended in their 1988 Information and Guidance Note No.4-11-02 [26], these revised values for vitrified clay drains and sewers. These bedding factors are used in the structural design of **only Vitrified Clay Pipelines** and the values are included in BS EN 1295-1 [14], the European standard for pipeline structural design.

Computation of Design Tables

The 1967 Working Party Report recommended that the basis for the structural design of sewers should be the work of Marston, Spangler and Schlick. The Report did not give all the data needed in design, but referred to the National Building Studies Special Report 37 [43] for the remainder of the data and methods of design. The Transport and Road Research Laboratory Simplified Tables of External Loads on Buried Pipelines [28] used the same data. These have been used in combination with the Working Party's values in calculating the tables. This method has been endorsed by its acceptance in the European standard for the structural design of buried pipelines, BS EN 1295-1 [14].

The pipe outside diameters used in the computation of the design tables are given in table A1.

Table A1 – Design Outside Pipe Diameter (B_c)

Nominal diameter (mm)	Outside diameter (mm)
100	130
150	190
200	245
225	280
300	370
375	460
400	500
450	550
500	615
600	730

The design data laid down by the 1967 Report [37] are:

Two Wheel Traffic Loads, Surcharge Loads, Impact Factors, Safety Margin, Bedding Factors.

Those extracted from Simplified Tables [28] are:

The product of the settlement deflection ratio and projection ratio.

The product of the Rankine coefficient of active soil pressure and the coefficient of internal soil friction.

The product of the Rankine coefficient of active soil pressure and the coefficient of soil friction between the trench wall and the fill.

The format of the Tables is that the height of fill upon the crown of pipe, called "cover", is shown vertically and for each cover the other variables are shown horizontally across the page.

Pipe crushing strength

The currently available crushing strengths for flexibly jointed clay pipes for drains and sewers specified to BS EN 295-1 [3] are given in table A2. The sampling procedures specified in BS EN 295-2 [3] enable these strengths to be used in design without application of an additional factor of safety.

Table A2 – Currently available crushing strengths (FN) in kN/m – for UK pipe sizes

Nominal Size (DN)	Crushing strength (FN)				
100	22	28	34	40	
150	22	28	34	40	
225		28	36	45	54
300		36	48	60	72
375		45	60		
400		48	64	80	
450	43	54	72		
500		60			
600	57	72			

Arrangement of Design Tables

The tables consist of two tables of fill loads, and two tables of loads acting upon the pipeline due to traffic wheel loads acting on the surface of the fill.

Table A3

Table A3 is for fill loads on vitrified clay pipes of 100mm to 1,000mm diameter in Wide Trench Conditions and gives loads per metre on the pipes.

The design criteria used in this Table are:

a. The product of the Rankine coefficient of active soil pressure and the coefficient of internal friction of the soil = 0.19

b. The product of the settlement deflection ratio and the projection ratio

(i) For pipe diameters ≤ 300mm = 0.7

(ii)For pipe diameters ≥ 375mm = 0.5

c. Density of fill = 2000kg/m³

d. Outside Diameter (B_C)

The values of 'a', 'b' and 'c' above have been taken from Simplified Tables [28]. The values of 'a' and 'c' are for damp clay and 'b' (i) is for fill loads on pipes and trenches where the bedding extends the whole width of the trench

Table A4
Table A4 is for fill loads in Narrow Trench Conditions and gives the loads per metre on pipes in trenches of widths from 0.5m to 2.6m.

The design data used in this Table are:

e. The product of the Rankine coefficient of active soil pressure and the coefficient of internal friction between the trench wall and the fill = 0.13.

f. Density of fill = 2000 kg/m³.

The values of 'e' and 'f' above have been taken from Simplified Tables [28] for damp clay.

Tables A5 and A6
Tables A5 and A6 are for traffic wheel loads recommended for design in the Working Party Report and used in Simplified Tables [28] and are:

Table A5 is for sewers laid in fields, gardens and lightly trafficked access roads, where provision is to be made for two wheel loads, each of 30 kN static weight, spaced 0.9m apart, acting simultaneously with an impact factor of 2.0.

Table A6 is for sewers laid under main traffic routes and under roads to be used for temporary diversion of heavy traffic loads, each of 112.5 kN acting simultaneously with an impact factor included, arranged as in BS 5400 Part 2: 1978 Type HB road loading [45].

Sewers laid under all roads accessible to normal traffic need to be designed for heavy traffic wheel loads.

The mean load on a 1.0 m length of vitrified clay pipe, caused by traffic loads in the 'worst' position, has been calculated by the use of the integration of the Boussinesq Equation for the intensity of vertical load at a point in an elastic isotropic halfspace due to a point surcharge on the surface. This mean load has been stated as an intensity of load per metre.

For pipelines at normal depths the distribution of load due to a vehicle tyre is sensibly uniform across the pipe width but when cover is very shallow there is a marked concentration of load on the centre line of the pipe. Spangler proposed to allow for this by reducing the bedding factor for shallow pipelines.

A more rational solution is to use the factor proposed by Clarke and Young in their paper 'Loads on Underground Pipes caused by Vehicle Wheels', published by the Institution of Civil Engineers in January 1962. This factor has been used in the calculation of the Tables herein and therefore no reduction of bedding factor need be made.

Use of Tables
The design load is calculated as the fill load plus the load due to the appropriate traffic load. The fill load is the smaller of the loads shown in tables A3 and A4 for a given cover, trench width and pipe diameter. The load due to traffic is taken from the appropriate one of tables A5 or A6.

The design load is multiplied by the safety factor which both the 1975 Report [42] and IGN 4-11-02 [26] give as 1.25; the result is then divided by the crushing strength of the pipe to give the minimum required bedding factor.

The trench width should be chosen as the minimum width of trench in which the pipe can be correctly laid. The trench widths shown in table A4 increase by 0.1m increments.

In Marston's original Trench theory, the load on a pipeline with a fixed cover increased continually with increasing trench width. Professor Schlick established a convention by which the use of the Trench theory was limited to trenches narrower than a Transition Width, beyond which the load was assumed to be constant. Trenches less than this width are termed Narrow; those greater, Wide. It follows from this convention and the nature of the load formulae that a Transition Depth or cover also exists for trenches of a fixed width. When cover is less than this depth the trench is Wide; when greater, Narrow.

The beddings of pipelines with 1.0 m or less of cover require precautions to be taken besides those needed to resist the loads acting upon them.

Equivalent Water Load
The weight of water in a pipe running full generates an additional load, the equivalent water load on the pipe. This load is approximately three quarters of the weight of water in the pipe, and may be calculated from the equation in Simplified Tables [28].

$$\text{Equivalent water load} = \frac{3}{4}\left(\frac{\pi}{4}\right)\left(\frac{9.81}{10^6}\right)D^2$$

Where D is the pipe diameter (mm).

The extra load is not significant for most current UK clay pipe diameters. For example, the equivalent water load for 600mm diameter pipes is 2.08 kN/m.

Where it is desired to incorporate this load in design, it should be added to the design load given in the tables, the total multiplied by the safety factor of 1.25, and the result divided by the crushing strength of the pipe to give the minimum bedding factor.

TABLE A3 FILL LOADS
WIDE TRENCH

PIPE DIAMETER

Cover	100	150	200	225	300	375	400	450	500	600	700	800	900	1000	Cover
m	kN/m	kN/m	kN/m	kN/m	kN/m	kN/m	kN/m	kN/m	kN/m	kN/m	kN/m	kN/m	kN/m	kN/m	m
0.6	2.40	3.49	4.48	5.09	6.02	7.01	7.45	8.02	8.76	10.08	11.41	12.87	14.33	15.79	0.6
0.7	2.81	4.08	5.24	5.97	7.43	8.55	9.06	9.71	10.56	12.09	13.63	15.32	17.02	18.72	0.7
0.8	3.21	4.68	6.01	6.85	8.99	10.23	10.80	11.52	12.48	14.21	15.96	17.87	19.80	21.74	0.8
0.9	3.62	5.27	6.77	7.72	10.14	11.89	12.67	13.46	14.52	16.44	18.39	20.53	22.89	24.88	0.9
1.0	4.02	5.86	7.53	8.59	11.30	13.24	14.37	15.54	16.69	18.78	20.93	23.29	25.67	28.07	1.0
1.1	4.43	6.45	8.30	9.47	12.45	14.60	15.84	17.38	19.00	21.26	23.59	26.16	28.77	31.39	1.1
1.2	4.84	7.05	9.06	10.34	13.60	15.95	17.31	19.00	21.19	23.86	26.37	29.15	31.97	34.82	1.2
1.3	5.24	7.64	9.83	11.21	14.76	17.30	18.78	20.62	23.00	26.61	29.27	32.25	35.28	38.35	1.3
1.4	5.65	8.23	10.59	12.09	15.91	18.66	20.25	22.24	24.81	29.34	32.31	35.48	38.71	41.99	1.4
1.5	6.05	8.82	11.35	12.96	17.07	20.01	21.72	23.86	26.62	31.48	35.50	38.84	42.27	45.75	1.5
1.6	6.46	9.42	12.12	13.83	18.22	21.36	23.19	25.47	28.43	33.63	38.80	42.33	45.94	49.63	1.6
1.7	6.86	10.01	12.88	14.71	19.37	22.72	24.66	27.09	30.24	35.78	41.28	45.96	49.75	53.63	1.7
1.8	7.27	10.60	13.65	15.58	20.53	24.07	26.13	28.71	32.05	37.93	43.77	49.74	53.69	57.76	1.8
1.9	7.67	11.19	14.41	16.45	21.68	25.42	27.61	30.33	33.86	40.07	46.25	52.93	57.77	62.01	1.9
2.0	8.08	11.79	15.17	17.33	22.84	26.78	29.08	31.95	35.67	42.22	48.74	55.78	62.00	66.41	2.0
2.1	8.48	12.38	15.94	18.20	23.99	28.13	30.55	33.56	37.48	44.37	51.23	58.64	66.00	70.94	2.1
2.2	8.89	12.97	18.70	19.07	25.14	29.48	32.02	35.18	39.29	46.52	53.71	61.49	69.23	75.61	2.2
2.3	9.29	13.56	17.47	19.94	26.30	30.84	33.49	36.80	41.10	48.66	56.20	64.34	72.45	80.44	2.3
2.4	9.70	14.16	18.23	20.82	27.45	32.19	34.96	38.42	42.90	50.81	58.68	67.20	75.67	84.10	2.4
2.5	10.11	14.75	18.99	21.69	28.60	33.54	36.43	40.04	44.71	52.96	61.17	70.05	78.89	87.69	2.5
2.6	10.51	15.34	19.76	22.56	29.76	34.90	37.90	41.66	46.52	55.11	63.66	72.91	82.11	91.28	2.6
2.7	10.92	15.93	20.52	23.44	30.91	36.25	39.37	43.27	48.33	57.26	66.14	75.76	85.33	94.87	2.7
2.8	11.32	16.53	21.29	24.31	32.07	37.60	40.84	44.89	50.14	59.40	68.63	78.61	88.56	98.46	2.8
2.9	11.73	17.12	22.05	25.18	33.22	38.96	42.32	46.51	51.95	61.55	71.11	81.47	91.78	102.04	2.9
3.0	12.13	17.71	22.82	26.06	34.37	40.31	43.79	48.13	53.76	63.70	73.60	84.32	95.00	105.63	3.0
3.1	12.54	18.30	23.58	26.93	35.53	41.66	45.26	49.75	55.57	65.85	76.09	87.17	98.22	109.22	3.1
3.2	12.94	18.90	24.34	27.80	36.68	43.02	46.73	51.36	57.38	67.99	78.57	90.03	101.44	112.81	3.2
3.3	13.35	19.49	25.11	28.68	37.84	44.37	48.20	52.98	59.19	70.14	81.06	92.88	104.66	116.40	3.3
3.4	13.75	20.08	25.87	29.55	38.99	45.72	49.67	54.60	61.00	72.29	83.54	95.74	107.88	119.99	3.4
3.5	14.16	20.67	26.64	30.42	40.14	47.08	51.14	56.22	62.81	74.44	86.03	98.59	111.11	123.58	3.5
3.6	14.56	21.27	27.40	31.30	41.30	48.43	52.61	57.84	64.62	76.58	88.52	101.44	114.33	127.17	3.6
3.7	14.97	21.86	28.16	32.17	42.45	49.78	54.08	59.45	66.43	78.73	91.00	104.30	117.55	130.76	3.7
3.8	15.38	22.45	28.93	33.04	43.60	51.14	55.55	61.07	68.24	80.88	93.49	107.15	120.77	134.35	3.8
3.9	15.78	23.04	29.69	33.92	44.76	52.49	57.03	62.69	70.04	83.03	95.97	110.00	123.99	137.94	3.9
4.0	16.19	23.64	30.46	34.79	45.91	53.84	58.50	64.31	71.85	85.17	98.46	112.86	127.21	141.53	4.0
4.1	16.59	24.23	31.22	35.66	47.07	55.20	59.97	65.93	73.66	87.32	100.95	115.71	130.43	145.12	4.1
4.2	17.00	24.82	31.98	36.54	48.22	56.55	61.44	67.54	75.47	89.47	103.43	118.57	133.66	148.70	4.2
4.3	17.40	25.41	32.75	37.41	49.37	57.90	62.91	69.16	77.28	91.62	105.92	121.42	136.88	152.29	4.3
4.4	17.81	26.01	33.51	38.28	50.53	59.26	64.38	70.78	79.09	93.77	108.40	124.27	140.10	155.88	4.4
4.5	18.21	26.60	34.28	39.15	51.68	60.61	65.85	72.40	80.90	95.91	110.89	127.13	143.32	159.47	4.5
4.6	18.62	27.19	35.04	40.03	52.84	61.96	67.32	74.02	82.71	98.06	113.38	129.98	146.54	163.06	4.6
4.7	19.02	27.78	35.80	40.90	53.99	63.32	68.79	75.64	84.52	100.21	115.86	132.83	149.76	166.65	4.7
4.8	19.43	28.38	36.57	41.77	55.14	64.67	70.26	77.25	86.33	102.36	118.35	135.69	152.99	170.24	4.8
4.9	19.84	28.97	37.33	42.65	56.30	66.02	71.74	78.87	88.14	104.50	120.83	138.54	156.21	173.83	4.9
5.0	20.24	29.56	38.10	43.52	57.45	67.38	73.21	80.49	89.95	106.65	123.32	141.39	159.43	177.42	5.0
5.1	20.65	30.15	38.86	44.39	58.60	68.73	74.68	82.11	91.76	108.80	125.80	144.25	162.65	181.01	5.1
5.2	21.05	30.75	39.62	45.27	59.76	70.08	76.15	83.73	93.57	110.95	128.29	147.10	165.87	184.60	5.2
5.3	21.46	31.34	40.39	46.14	60.91	71.44	77.62	85.34	95.38	113.09	130.78	149.96	169.09	188.19	5.3
5.4	21.86	31.93	41.15	47.01	62.07	72.79	79.09	86.96	97.18	115.24	133.26	152.81	172.31	191.78	5.4
5.5	22.27	32.52	41.92	47.89	63.22	74.14	80.56	88.58	98.99	117.39	135.75	155.66	175.54	195.36	5.5
5.6	22.67	33.12	42.68	48.76	64.37	75.50	82.03	90.20	100.80	119.54	138.23	158.52	178.76	198.95	5.6
5.7	23.08	33.71	43.44	49.63	65.53	76.85	83.50	91.82	102.61	121.68	140.72	161.37	181.98	202.54	5.7
5.8	23.48	34.30	44.21	50.51	66.68	78.20	84.97	93.43	104.42	123.83	143.21	164.22	185.20	206.13	5.8
5.9	23.89	34.89	44.97	51.38	67.84	79.56	86.45	95.05	106.23	125.98	145.69	167.08	188.42	209.72	5.9
6.0	24.29	35.49	45.74	52.25	68.99	80.91	87.92	96.67	108.04	128.13	148.18	169.93	191.64	213.31	6.0
6.1	24.70	36.08	46.50	53.13	70.14	82.26	89.39	98.29	109.85	130.28	150.66	172.79	194.86	216.90	6.1
6.2	25.11	36.67	47.26	54.00	71.30	83.62	90.86	99.91	111.66	132.42	153.15	175.64	198.09	220.49	6.2
6.3	25.51	37.26	48.03	54.87	72.45	84.97	92.33	101.52	113.47	134.57	155.64	178.49	201.31	224.08	6.3
6.4	25.92	37.86	48.79	55.75	73.60	86.32	93.80	103.14	115.28	136.72	158.12	181.35	204.53	227.67	6.4
6.5	26.32	38.45	49.56	56.62	74.76	87.68	95.27	104.76	117.09	138.87	160.61	184.20	207.75	231.26	6.5
6.6	26.73	39.04	50.32	57.49	75.91	89.03	96.74	106.38	118.90	141.01	163.09	187.05	210.97	234.85	6.6
6.7	27.13	39.63	51.08	58.36	77.07	90.38	98.21	108.00	120.71	143.16	165.58	189.91	214.19	238.44	6.7
6.8	27.54	40.23	51.85	59.24	78.22	91.74	99.68	109.62	122.51	145.31	168.07	192.76	217.41	242.02	6.8
6.9	27.94	40.82	52.61	60.11	79.37	93.09	101.16	111.23	124.32	147.46	170.55	195.62	220.64	245.61	6.9
7.0	28.35	41.41	53.38	60.98	80.53	94.44	102.63	112.85	126.13	149.60	173.04	198.47	223.86	249.20	7.0
7.1	28.75	42.01	54.14	61.86	81.68	95.80	104.10	114.47	127.94	151.75	175.52	201.32	227.08	252.79	7.1
7.2	29.16	42.60	54.90	62.73	82.84	97.15	105.57	116.09	129.75	153.90	178.01	204.18	230.30	256.38	7.2
7.3	29.56	43.19	55.67	63.60	83.99	98.50	107.04	117.71	131.56	156.05	180.50	207.03	233.52	259.97	7.3
7.4	29.97	43.78	56.43	64.48	85.14	99.85	108.51	119.32	133.37	158.19	182.98	209.88	236.74	263.56	7.4
7.5	30.38	44.38	57.20	65.35	86.30	101.21	109.98	120.94	135.18	160.34	185.47	212.74	239.97	267.15	7.5
7.6	30.78	44.97	57.96	66.22	87.45	102.56	111.45	122.56	136.99	162.49	187.95	215.59	243.19	270.74	7.6
7.7	31.19	45.56	58.72	67.10	88.60	103.91	112.92	124.18	138.80	164.64	190.44	218.45	246.41	274.33	7.7
7.8	31.59	46.15	59.49	67.97	89.76	105.27	114.39	125.80	140.61	166.79	192.93	221.30	249.63	277.92	7.8
7.9	32.00	46.75	60.25	68.84	90.91	106.62	115.86	127.41	142.42	168.93	195.41	224.15	252.85	281.51	7.9
8.0	32.40	47.34	61.02	69.72	92.07	107.97	117.34	129.03	144.23	171.08	197.90	227.01	256.07	285.10	8.0
8.1	32.81	47.93	61.78	70.59	93.22	109.33	118.81	130.65	146.04	173.23	200.38	229.86	259.29	288.68	8.1
8.2	33.21	48.52	62.55	71.46	94.37	110.68	120.28	132.27	147.85	175.38	202.87	232.71	262.52	292.27	8.2
8.3	33.62	49.12	63.31	72.34	95.53	112.03	121.75	133.89	149.65	177.52	205.36	235.57	265.74	295.86	8.3
8.4	34.02	49.71	64.07	73.21	96.68	113.39	123.22	135.50	151.46	179.67	207.84	238.42	268.96	299.45	8.4
8.5	34.43	50.30	64.84	74.08	97.84	114.74	124.69	137.12	153.27	181.82	210.33	241.28	272.18	303.04	8.5
8.6	34.84	50.89	65.60	74.96	98.99	116.09	126.16	138.74	155.08	183.97	212.81	244.13	275.40	306.63	8.6
8.7	35.24	51.49	66.37	75.83	100.14	117.45	127.63	140.36	156.89	186.11	215.30	246.98	278.62	310.22	8.7
8.8	35.65	52.08	67.13	76.70	101.30	118.80	129.10	141.98	158.70	188.26	217.79	249.84	281.84	313.81	8.8
8.9	36.05	52.67	67.89	77.57	102.45	120.15	130.58	143.60	160.51	190.41	220.27	252.69	285.07	317.40	8.9
9.0	36.46	53.26	68.66	78.45	103.60	121.51	132.05	145.21	162.32	192.56	222.76	255.54	288.29	320.99	9.0
9.1	36.86	53.86	69.42	79.32	104.76	122.86	133.52	146.83	164.13	194.71	225.24	258.40	291.51	324.58	9.1
9.2	37.27	54.45	70.19	80.19	105.91	124.21	134.99	148.45	165.94	196.85	227.73	261.25	294.73	328.17	9.2
9.3	37.67	55.04	70.95	81.07	107.07	125.57	136.46	150.07	167.75	199.00	230.22	264.11	297.95	331.76	9.3
9.4	38.08	55.63	71.71	81.94	108.22	126.92	137.93	151.69	169.56	201.15	232.70	266.96	301.17	335.34	9.4
9.5	38.48	56.23	72.48	82.81	109.37	128.27	139.40	153.30	171.37	203.30	235.19	269.81	304.39	338.93	9.5
9.6	38.89	56.82	73.24	83.69	110.53	129.63	140.87	154.92	173.18	205.44	237.67	272.67	307.62	342.52	9.6
9.7	39.29	57.41	74.01	84.56	111.68	130.98	142.34	156.54	174.99	207.59	240.16	275.52	310.84	346.11	9.7
9.8	39.70	58.00	74.77	85.43	112.84	132.33	143.81	158.16	176.79	209.74	242.65	278.37	314.06	349.70	9.8
9.9	40.11	58.60	75.53	86.31	113.99	133.69	145.29	159.78	178.60	211.89	245.13	281.23	317.28	353.29	9.9
10.0	40.51	59.19	76.30	87.18	115.14	135.04	146.76	161.39	180.41	214.03	247.62	284.08	320.50	356.88	10.0

TABLE A4 FILL LOADS
NARROW TRENCH

TRENCH WIDTH

Cover m	0.5 kN/m	0.6 kN/m	0.7 kN/m	0.8 kN/m	0.9 kN/m	1.0 kN/m	1.1 kN/m	1.2 kN/m	1.3 kN/m	1.4 kN/m	1.5 kN/m	Cover m
0.6	5.05	6.22	7.38	8.55	9.72	10.90	12.07	13.24	14.42	15.59	16.77	0.6
0.7	5.75	7.11	8.46	9.82	11.19	12.55	13.92	15.29	16.66	18.02	19.39	0.7
0.8	6.42	7.96	9.50	11.05	12.61	14.17	15.73	17.29	18.85	20.41	21.98	0.8
0.9	7.05	8.77	10.50	12.24	13.99	15.74	17.49	19.25	21.00	22.76	24.52	0.9
1.0	7.65	9.55	11.47	13.40	15.33	17.27	19.21	21.16	23.11	25.06	27.01	1.0
1.1	8.22	10.30	12.40	14.51	16.63	18.76	20.90	23.04	25.18	27.32	29.46	1.1
1.2	8.75	11.01	13.29	15.59	17.90	20.22	22.54	24.87	27.20	29.54	31.87	1.2
1.3	9.27	11.70	14.16	16.64	19.13	21.64	24.15	26.67	29.19	31.71	34.24	1.3
1.4	9.75	12.35	14.99	17.65	20.33	23.02	25.72	28.42	31.13	33.85	36.57	1.4
1.5	10.21	12.98	15.79	18.63	21.49	24.36	27.25	30.14	33.04	35.95	38.86	1.5
1.6	10.65	13.58	16.56	19.58	22.62	25.67	28.74	31.82	34.91	38.01	41.11	1.6
1.7	11.07	14.16	17.31	20.49	23.71	26.95	30.20	33.47	36.75	40.03	43.32	1.7
1.8	11.46	14.71	18.02	21.38	24.78	28.19	31.63	35.08	38.54	42.01	45.49	1.8
1.9	11.84	15.24	18.71	22.24	25.81	29.41	33.02	36.66	40.30	43.96	47.63	1.9
2.0	12.19	15.74	19.38	23.08	26.82	30.59	34.38	38.20	42.03	45.87	49.72	2.0
2.1	12.53	16.23	20.02	23.88	27.79	31.74	35.71	39.71	43.72	47.75	51.79	2.1
2.2	12.85	16.69	20.64	24.66	28.74	32.86	37.01	41.19	45.38	49.59	53.81	2.2
2.3	13.16	17.13	21.23	25.42	29.66	33.95	38.28	42.63	47.01	51.40	55.80	2.3
2.4	13.44	17.56	21.81	26.15	30.56	35.02	39.52	44.05	48.60	53.17	57.76	2.4
2.5	13.72	17.97	22.36	26.86	31.43	36.05	40.73	45.43	50.16	54.92	59.69	2.5
2.6	13.98	18.36	22.89	27.54	32.27	37.07	41.91	46.78	51.69	56.63	61.58	2.6
2.7	14.23	18.73	23.40	28.20	33.09	38.05	43.06	48.11	53.19	58.30	63.44	2.7
2.8	14.46	19.09	23.90	28.85	33.89	39.01	44.19	49.41	54.67	59.95	65.26	2.8
2.9	14.68	19.43	24.37	29.47	34.67	39.94	45.29	50.68	56.11	61.57	67.06	2.9
3.0	14.90	19.76	24.83	30.07	35.42	40.86	46.36	51.92	57.52	63.16	68.82	3.0
3.1	15.10	20.07	25.28	30.65	36.15	41.74	47.41	53.13	58.91	64.72	70.56	3.1
3.2	15.29	20.37	25.70	31.21	36.86	42.61	48.43	54.32	60.26	66.25	72.26	3.2
3.3	15.47	20.66	26.11	31.76	37.55	43.45	49.44	55.49	61.59	67.75	73.94	3.3
3.4	15.64	20.93	26.51	32.29	38.22	44.27	50.41	56.63	62.90	69.22	75.58	3.4
3.5	15.80	21.20	26.89	32.80	38.87	45.07	51.37	57.74	64.18	70.67	77.20	3.5
3.6	15.96	21.45	27.26	33.29	39.51	45.85	52.30	58.83	65.43	72.09	78.79	3.6
3.7	16.11	21.69	27.61	33.77	40.12	46.61	53.21	59.90	66.66	73.48	80.35	3.7
3.8	16.24	21.92	27.95	34.24	40.72	47.35	54.10	60.94	67.87	74.85	81.89	3.8
3.9	16.38	22.15	28.28	34.69	41.30	48.07	54.97	61.97	69.05	76.19	83.40	3.9
4.0	16.50	22.36	28.60	35.12	41.86	48.77	55.82	62.97	70.20	77.51	84.88	4.0
4.1	16.62	22.56	28.90	35.54	42.41	49.46	56.64	63.94	71.34	78.81	86.34	4.1
4.2	16.74	22.76	29.20	35.95	42.94	50.12	57.45	64.90	72.45	80.08	87.77	4.2
4.3	16.84	22.94	29.48	36.34	43.46	50.77	58.24	65.84	73.54	81.32	89.18	4.3
4.4	16.95	23.12	29.75	36.73	43.96	51.41	59.01	66.76	74.61	82.55	90.56	4.4
4.5	17.04	23.29	30.02	37.09	44.45	52.02	59.77	67.65	75.65	83.75	91.93	4.5
4.6	17.13	23.46	30.27	37.45	44.92	52.62	60.50	68.53	76.68	84.93	93.26	4.6
4.7	17.22	23.61	30.51	37.80	45.39	53.21	61.22	69.39	77.69	86.09	94.58	4.7
4.8	17.30	23.76	30.75	38.13	45.83	53.78	61.93	70.23	78.67	87.22	95.87	4.8
4.9	17.38	23.91	30.97	38.46	46.27	54.34	62.61	71.06	79.64	88.34	97.14	4.9
5.0	17.46	24.05	31.19	38.77	46.69	54.88	63.28	71.86	80.59	89.43	98.38	5.0
5.1	17.53	24.18	31.40	39.08	47.10	55.40	63.93	72.65	81.52	90.51	99.61	5.1
5.2	17.60	24.30	31.61	39.37	47.50	55.92	64.57	73.42	82.43	91.56	100.82	5.2
5.3	17.66	24.43	31.80	39.66	47.89	56.42	65.20	74.17	83.32	92.60	102.00	5.3
5.4	17.72	24.54	31.99	39.93	48.26	56.91	65.81	74.91	84.19	93.62	103.16	5.4
5.5	17.78	24.65	32.17	40.20	48.63	57.38	66.40	75.64	85.05	94.61	104.31	5.5
5.6	17.83	24.76	32.35	40.46	48.98	57.85	66.98	76.34	85.89	95.59	105.43	5.6
5.7	17.89	24.86	32.51	40.71	49.33	58.30	67.55	77.03	86.71	96.56	106.54	5.7
5.8	17.93	24.96	32.68	40.95	49.66	58.74	68.10	77.71	87.52	97.50	107.62	5.8
5.9	17.98	25.05	32.83	41.18	49.99	59.17	68.65	78.37	88.31	98.43	108.69	5.9
6.0	18.03	25.14	32.98	41.41	50.31	59.58	69.17	79.02	89.09	99.34	109.74	6.0
6.1	18.07	25.23	33.13	41.63	50.61	59.99	69.69	79.66	89.85	100.23	110.77	6.1
6.2	18.11	25.31	33.27	41.84	50.91	60.39	70.19	80.28	90.59	101.10	111.78	6.2
6.3	18.15	25.39	33.40	42.05	51.20	60.77	70.69	80.89	91.32	101.97	112.78	6.3
6.4	18.18	25.46	33.53	42.25	51.48	61.15	71.17	81.48	92.04	102.81	113.76	6.4
6.5	18.22	25.53	33.66	42.44	51.76	61.52	71.64	82.06	92.74	103.64	114.72	6.5
6.6	18.25	25.60	33.78	42.63	52.02	61.87	72.10	82.63	93.43	104.45	115.66	6.6
6.7	18.28	25.67	33.89	42.81	52.28	62.22	72.54	83.19	94.10	105.25	116.59	6.7
6.8	18.31	25.73	34.01	42.98	52.53	62.56	72.98	83.73	94.77	106.03	117.51	6.8
6.9	18.34	25.79	34.11	43.15	52.78	62.89	73.41	84.27	95.41	106.80	118.40	6.9
7.0	18.36	25.85	34.22	43.32	53.02	63.21	73.83	84.79	96.05	107.56	119.29	7.0
7.1	18.39	25.90	34.32	43.47	53.25	63.53	74.23	85.30	96.67	108.30	120.15	7.1
7.2	18.41	25.96	34.41	43.63	53.47	63.83	74.63	85.80	97.28	109.03	121.00	7.2
7.3	18.44	26.01	34.51	43.78	53.69	64.13	75.02	86.29	97.88	109.74	121.84	7.3
7.4	18.46	26.06	34.60	43.92	53.90	64.42	75.40	86.77	98.47	110.44	122.66	7.4
7.5	18.48	26.10	34.68	44.06	54.10	64.70	75.77	87.24	99.04	111.13	123.47	7.5
7.6	18.50	26.15	34.77	44.20	54.30	64.98	76.13	87.70	99.60	111.81	124.27	7.6
7.7	18.51	26.19	34.85	44.33	54.50	65.25	76.49	88.14	100.16	112.47	125.05	7.7
7.8	18.53	26.23	34.92	44.45	54.68	65.51	76.83	88.58	100.70	113.12	125.82	7.8
7.9	18.55	26.27	35.00	44.57	54.87	65.76	77.17	89.01	101.23	113.76	126.57	7.9
8.0	18.56	26.31	35.07	44.69	55.04	66.01	77.50	89.43	101.75	114.39	127.31	8.0
8.1	18.58	26.34	35.14	44.81	55.22	66.25	77.82	89.85	102.26	115.00	128.04	8.1
8.2	18.59	26.38	35.21	44.92	55.38	66.49	78.14	90.25	102.76	115.61	128.76	8.2
8.3	18.61	26.41	35.27	45.03	55.55	66.72	78.44	90.64	103.25	116.20	129.46	8.3
8.4	18.62	26.44	35.33	45.13	55.71	66.94	78.74	91.03	103.73	116.78	130.15	8.4
8.5	18.63	26.47	35.39	45.23	55.86	67.16	79.04	91.40	104.20	117.36	130.83	8.5
8.6	18.64	26.50	35.45	45.33	56.01	67.37	79.32	91.77	104.66	117.92	131.50	8.6
8.7	18.65	26.53	35.50	45.42	56.15	67.58	79.60	92.13	105.11	118.47	132.16	8.7
8.8	18.66	26.56	35.56	45.51	56.29	67.78	79.87	92.49	105.55	119.01	132.81	8.8
8.9	18.67	26.58	35.61	45.60	56.43	67.98	80.14	92.83	105.99	119.54	133.44	8.9
9.0	18.68	26.61	35.66	45.69	56.56	68.17	80.40	93.17	106.41	120.06	134.06	9.0
9.1	18.69	26.63	35.71	45.77	56.69	68.36	80.65	93.50	106.83	120.57	134.68	9.1
9.2	18.70	26.65	35.75	45.85	56.82	68.54	80.90	93.83	107.24	121.07	135.28	9.2
9.3	18.71	26.67	35.80	45.93	56.94	68.71	81.15	94.15	107.64	121.57	135.87	9.3
9.4	18.72	26.69	35.84	46.00	57.06	68.89	81.38	94.46	108.03	122.05	136.45	9.4
9.5	18.72	26.71	35.88	46.08	57.13	69.06	81.61	94.76	108.42	122.53	137.02	9.5
9.6	18.73	26.73	35.92	46.15	57.29	69.22	81.84	95.06	108.80	122.99	137.59	9.6
9.7	18.74	26.75	35.96	46.22	57.40	69.38	82.06	95.35	109.17	123.45	138.14	9.7
9.8	18.74	26.77	35.99	46.28	57.50	69.53	82.27	95.63	109.53	123.90	138.68	9.8
9.9	18.75	26.78	36.03	46.35	57.60	69.69	82.48	95.91	109.88	124.34	139.22	9.9
10.0	18.75	26.80	36.06	46.41	57.70	69.83	82.69	96.18	110.23	124.77	139.74	10.0

TABLE A4 FILL LOADS (continued)
NARROW TRENCH

TRENCH WIDTH

Cover m	1.6 kN/m	1.7 kN/m	1.8 kN/m	1.9 kN/m	2.0 kN/m	2.1 kN/m	2.2 kN/m	2.3 kN/m	2.4 kN/m	2.5 kN/m	2.6 kN/m	Cover m
0.6	17.94	19.12	20.29	21.47	22.64	23.82	24.99	26.17	27.34	28.52	29.70	0.6
0.7	20.76	22.13	23.50	24.88	26.25	27.62	28.99	30.36	31.73	33.10	34.48	0.7
0.8	23.54	25.11	26.67	28.24	29.80	31.37	32.94	34.50	36.07	37.64	39.21	0.8
0.9	26.27	28.03	29.79	31.56	33.32	35.08	36.84	38.60	40.36	42.13	43.89	0.9
1.0	28.96	30.92	32.87	34.83	36.78	38.74	40.70	42.65	44.61	46.57	48.53	1.0
1.1	31.61	33.76	35.91	38.06	40.21	42.36	44.51	46.66	48.81	50.97	53.12	1.1
1.2	34.21	36.55	38.90	41.24	43.58	45.93	48.28	50.62	52.97	55.32	57.66	1.2
1.3	36.77	39.31	41.84	44.38	46.92	49.46	52.00	54.54	57.08	59.62	62.16	1.3
1.4	39.29	42.02	44.75	47.48	50.21	52.94	55.68	58.41	61.15	63.88	66.62	1.4
1.5	41.77	44.69	47.61	50.53	53.46	56.38	59.31	62.24	65.17	68.10	71.03	1.5
1.6	44.21	47.32	50.43	53.55	56.67	59.78	62.90	66.03	69.15	72.27	75.40	1.6
1.7	46.61	49.91	53.22	56.52	59.83	63.14	66.45	69.77	73.09	76.40	79.72	1.7
1.8	48.98	52.46	55.96	59.45	62.96	66.46	69.96	73.47	76.98	80.49	84.00	1.8
1.9	51.30	54.98	58.66	62.35	66.04	69.73	73.43	77.13	80.83	84.54	88.24	1.9
2.0	53.58	57.45	61.32	65.20	69.08	72.97	76.86	80.75	84.64	88.54	92.44	2.0
2.1	55.83	59.89	63.95	68.02	72.09	76.16	80.24	84.33	88.41	92.50	96.59	2.1
2.2	58.05	62.29	66.54	70.79	75.05	79.32	83.59	87.87	92.14	96.42	100.70	2.2
2.3	60.22	64.65	69.09	73.53	77.98	82.44	86.90	91.36	95.83	100.30	104.78	2.3
2.4	62.37	66.98	71.60	76.23	80.87	85.52	90.17	94.82	99.48	104.14	108.81	2.4
2.5	64.47	69.27	74.08	78.90	83.73	88.56	93.40	98.24	103.09	107.94	112.80	2.5
2.6	66.55	71.53	76.52	81.53	86.54	91.56	96.59	101.62	106.66	111.70	116.75	2.6
2.7	68.59	73.75	78.93	84.12	89.32	94.53	99.74	104.97	110.19	115.43	120.66	2.7
2.8	70.59	75.94	81.30	86.68	92.06	97.46	102.86	108.27	113.69	119.11	124.54	2.8
2.9	72.57	78.10	83.64	89.20	94.77	100.35	105.94	111.54	117.15	122.76	128.37	2.9
3.0	74.51	80.22	85.95	91.69	97.45	103.21	108.99	114.77	120.56	126.36	132.17	3.0
3.1	76.42	82.31	88.22	94.15	100.08	106.04	112.00	117.97	123.95	129.93	135.93	3.1
3.2	78.30	84.37	90.46	96.57	102.69	108.82	114.97	121.13	127.29	133.47	139.65	3.2
3.3	80.15	86.40	92.87	98.96	105.26	111.58	117.91	124.25	130.60	136.96	143.33	3.3
3.4	81.98	88.40	94.84	101.31	107.80	114.30	120.81	127.34	133.88	140.43	146.98	3.4
3.5	83.77	90.37	96.99	103.64	110.30	116.99	123.68	130.39	137.12	143.85	150.59	3.5
3.6	85.53	92.30	99.10	106.93	112.78	119.64	126.52	133.41	140.32	147.24	154.17	3.6
3.7	87.26	94.21	101.19	108.19	115.22	122.26	129.32	136.40	143.49	150.59	157.71	3.7
3.8	88.97	96.09	103.24	110.42	117.63	124.85	132.09	139.35	146.63	153.91	161.21	3.8
3.9	90.65	97.94	105.27	112.62	120.00	127.41	134.83	142.27	149.73	157.20	164.68	3.9
4.0	92.30	99.76	107.26	114.79	122.35	129.93	137.54	145.16	152.80	160.45	168.12	4.0
4.1	93.93	101.56	109.23	116.93	124.67	132.43	140.21	148.01	155.83	163.67	171.52	4.1
4.2	95.52	103.32	111.17	119.05	126.95	134.89	142.85	150.83	158.84	166.85	174.89	4.2
4.3	97.10	105.07	113.08	121.13	129.21	137.33	145.46	153.62	161.81	170.01	178.22	4.3
4.4	98.64	106.78	114.96	123.18	131.44	139.73	148.04	156.38	164.74	173.12	181.52	4.4
4.5	100.17	108.47	116.82	125.21	133.64	142.10	150.59	159.11	167.65	176.21	184.79	4.5
4.6	101.67	110.13	118.65	127.21	135.81	144.45	153.11	161.81	170.53	179.27	188.03	4.6
4.7	103.14	111.77	120.45	129.18	137.95	146.76	155.61	164.48	173.37	182.29	191.23	4.7
4.8	104.59	113.38	122.23	131.13	140.07	149.05	158.07	167.11	176.18	185.28	194.40	4.8
4.9	106.02	114.97	123.98	133.05	142.16	151.31	160.50	169.72	178.97	188.24	197.54	4.9
5.0	107.42	116.53	125.71	134.94	144.22	153.54	162.90	172.30	181.72	191.17	200.65	5.0
5.1	108.80	118.07	127.41	136.81	146.25	155.75	165.28	174.85	184.45	194.07	203.73	5.1
5.2	110.16	119.59	129.09	138.65	148.26	157.92	167.63	177.37	187.14	196.94	206.77	5.2
5.3	111.50	121.08	130.74	140.47	150.24	160.07	169.95	179.86	189.81	199.78	209.79	5.3
5.4	112.81	122.55	132.37	142.26	152.20	162.20	172.24	182.32	192.44	202.59	212.78	5.4
5.5	114.11	124.00	133.98	144.02	154.13	164.30	174.51	184.76	195.05	205.38	215.73	5.5
5.6	115.38	125.43	135.56	145.77	156.04	166.37	176.74	187.17	197.63	208.13	218.66	5.6
5.7	116.63	126.84	137.12	147.49	157.92	168.41	178.96	189.55	200.18	210.85	221.56	5.7
5.8	117.87	128.22	138.66	149.19	159.78	170.43	181.14	191.90	202.71	213.55	224.43	5.8
5.9	119.08	129.58	140.18	150.86	161.61	172.43	183.31	194.23	205.21	216.22	227.27	5.9
6.0	120.27	130.92	141.67	152.51	163.42	174.40	185.44	196.54	207.68	218.86	230.08	6.0
6.1	121.45	132.25	143.15	154.14	165.21	176.35	187.55	198.81	210.12	221.47	232.87	6.1
6.2	122.60	133.55	144.60	155.74	166.97	178.27	189.64	201.06	212.54	224.06	235.62	6.2
6.3	123.74	134.83	146.03	157.33	168.71	180.17	191.70	203.29	214.93	226.62	238.35	6.3
6.4	124.86	136.09	147.44	158.89	170.43	182.05	193.74	205.49	217.30	229.15	241.06	6.4
6.5	125.96	137.34	148.83	160.43	172.13	183.90	195.75	207.66	219.64	231.66	243.73	6.5
6.6	127.04	138.56	150.20	161.95	173.80	185.73	197.74	209.82	221.95	234.14	246.38	6.6
6.7	128.11	139.77	151.55	163.45	175.45	187.54	199.71	211.94	224.24	236.60	249.00	6.7
6.8	129.15	140.95	152.89	164.93	177.08	189.33	201.65	214.05	226.51	239.03	251.60	6.8
6.9	130.18	142.12	154.20	166.39	178.69	191.09	203.57	216.13	228.75	241.43	254.17	6.9
7.0	131.20	143.27	155.49	167.83	180.28	192.83	205.47	218.18	230.97	243.81	256.71	7.0
7.1	132.20	144.41	156.77	169.25	181.85	194.55	207.34	220.22	233.16	246.17	259.23	7.1
7.2	133.18	145.53	158.02	170.65	183.40	196.25	209.20	222.23	235.33	248.50	261.73	7.2
7.3	134.14	146.63	159.26	172.04	184.93	197.93	211.03	224.21	237.47	250.80	264.20	7.3
7.4	135.10	147.71	160.48	173.40	186.44	199.59	212.84	226.18	239.60	253.09	266.64	7.4
7.5	136.03	148.78	161.69	174.74	187.93	201.23	214.63	228.12	241.70	255.35	269.06	7.5
7.6	136.95	149.83	162.87	176.07	189.40	202.84	216.40	230.04	243.77	257.58	271.46	7.6
7.7	137.86	150.86	164.04	177.38	190.85	204.44	218.14	231.94	245.83	259.80	273.83	7.7
7.8	138.75	151.88	165.20	178.67	192.28	206.02	219.87	233.82	247.86	261.99	276.18	7.8
7.9	139.62	152.88	166.33	179.94	193.70	207.58	221.58	235.68	249.87	264.15	278.51	7.9
8.0	140.49	153.87	167.45	181.20	195.09	209.12	223.26	237.52	251.86	266.30	280.81	8.0
8.1	141.33	154.85	168.55	182.43	196.47	210.64	224.93	239.33	253.83	268.42	283.09	8.1
8.2	142.17	155.81	169.64	183.66	197.83	212.14	226.58	241.13	255.78	270.52	285.35	8.2
8.3	142.99	156.75	170.71	184.86	199.17	213.62	228.20	242.90	257.70	272.60	287.58	8.3
8.4	143.80	157.68	171.77	186.05	200.49	215.09	229.81	244.66	259.61	274.66	289.80	8.4
8.5	144.59	158.59	172.81	187.22	201.80	216.53	231.40	246.39	261.49	276.70	291.99	8.5
8.6	145.37	159.50	173.84	188.38	203.09	217.96	232.97	248.11	263.36	278.71	294.16	8.6
8.7	146.14	160.38	174.85	189.52	204.37	219.37	234.53	249.81	265.20	280.70	296.30	8.7
8.8	146.90	161.26	175.85	190.65	205.63	220.77	236.06	251.48	267.03	282.68	298.43	8.8
8.9	147.65	162.12	176.83	191.76	206.87	222.15	237.58	253.14	268.83	284.63	300.53	8.9
9.0	148.38	162.97	177.80	192.35	208.09	223.51	239.07	254.78	270.62	286.56	302.62	9.0
9.1	149.10	163.80	178.76	193.93	209.30	224.85	240.55	256.40	272.38	288.48	304.68	9.1
9.2	149.81	164.63	179.70	195.00	210.50	226.18	242.02	258.01	274.13	290.37	306.72	9.2
9.3	150.51	165.44	180.63	196.05	211.67	227.49	243.46	259.59	275.86	292.24	308.74	9.3
9.4	151.19	166.24	181.54	197.08	212.84	228.78	244.89	261.16	277.57	294.10	310.75	9.4
9.5	151.87	167.02	182.44	198.11	213.99	230.06	246.31	262.71	279.26	295.93	312.73	9.5
9.6	152.54	167.79	183.33	199.12	215.12	231.32	247.70	264.24	280.93	297.75	314.69	9.6
9.7	153.19	168.56	184.21	200.11	216.24	232.57	249.08	265.76	282.59	299.55	316.63	9.7
9.8	153.83	169.31	185.07	201.09	217.34	233.80	250.44	267.26	284.22	301.33	318.56	9.8
9.9	154.47	170.05	185.92	202.06	218.43	235.02	251.79	268.74	285.84	303.09	320.46	9.9
10.0	155.09	170.77	186.76	203.01	219.51	236.22	253.12	270.20	287.44	304.83	322.35	10.0

TABLE A5 TRAFFIC LOADS

2 WHEELS 30kN
IMPACT FACTOR 2.0

PIPE DIAMETER

Cover m	100 kN/m	150 kN/m	200 kN/m	225 kN/m	300 kN/m	375 kN/m	400 kN/m	450 kN/m	500 kN/m	600 kN/m	700 kN/m	800 kN/m	900 kN/m	1000 kN/m	Cover m
0.6	8.95	12.96	16.53	18.92	24.59	30.02	32.30	35.57	39.04	48.15	52.16	58.22	63.76	68.85	0.6
0.7	7.43	10.78	13.79	15.77	20.63	25.29	27.35	30.05	33.19	39.05	44.47	50.04	55.42	59.20	0.7
0.8	6.28	9.13	11.70	13.36	17.58	21.60	23.36	25.61	28.09	33.20	38.05	43.16	47.93	52.23	0.8
0.9	5.39	7.85	10.06	11.46	15.11	18.61	20.14	22.01	23.94	28.26	32.68	37.14	41.43	45.45	0.9
1.0	4.68	6.81	8.74	9.96	13.12	16.16	17.45	19.05	20.78	24.66	28.49	32.51	36.35	40.05	1.0
1.1	4.09	5.96	7.86	8.73	11.44	14.07	15.21	16.60	18.37	21.34	24.12	26.90	29.43	31.72	1.1
1.2	3.61	5.26	6.76	7.71	10.11	12.45	13.48	14.73	16.32	19.02	21.56	24.14	26.51	28.68	1.2
1.3	3.20	4.67	6.01	8.85	8.99	11.09	12.01	13.14	14.79	17.02	19.35	21.73	23.94	25.99	1.3
1.4	2.86	4.17	5.36	6.12	8.04	9.93	10.75	11.77	13.07	15.30	17.43	19.62	21.68	23.59	1.4
1.5	2.57	3.74	4.82	5.50	7.23	8.93	9.68	10.60	11.96	13.81	15.76	17.77	19.68	21.48	1.5
1.6	2.31	3.38	4.34	4.96	6.52	8.07	8.74	9.58	10.65	12.51	14.29	16.15	17.92	19.60	1.6
1.7	2.09	3.06	3.94	4.49	5.91	7.32	7.93	8.69	9.67	11.37	13.01	14.73	16.37	17.93	1.7
1.8	1.90	2.78	3.58	4.09	5.38	6.66	7.22	7.92	8.82	10.37	11.88	13.47	14.99	16.45	1.8
1.9	1.74	2.54	3.27	3.73	4.91	6.09	6.60	7.24	8.06	9.49	10.89	12.36	13.77	15.13	1.9
2.0	1.59	2.32	2.99	3.42	4.50	5.58	6.05	6.64	7.40	8.72	10.01	11.37	12.68	13.95	2.0
2.1	1.46	2.14	2.75	3.14	4.14	5.13	5.57	6.11	6.81	8.03	9.22	10.48	11.71	12.89	2.1
2.2	1.35	1.97	2.54	2.90	3.82	4.73	5.14	5.64	6.28	7.41	8.52	9.69	10.83	11.94	2.2
2.3	1.25	1.82	2.34	2.68	3.53	4.38	4.75	5.21	5.82	6.86	7.89	8.99	10.05	11.09	2.3
2.4	1.15	1.69	2.17	2.48	3.27	4.06	4.41	4.84	5.39	6.37	7.33	8.35	9.35	10.32	2.4
2.5	1.07	1.57	2.02	2.31	3.04	3.77	4.10	4.50	5.02	5.93	6.82	7.78	8.71	9.52	2.5
2.6	1.00	1.46	1.88	2.15	2.83	3.52	3.82	4.19	4.68	5.53	6.36	7.26	8.13	8.99	2.6
2.7	0.93	1.36	1.76	2.01	2.65	3.28	3.56	3.91	4.37	5.16	5.95	6.79	7.61	8.41	2.7
2.8	0.87	1.27	1.64	1.88	2.48	3.07	3.34	3.66	4.09	4.83	5.57	6.36	7.13	7.89	2.8
2.9	0.82	1.19	1.54	1.76	2.32	2.88	3.13	3.44	3.84	4.54	5.23	5.97	6.70	7.41	2.9
3.0	0.77	1.12	1.45	1.65	2.18	2.71	2.94	3.23	3.60	4.26	4.91	5.61	6.30	6.98	3.0
3.1	0.72	1.06	1.36	1.55	2.05	2.55	2.76	3.04	3.39	4.01	4.63	5.29	5.94	6.58	3.1
3.2	0.68	0.99	1.28	1.46	1.93	2.40	2.61	2.86	3.20	3.78	4.36	4.99	5.60	6.21	3.2
3.3	0.64	0.94	1.21	1.38	1.82	2.27	2.46	2.70	3.02	3.57	4.12	4.71	5.30	5.87	3.3
3.4	0.61	0.89	1.14	1.31	1.72	2.14	2.33	2.56	2.86	3.38	3.90	4.46	5.01	5.58	3.4
3.5	0.57	0.84	1.08	1.24	1.63	2.03	2.20	2.42	2.70	3.20	3.69	4.23	4.75	5.27	3.5
3.6	0.55	0.80	1.03	1.17	1.55	1.92	2.09	2.30	2.56	3.04	3.50	4.01	4.51	5.00	3.6
3.7	0.52	0.76	0.97	1.11	1.47	1.83	1.98	2.18	2.43	2.88	3.33	3.81	4.28	4.75	3.7
3.8	0.49	0.72	0.93	1.06	1.40	1.74	1.89	2.07	2.31	2.74	3.17	3.62	4.07	4.52	3.8
3.9	0.47	0.68	0.88	1.01	1.33	1.65	1.79	1.97	2.20	2.61	3.01	3.45	3.88	4.31	3.9
4.0	0.45	0.65	0.84	0.96	1.27	1.57	1.71	1.88	2.10	2.49	2.87	3.29	3.70	4.11	4.0
4.1	0.43	0.62	0.80	0.92	1.21	1.50	1.63	1.79	2.00	2.37	2.74	3.14	3.53	3.92	4.1
4.2	0.41	0.59	0.76	0.87	1.15	1.43	1.56	1.71	1.91	2.27	2.62	3.00	3.37	3.75	4.2
4.3	0.39	0.57	0.73	0.84	1.10	1.37	1.49	1.64	1.83	2.17	2.50	2.87	3.23	3.58	4.3
4.4	0.37	0.54	0.70	0.80	1.05	1.31	1.42	1.57	1.75	2.07	2.39	2.74	3.09	3.43	4.4
4.5	0.36	0.52	0.67	0.76	1.01	1.25	1.36	1.50	1.68	1.99	2.29	2.63	2.96	3.29	4.5
4.6	0.34	0.50	0.64	0.73	0.97	1.20	1.31	1.44	1.61	1.90	2.20	2.52	2.84	3.15	4.6
4.7	0.33	0.48	0.62	0.70	0.93	1.15	1.25	1.38	1.54	1.83	2.11	2.42	2.72	3.02	4.7
4.8	0.31	0.46	0.59	0.68	0.89	1.11	1.20	1.32	1.48	1.75	2.03	2.32	2.61	2.91	4.8
4.9	0.30	0.44	0.57	0.65	0.86	1.06	1.16	1.27	1.42	1.68	1.95	2.23	2.51	2.79	4.9
5.0	0.29	0.42	0.55	0.62	0.82	1.02	1.11	1.22	1.37	1.62	1.87	2.15	2.42	2.69	5.0
5.1	0.28	0.41	0.53	0.80	0.79	0.98	1.07	1.18	1.31	1.56	1.80	2.06	2.33	2.59	5.1
5.2	0.27	0.39	0.51	0.58	0.76	0.95	1.03	1.13	1.27	1.50	1.74	1.99	2.24	2.49	5.2
5.3	0.26	0.38	0.49	0.56	0.74	0.91	0.99	1.09	1.22	1.45	1.67	1.92	2.16	2.40	5.3
5.4	0.25	0.36	0.47	0.54	0.71	0.88	0.96	1.05	1.18	1.40	1.61	1.85	2.08	2.32	5.4
5.5	0.24	0.35	0.45	0.52	0.68	0.85	0.92	1.02	1.14	1.35	1.56	1.78	2.01	2.24	5.5
5.6	0.23	0.34	0.44	0.50	0.66	0.82	0.89	0.98	1.10	1.30	1.50	1.72	1.94	2.16	5.6
5.7	0.22	0.33	0.42	0.48	0.64	0.79	0.86	0.95	1.06	1.26	1.45	1.66	1.88	2.09	5.7
5.8	0.22	0.32	0.41	0.47	0.62	0.77	0.83	0.92	1.02	1.21	1.40	1.61	1.81	2.02	5.8
5.9	0.21	0.31	0.40	0.45	0.60	0.74	0.81	0.89	0.99	1.17	1.36	1.56	1.75	1.95	5.9
6.0	0.20	0.30	0.38	0.44	0.58	0.72	0.78	0.86	0.96	1.14	1.31	1.51	1.70	1.89	6.0
6.1	0.20	0.29	0.37	0.42	0.56	0.69	0.75	0.83	0.93	1.10	1.27	1.46	1.64	1.83	6.1
6.2	0.19	0.28	0.36	0.41	0.54	0.67	0.73	0.80	0.90	1.07	1.23	1.41	1.59	1.77	6.2
6.3	0.18	0.27	0.35	0.40	0.52	0.65	0.71	0.78	0.87	1.03	1.19	1.37	1.54	1.72	6.3
6.4	0.18	0.26	0.34	0.38	0.51	0.63	0.69	0.76	0.84	1.00	1.16	1.33	1.50	1.66	6.4
6.5	0.17	0.25	0.33	0.37	0.49	0.61	0.67	0.73	0.82	0.97	1.12	1.29	1.45	1.62	6.5
6.6	0.17	0.25	0.32	0.36	0.48	0.59	0.65	0.71	0.79	0.94	1.09	1.25	1.41	1.57	6.6
6.7	0.16	0.24	0.31	0.35	0.46	0.58	0.63	0.69	0.77	0.91	1.06	1.21	1.37	1.52	6.7
6.8	0.16	0.23	0.30	0.34	0.45	0.56	0.61	0.67	0.75	0.89	1.03	1.18	1.33	1.48	6.8
6.9	0.15	0.23	0.29	0.33	0.44	0.54	0.59	0.65	0.73	0.86	1.00	1.15	1.29	1.44	6.9
7.0	0.15	0.22	0.28	0.32	0.43	0.53	0.58	0.63	0.71	0.84	0.97	1.11	1.26	1.40	7.0
7.1	0.15	0.21	0.27	0.31	0.41	0.52	0.56	0.62	0.69	0.82	0.94	1.08	1.22	1.36	7.1
7.2	0.14	0.21	0.27	0.31	0.40	0.50	0.54	0.60	0.67	0.79	0.92	1.05	1.19	1.32	7.2
7.3	0.14	0.20	0.26	0.30	0.39	0.49	0.53	0.58	0.65	0.77	0.89	1.03	1.16	1.29	7.3
7.4	0.13	0.20	0.25	0.29	0.38	0.47	0.52	0.57	0.63	0.75	0.87	1.00	1.13	1.25	7.4
7.5	0.13	0.19	0.25	0.28	0.37	0.46	0.50	0.55	0.62	0.73	0.85	0.97	1.10	1.22	7.5
7.6	0.13	0.19	0.24	0.27	0.36	0.45	0.49	0.54	0.60	0.71	0.83	0.95	1.07	1.19	7.6
7.7	0.12	0.18	0.23	0.27	0.35	0.44	0.48	0.52	0.59	0.70	0.80	0.92	1.04	1.16	7.7
7.8	0.12	0.18	0.23	0.26	0.34	0.43	0.47	0.51	0.57	0.68	0.78	0.90	1.02	1.13	7.8
7.9	0.12	0.17	0.22	0.25	0.34	0.42	0.45	0.50	0.56	0.66	0.77	0.88	0.99	1.10	7.9
8.0	0.12	0.17	0.22	0.25	0.33	0.41	0.44	0.49	0.54	0.65	0.75	0.86	0.97	1.08	8.0
8.1	0.11	0.16	0.21	0.24	0.32	0.40	0.43	0.47	0.53	0.63	0.73	0.84	0.94	1.05	8.1
8.2	0.11	0.16	0.21	0.24	0.31	0.39	0.42	0.46	0.52	0.61	0.71	0.82	0.92	1.02	8.2
8.3	0.11	0.16	0.20	0.23	0.30	0.38	0.41	0.45	0.51	0.60	0.69	0.80	0.90	1.00	8.3
8.4	0.10	0.15	0.20	0.23	0.30	0.37	0.40	0.44	0.49	0.59	0.68	0.78	0.88	0.98	8.4
8.5	0.10	0.15	0.19	0.22	0.29	0.36	0.39	0.43	0.48	0.57	0.66	0.76	0.86	0.95	8.5
8.6	0.10	0.15	0.19	0.21	0.28	0.35	0.38	0.42	0.47	0.56	0.65	0.74	0.84	0.93	8.6
8.7	0.10	0.14	0.18	0.21	0.28	0.34	0.37	0.41	0.46	0.55	0.63	0.73	0.82	0.91	8.7
8.8	0.10	0.14	0.18	0.21	0.27	0.34	0.37	0.40	0.45	0.53	0.62	0.71	0.80	0.89	8.8
8.9	0.09	0.14	0.18	0.20	0.27	0.33	0.36	0.39	0.44	0.52	0.60	0.69	0.78	0.87	8.9
9.0	0.09	0.13	0.17	0.20	0.26	0.32	0.35	0.39	0.43	0.51	0.59	0.68	0.77	0.85	9.0
9.1	0.09	0.13	0.17	0.19	0.25	0.32	0.34	0.38	0.42	0.50	0.58	0.66	0.75	0.83	9.1
9.2	0.09	0.13	0.16	0.19	0.25	0.31	0.34	0.37	0.41	0.49	0.57	0.65	0.73	0.82	9.2
9.3	0.09	0.12	0.16	0.18	0.24	0.30	0.33	0.36	0.40	0.48	0.55	0.64	0.72	0.80	9.3
9.4	0.08	0.12	0.16	0.18	0.24	0.30	0.32	0.35	0.40	0.47	0.54	0.62	0.70	0.78	9.4
9.5	0.08	0.12	0.15	0.18	0.23	0.29	0.31	0.35	0.39	0.46	0.53	0.61	0.69	0.77	9.5
9.6	0.08	0.12	0.15	0.17	0.23	0.28	0.31	0.34	0.38	0.45	0.52	0.60	0.67	0.75	9.6
9.7	0.08	0.11	0.15	0.17	0.22	0.28	0.30	0.33	0.37	0.44	0.51	0.59	0.66	0.73	9.7
9.8	0.08	0.11	0.15	0.17	0.22	0.27	0.30	0.33	0.36	0.43	0.50	0.57	0.65	0.72	9.8
9.9	0.08	0.11	0.14	0.16	0.21	0.27	0.29	0.32	0.36	0.42	0.49	0.56	0.63	0.71	9.9
10.0	0.07	0.11	0.14	0.16	0.21	0.26	0.28	0.31	0.35	0.41	0.48	0.55	0.62	0.69	10.0

TABLE A6 TRAFFIC LOADS

8 WHEELS 112.5kN
INCLUDING IMPACT FACTOR

PIPE DIAMETER

Cover m	100 kN/m	150 kN/m	200 kN/m	225 kN/m	300 kN/m	375 kN/m	400 kN/m	450 kN/m	500 kN/m	600 kN/m	700 kN/m	800 kN/m	900 kN/m	1000 kN/m	Cover m
0.6	15.47	22.41	28.60	32.74	42.63	52.14	56.16	61.91	68.07	80.73	91.58	102.65	121.49	143.20	0.6
0.7	13.33	19.36	24.77	28.33	37.13	45.61	49.36	54.31	60.09	70.95	81.12	91.70	108.13	123.99	0.7
0.8	11.73	17.06	21.87	24.98	32.87	40.52	43.87	48.16	52.92	62.77	72.26	82.38	96.42	111.34	0.8
0.9	10.49	15.27	19.61	22.33	29.50	36.40	39.45	43.16	47.03	55.75	64.73	74.03	86.43	99.47	0.9
1.0	9.51	13.85	17.80	20.29	26.76	33.04	35.72	39.04	42.68	50.86	59.05	67.88	79.00	90.61	1.0
1.1	8.71	12.70	16.33	18.62	24.43	30.11	32.58	35.62	39.50	46.10	54.19	62.75	72.85	83.10	1.1
1.2	8.05	11.74	15.10	17.23	22.64	27.95	30.27	33.13	36.79	43.07	49.82	58.14	67.25	76.32	1.2
1.3	7.49	10.93	14.07	16.06	21.12	26.10	28.29	30.99	34.45	40.43	46.20	54.48	62.92	71.39	1.3
1.4	7.01	10.24	13.18	15.05	19.81	24.51	26.57	29.13	32.42	38.12	43.74	51.19	58.99	66.91	1.4
1.5	6.60	9.64	12.41	14.17	18.66	23.11	25.07	27.49	30.62	36.06	41.65	48.25	55.48	62.80	1.5
1.6	6.24	9.11	11.73	13.39	17.65	21.87	23.73	26.04	29.02	34.36	39.73	45.56	52.48	59.40	1.6
1.7	5.91	8.63	11.12	12.70	16.74	20.75	22.53	24.77	27.68	32.83	37.96	43.51	49.87	56.44	1.7
1.8	5.62	8.20	10.57	12.08	15.96	19.83	21.55	23.70	26.48	31.40	36.31	41.61	47.36	53.70	1.8
1.9	5.37	7.85	10.13	11.57	15.28	18.99	20.64	22.69	25.36	30.07	34.76	39.84	45.11	50.90	1.9
2.0	5.15	7.53	9.71	11.09	14.65	18.20	19.78	21.75	24.31	28.82	33.31	38.17	43.00	47.80	2.0
2.1	4.94	7.22	9.31	10.64	14.05	17.46	18.97	20.86	23.31	27.63	31.94	36.60	41.23	45.83	2.1
2.2	4.74	6.93	8.93	10.21	13.48	16.75	18.20	20.01	22.37	26.52	30.65	35.11	39.55	43.96	2.2
2.3	4.55	6.65	8.58	9.80	12.94	16.08	17.48	19.21	21.47	25.45	29.42	33.71	37.97	42.20	2.3
2.4	4.37	6.39	8.24	9.41	12.43	15.45	16.78	18.45	20.62	24.45	28.25	32.37	36.46	40.52	2.4
2.5	4.20	6.14	7.91	9.04	11.94	14.84	16.13	17.73	19.81	23.49	27.15	31.10	35.03	38.93	2.5
2.6	4.04	5.90	7.61	8.89	11.48	14.26	15.50	17.04	19.04	22.57	26.09	29.89	33.67	37.42	2.6
2.7	3.88	5.67	7.31	8.36	11.04	13.71	14.90	16.39	18.31	21.70	25.09	28.74	32.37	35.98	2.7
2.8	3.73	5.46	7.03	8.04	10.62	13.19	14.33	15.76	17.61	20.88	24.13	27.64	31.14	34.61	2.8
2.9	3.59	5.25	6.77	7.73	10.21	12.69	13.79	15.16	16.94	20.09	23.21	26.60	29.96	33.30	2.9
3.0	3.46	5.05	6.51	7.44	9.83	12.21	13.27	14.59	16.31	19.33	22.34	25.60	28.84	32.05	3.0
3.1	3.33	4.86	6.27	7.17	9.46	11.76	12.78	14.05	15.70	18.61	21.51	24.65	27.76	30.86	3.1
3.2	3.21	4.68	6.04	6.90	9.11	11.32	12.31	13.53	15.12	17.92	20.72	23.74	26.74	29.72	3.2
3.3	3.09	4.51	5.82	6.65	8.78	10.91	11.86	13.04	14.57	17.27	19.96	22.87	25.77	28.64	3.3
3.4	2.98	4.35	5.61	6.41	8.46	10.51	11.43	12.56	14.04	16.64	19.24	22.04	24.83	27.61	3.4
3.5	2.87	4.19	5.40	6.18	8.16	10.14	11.01	12.11	13.53	16.05	18.55	21.25	23.95	26.62	3.5
3.6	2.77	4.04	5.21	5.96	7.87	9.78	10.62	11.68	13.05	15.48	17.89	20.50	23.10	25.68	3.6
3.7	2.67	3.90	5.03	5.75	7.59	9.43	10.25	11.27	12.59	14.93	17.26	19.78	22.29	24.78	3.7
3.8	2.58	3.76	4.85	5.55	7.32	9.10	9.89	10.87	12.15	14.41	16.66	19.09	21.51	23.92	3.8
3.9	2.49	3.63	4.68	5.35	7.07	8.79	9.55	10.50	11.73	13.91	16.08	18.43	20.77	23.09	3.9
4.0	2.40	3.51	4.52	5.17	6.83	8.49	9.22	10.14	11.33	13.44	15.53	17.80	20.06	22.31	4.0
4.1	2.32	3.39	4.37	4.99	6.60	8.20	8.91	9.80	10.95	12.98	15.01	17.20	19.39	21.56	4.1
4.2	2.24	3.28	4.22	4.83	6.38	7.92	8.61	9.47	10.58	12.55	14.51	16.63	18.74	20.84	4.2
4.3	2.17	3.17	4.08	4.67	6.17	7.66	8.32	9.15	10.23	12.13	14.03	16.08	18.12	20.15	4.3
4.4	2.10	3.06	3.95	4.51	5.96	7.41	8.05	8.85	9.90	11.73	13.57	15.55	17.53	19.49	4.4
4.5	2.03	2.96	3.82	4.37	5.77	7.17	7.79	8.57	9.57	11.35	13.13	15.05	16.96	18.86	4.5
4.6	1.96	2.87	3.70	4.23	5.58	6.94	7.54	8.29	9.27	10.99	12.71	14.57	16.42	18.26	4.6
4.7	1.90	2.78	3.58	4.09	5.41	6.72	7.30	8.03	8.97	10.64	12.31	14.11	15.90	17.69	4.7
4.8	1.84	2.69	3.47	3.96	5.24	6.51	7.07	7.78	8.69	10.31	11.92	13.67	15.40	17.13	4.8
4.9	1.78	2.61	3.36	3.84	5.07	6.31	6.85	7.54	8.42	9.99	11.55	13.24	14.93	16.60	4.9
5.0	1.73	2.53	3.26	3.72	4.92	6.11	6.64	7.30	8.16	9.68	11.20	12.84	14.47	16.10	5.0
5.1	1.68	2.45	3.16	3.61	4.77	5.93	6.44	7.08	7.92	9.39	10.86	12.45	14.03	15.61	5.1
5.2	1.63	2.38	3.06	3.50	4.63	5.75	6.25	6.87	7.68	9.11	10.53	12.07	13.61	15.14	5.2
5.3	1.58	2.31	2.97	3.40	4.49	5.58	6.06	6.67	7.45	8.84	10.22	11.72	13.21	14.70	5.3
5.4	1.53	2.24	2.89	3.30	4.36	5.41	5.88	6.47	7.23	8.58	9.92	11.37	12.82	14.27	5.4
5.5	1.49	2.17	2.80	3.20	4.23	5.26	5.71	6.28	7.02	8.33	9.63	11.04	12.45	13.85	5.5
5.6	1.44	2.11	2.72	3.11	4.11	5.11	5.55	6.10	6.82	8.09	9.36	10.73	12.10	13.46	5.6
5.7	1.40	2.05	2.64	3.02	3.99	4.96	5.39	5.93	6.63	7.86	9.09	10.42	11.75	13.08	5.7
5.8	1.36	1.99	2.57	2.94	3.88	4.82	5.24	5.76	6.44	7.64	8.84	10.13	11.42	12.71	5.8
5.9	1.33	1.94	2.50	2.85	3.77	4.69	5.09	5.60	6.26	7.43	8.59	9.85	11.11	12.36	5.9
6.0	1.29	1.88	2.43	2.78	3.67	4.56	4.95	5.45	6.09	7.22	8.35	9.58	10.80	12.02	6.0
6.1	1.25	1.83	2.36	2.70	3.57	4.43	4.82	5.30	5.92	7.03	8.13	9.32	10.51	11.70	6.1
6.2	1.22	1.78	2.30	2.63	3.47	4.31	4.69	5.16	5.76	6.84	7.91	9.07	10.23	11.38	6.2
6.3	1.19	1.74	2.24	2.56	3.38	4.20	4.56	5.02	5.61	6.66	7.70	8.83	9.96	11.08	6.3
6.4	1.16	1.69	2.18	2.49	3.29	4.09	4.44	4.89	5.46	6.48	7.50	8.60	9.70	10.79	6.4
6.5	1.13	1.65	2.12	2.43	3.20	3.98	4.33	4.76	5.32	6.31	7.30	8.38	9.45	10.51	6.5
6.6	1.10	1.60	2.07	2.36	3.12	3.88	4.22	4.64	5.18	6.15	7.12	8.16	9.20	10.24	6.6
6.7	1.07	1.56	2.02	2.30	3.04	3.78	4.11	4.52	5.05	5.99	6.93	7.95	8.97	9.98	6.7
6.8	1.04	1.52	1.96	2.24	2.97	3.69	4.01	4.41	4.93	5.84	6.76	7.75	8.74	9.73	6.8
6.9	1.02	1.49	1.92	2.19	2.89	3.59	3.91	4.30	4.80	5.70	6.59	7.56	8.53	9.49	6.9
7.0	0.99	1.45	1.87	2.13	2.82	3.51	3.81	4.19	4.68	5.56	6.43	7.37	8.32	9.26	7.0
7.1	0.97	1.41	1.82	2.08	2.75	3.42	3.72	4.09	4.57	5.42	6.27	7.19	8.11	9.03	7.1
7.2	0.94	1.38	1.78	2.03	2.69	3.34	3.63	3.99	4.46	5.29	6.12	7.02	7.92	8.82	7.2
7.3	0.92	1.35	1.74	1.98	2.62	3.26	3.54	3.89	4.35	5.16	5.97	6.85	7.73	8.61	7.3
7.4	0.90	1.31	1.69	1.94	2.56	3.18	3.46	3.80	4.25	5.04	5.83	6.69	7.55	8.40	7.4
7.5	0.88	1.28	1.66	1.89	2.50	3.11	3.38	3.71	4.15	4.92	5.70	6.54	7.37	8.21	7.5
7.6	0.86	1.25	1.62	1.85	2.44	3.03	3.30	3.63	4.05	4.81	5.57	6.38	7.20	8.02	7.6
7.7	0.84	1.23	1.58	1.81	2.38	2.96	3.22	3.54	3.96	4.70	5.44	6.24	7.04	7.83	7.7
7.8	0.82	1.20	1.54	1.76	2.33	2.90	3.15	3.46	3.87	4.59	5.31	6.10	6.88	7.66	7.8
7.9	0.80	1.17	1.51	1.72	2.28	2.83	3.08	3.38	3.78	4.49	5.19	5.96	6.72	7.48	7.9
8.0	0.78	1.14	1.48	1.69	2.23	2.77	3.01	3.31	3.70	4.39	5.08	5.83	6.57	7.32	8.0
8.1	0.77	1.12	1.44	1.65	2.18	2.71	2.94	3.24	3.62	4.29	4.97	5.70	6.43	7.16	8.1
8.2	0.75	1.09	1.41	1.61	2.13	2.65	2.88	3.17	3.54	4.20	4.86	5.57	6.29	7.00	8.2
8.3	0.73	1.07	1.38	1.58	2.08	2.59	2.82	3.10	3.46	4.11	4.75	5.45	6.15	6.85	8.3
8.4	0.72	1.05	1.35	1.54	2.04	2.54	2.76	3.03	3.38	4.02	4.65	5.34	6.02	6.70	8.4
8.5	0.70	1.03	1.32	1.51	2.00	2.48	2.70	2.97	3.32	3.94	4.55	5.22	5.89	6.56	8.5
8.6	0.69	1.00	1.29	1.48	1.95	2.43	2.64	2.90	3.25	3.85	4.46	5.11	5.77	6.42	8.6
8.7	0.67	0.98	1.27	1.45	1.91	2.38	2.59	2.84	3.18	3.77	4.36	5.01	5.65	6.29	8.7
8.8	0.66	0.96	1.24	1.42	1.87	2.33	2.53	2.79	3.11	3.69	4.27	4.90	5.53	6.16	8.8
8.9	0.65	0.94	1.22	1.39	1.84	2.28	2.48	2.73	3.05	3.62	4.19	4.80	5.42	6.04	8.9
9.0	0.63	0.92	1.19	1.36	1.80	2.24	2.43	2.67	2.99	3.55	4.10	4.71	5.31	5.91	9.0
9.1	0.62	0.91	1.17	1.33	1.76	2.19	2.38	2.62	2.93	3.47	4.02	4.61	5.20	5.80	9.1
9.2	0.61	0.89	1.14	1.31	1.73	2.15	2.33	2.57	2.87	3.41	3.94	4.52	5.10	5.68	9.2
9.3	0.60	0.87	1.12	1.28	1.69	2.11	2.29	2.52	2.81	3.34	3.86	4.43	5.00	5.57	9.3
9.4	0.58	0.85	1.10	1.26	1.66	2.06	2.24	2.47	2.76	3.27	3.79	4.35	4.90	5.46	9.4
9.5	0.57	0.84	1.08	1.23	1.63	2.02	2.20	2.42	2.71	3.21	3.71	4.26	4.81	5.35	9.5
9.6	0.56	0.82	1.06	1.21	1.60	1.99	2.16	2.37	2.65	3.15	3.64	4.18	4.72	5.25	9.6
9.7	0.55	0.80	1.04	1.19	1.57	1.95	2.12	2.33	2.60	3.09	3.57	4.10	4.63	5.15	9.7
9.8	0.54	0.79	1.02	1.16	1.54	1.91	2.08	2.28	2.55	3.03	3.51	4.02	4.54	5.06	9.8
9.9	0.53	0.77	1.00	1.14	1.51	1.88	2.04	2.24	2.51	2.97	3.44	3.95	4.46	4.96	9.9
10.0	0.52	0.76	0.98	1.12	1.48	1.84	2.00	2.20	2.46	2.92	3.38	3.88	4.37	4.87	10.0

Appendix B - Determining the flow capacity of vitrified clay pipelines

Introduction
This appendix has been written to assist the designer of foul and surface water drainage and sewerage schemes to size pipelines hydraulically by the use of the Uniform Flow equation derived by Colebrook and White. The information is in tabular form and the range of nominal bores covered is 100 to 1000 mm.

The relationship of the research results obtained and the design parameters that came from them is firstly identified with the then codes of practice and other specification documents. Current practice has then been related to the relevant European standards as appropriate.

Hydraulic Formulae
Around 1770, Chezy developed a hydraulic discharge equation that was used by engineers for over a century. During the past hundred years many empirical equations have been used. In the 1930's von Karman and Prandtl proposed a theory for turbulent flow in pipelines. In 1939, Colebrook and White studied the hydraulic properties of commercial pipelines, over a large range of flow conditions. From their experimental results and the von Karman and Prandtl theory they derived an equation which has been used in calculating the design tables in this appendix.

Hydraulic Roughness
In the equation of Colebrook and White, the velocity of flow is dependent on the pipe bore, the kinematic viscosity, the gradient and the surface roughness of the interior of the pipeline. This roughness (k_s) is dependent up in the following factors:

Length of pipes.
Surface texture of pipes.
Types of joints.
Deposited grit on the invert.
Adherent slime and grease on the walls.
Deviation from nominal circular cross-section.
Deviation from longitudinal straightness.

Each factor has its own effect on the apparent roughness and hence the flow in the pipeline. When a drain or sewer is conveying sewage or a combination of sewage and surface water, slime, mostly microbiological, adheres to and grows on the interior surface. After a short period of time a film of slime coats the surface of the pipeline covered by the flow. This slime blankets most effects of the other factors affecting the hydraulic roughness of rigid pipes. The same case applies where grit is deposited on the invert of a surface water sewer. In pipelines of flexible materials, the cross sectional area of the pipeline can be reduced by the fill and surcharge loads. This will have an effect on the apparent hydraulic roughness and will be additional to the effect of the slime.

Hydraulic Experiments
The Clay Pipe Development Association conducted many experiments to determine the hydraulic roughness of various pipelines; firstly with clean water at Messrs. Wimpey's Central Hydraulic Research Laboratory at Hayes, Middlesex, and then with sewage at the Water Research Centre (Stevenage Laboratory). Further tests with clean water were carried out by the Hydraulics Research Station, Wallingford and were followed by tests using sewage.

Clean Water Tests
The k_s values determined at Wimpey's and the Hydraulics Research Station for clean vitrified clay pipes of three interior surface finishes, flowing full, over the range of discharges for which tests were carried out, are as shown in table B1.

Table B1 – Roughness values from clean water tests

Nominal Bore (mm)	Interior Finish	Joint	k_s (mm)
100	Salt Glazed	Sleeve	0.030
	Unglazed	Sleeve	0.023
	Ceramic glazed	Sleeve	0.006
150	Ceramic glazed	'O' ring	0.022
	Unglazed	Sleeve	0.024
	Unglazed	'O' ring	0.024
300	Unglazed	'O' ring	0.060

Foul Water Tests
When drains and sewers are in service they carry foul not clean water. Therefore, the hydraulic roughness values derived from experiments with clean pipes are not appropriate for the hydraulic design of foul and surface water drains and sewers.

The Clay Pipe Development Association sponsored research [38] at the Water Research Centre (Stevenage Laboratory) to determine the amount of slime that adheres to the interior surface of pipes made of various materials. The materials tested were: vitrified clay with salt glazed, unglazed and ceramic glazed interior finishes; asbestos cement; pitch fibre and pvc pipes. A continuous flow of domestic sewerage was passed through them for six weeks. The pipes were flowing half full.

The results showed that the growth and weight of slime were statistically independent of the pipe material, but dependent upon the velocity of the sewage flow.

In order to determine the hydraulic roughness of unglazed vitrified clay and pvc pipes, a second series of tests was conducted with the pipes flowing full.

It was found that the pvc pipeline, at the commencement of the test, was hydraulically smoother than the vitrified clay pipeline, but, as the test progressed the difference between the two diminished until the time came when the pvc pipeline was hydraulically rougher than the vitrified clay pipeline. Then as some of the microbiological slime was sloughed off, the vitrified clay pipeline became rougher until sloughing again took place. This alternation happened quite often. The velocities of sewage flow in these tests varied from 0.75 m/sec to 2.25 m/sec but there was no significant difference in the hydraulic roughness of the vitrified clay and pvc pipelines as shown in figure B1.

Therefore, as the first series of tests showed negligible differences in the weight of microbiological slime on any of the materials tested and the second series of tests showed negligible difference in hydraulic roughness between the matured vitrified clay and pvc pipelines, it would be anticipated that there would be negligible significant difference in hydraulic roughness between pvc and clay pipes and hence for design purposes the same hydraulic roughness would apply.

The Hydraulic Research Station continued the research at the Littlemore Sewage Pumping station, Oxford. In these experiments, 225mm nominal bore vertically-cast and spun concrete, asbestos cement, pvc and clay pipes had sewage passing through them. In each year of the work a different hydrograph of flow was used. Maximum proportional depth was 0.60 (0.78 m/s) and the minimum 0.16 (0.38 m/s). The maximum velocity was 1.18m/s.

Typical variations of roughness with time graphs are shown in figures B2 and B3.

Subsequently, the Water Research Engineering Centre carried out a programme of analysis of sewerage systems. It was found that the k_s values were larger at low velocities than at higher velocities. A range of 3 values of k_s was published in the Sewerage Rehabilitation Manual [39], dependent on velocity of flow.

Design k_s Values

Surface Water Pipelines

The k_s values obtained from the clean water tests at Wimpey's and the Hydraulics Research Station were confirmed in the subsequent publication by the Water Research Centre of values of k_s for a range of pipe materials in the Sewerage Rehabilitation Manual [39]. The same values were published in BS 8005: 1987 [5], the British Standard for Sewerage.

Table 3 of BS 8005: Part 1: 1987 gives design k_s values of 0.03mm for sleeve jointed clay pipes and 0.06mm for spigot and socket jointed clay pipes.

The Water Authorities Association design and construction guide for developers Sewers for Adoption [8] specifies a design k_s value of 0.6mm. This value has also been adopted in the European standard for hydraulic design (BS EN 752-4 NB.2).

The Code of Practice for Building Drainage, BS 8301: 1985 [6] defines two methods of calculating surface water run-off building drainage depending on the size of area to be drained.

For small areas, the flat rate of rainfall method is recommended and a specific k_s value is not given. It has been traditional to use the conservative k_s value of 0.6mm for all pipe materials for this method. It should be noted that this value has also been used to calculate the design flow chart in Approval Document H to the Building Regulations 1991 [10] and in BS EN 752-4 [13].

BS 8301 recommends for larger areas the use of the Wallingford Rational Method [40] of calculating run-off and the Hydraulics Research Station Tables for the Hydraulic design of pipes [41] for flow calculations.

The use of these two methods is continued and extended in BS EN 752-4 [13], clauses 11.3.2, Annex D and National Annexes ND and NE.

Foul Water Pipelines

The range of three values of k_s for pipe sewers put forward in the Sewerage Rehabilitation Manual [39] are now advocated in Table 4 of BS 8005 : Part 1 [5] for typical peak DWF velocities, as set out in table B2.

Table B2 – Design roughness values for pipe sewers of any material

velocity	k_s (mm)
> 1.5 m/s	0.3
> 1.0 m/s	0.6
≥ 0.76 m/s ≤1.0 m/s	1.5

BS 8301 [6] also recognised the change of k_s value with velocity. Design values of 1.5mm and 0.6mm are shown, dependent on whether pipes flow continuously or intermittently.

BS 8301 also recommended that foul drains should not flow at a proportional depth greater than 0.75, in order to prevent trap syphonage. This will also limit the likelihood of solids being deposited on manhole and inspection chamber benching. The flow chart in Approved Document H [10] to the Building Regulations 1991 is based on the same principle.

The minimum size of pipe for a foul drain is DN 100, where there is a minimum of 1 wc connected. Sewerage Undertakers do not normally adopt sewers of less than DN 150.

The minimum gradients of foul drains and sewers which will be self cleansing are given below, where the peak flow rates are calculated by using the flow rates from the discharge unit method given in BS EN 752-4 [13].

(a) For flows of less than 1 litre per second, pipes not exceeding DN100 need to be laid at gradients not flatter than 1:40.
(b) Where the peak flow is more than 1 litre per second, a DN100 pipe may be laid at a gradient no flatter than 1:80, provided that at least one W.C is connected.
(c) DN150 pipe may be laid at a gradient not flatter than 1:150, provided that at least five WC's are connected.

Gradients flatter than those given above can be used if a high standard of workmanship is maintained. Minimum gradients of 1:130 for DN 100 and 1:200 for DN 150 have worked successfully.

For pipes larger than DN150 a minimum velocity of 0.75 m/s can be used for design. The hydraulic capacity is based on the water consumption of the population served and twice the average domestic flow rate is used for the peak flow, which should achieve the minimum velocity.

Design Tables
The tables are calculated from the following equation derived by Ackers from Colebrook and White.

$$V = -2\sqrt{(2gDi)}\,\mathrm{Log}\left(\frac{k_s}{3.7D} + \frac{2.51\mu}{D\sqrt{(2gDi)}}\right)$$

and Q = VA

A	=	Cross sectional area of flow
D	=	Bore of pipeline
g	=	Gravitational acceleration
i	=	Hydraulic gradient
k_s	=	Linear measure of roughness
Q	=	Discharge
V	=	Mean velocity of flow
μ	=	Kinematic viscosity

The values of D used were the Nominal Bores. The value of the kinematic viscosity used was 1.141×10^{-6} m²/sec for water at 15 °C [41].

In drainage and sewerage design it is usual to know the discharge and optimum gradient, and to require a suitable combination of nominal bore and velocity.

The first two columns of the table show the gradients in both decimal and vulgar fraction form. The remaining columns are grouped in pairs for each nominal bore of pipe, the first column of each pair giving the velocity in metres per second and the second the discharge in litres per second.

The individual tables are constituted as follows:

Table B3
Table B3 is for pipes flowing at a proportional depth of 0.75. It incorporates the use of different k_s values over the velocity range as recommended by BS 8005: 1987 [5] for foul water pipelines.

Table B4
Table B4 uses the same k_s values as Table 27, but is for pipes flowing full.

Tables B5 and B6
Tables B5 and B6 are for pipes flowing full at k_s values of 0.6mm and 1.5mm respectively, where these values are required separately for design, for example for surface water design or in carrying out proportional flow calculations in conjunction with Table B7.

Table B7
Table B7 gives the depth, simplified velocity and discharge as a proportion of the full-bore values for pipes flowing part full.

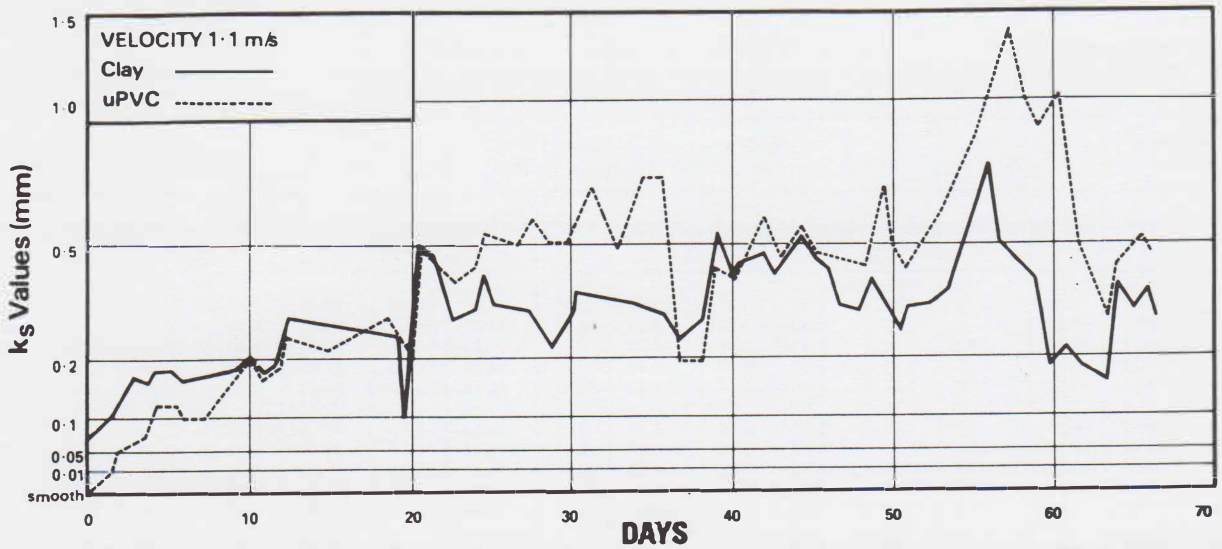


Figure B1 - A typical k_s time graph for 100 mm bore pipes flowing full, plotted from the results of the experimental work at WRc

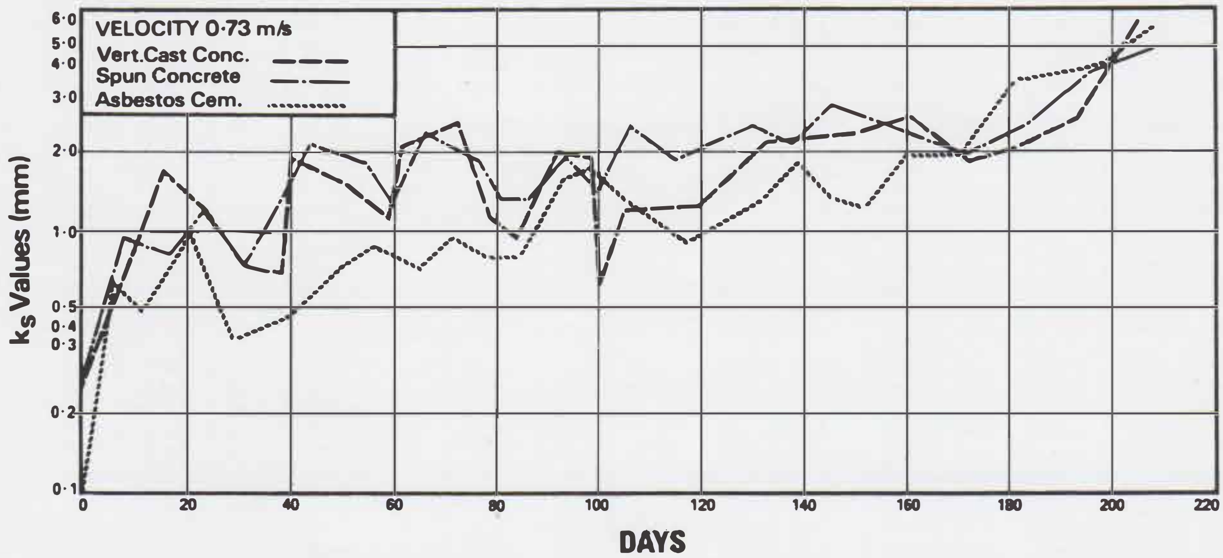


Figure B2 - k_s time graph from the results of the 1977 experimental work by HRS for concrete and asbestos-cement pipes

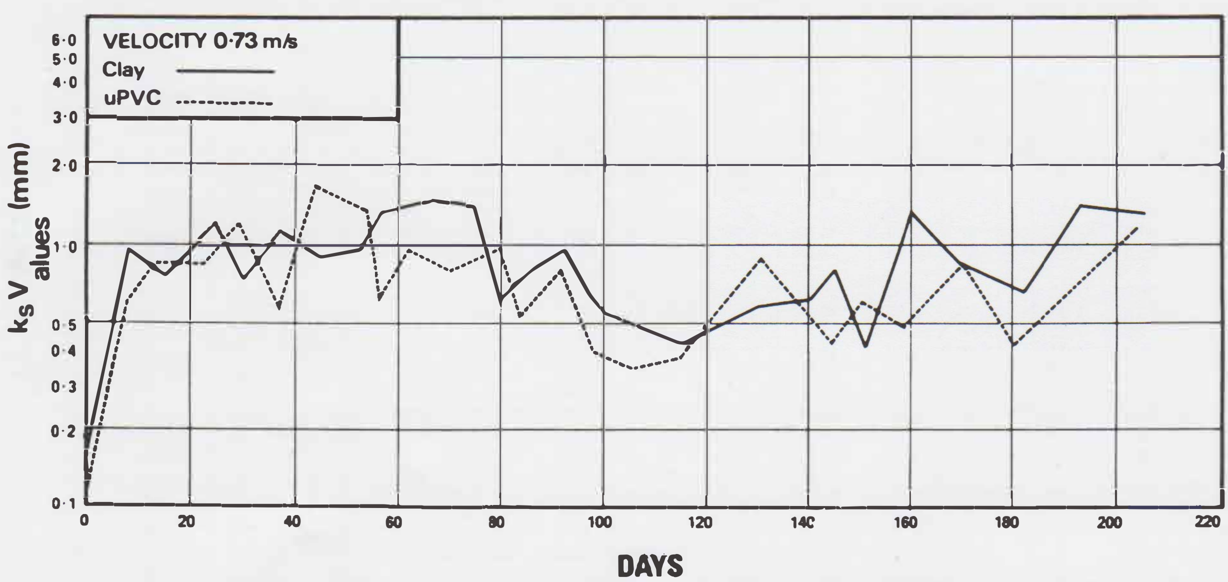


Figure B3 - k_s time graph from the results of the 1977 experimental work by HRS for clay and pvc-u pipes

TABLE B3 **PIPE FLOWING AT A PROPORTIONAL DEPTH OF 0.75**

k_s = 1.5mm for velocities less than or equal to 1.0m/s
k_s = 0.6mm for velocities greater than 1.0m/s less than or equal to 1.5m/s
k_s = 0.3mm for velocities greater than 1.5m/s

100mm to 400mm Nominal Bore

Nominal Bore mm		100		150		200		225		300		375		400	
Hydraulic Gradient	1 in	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s
.0010	1000.0	0.23	1.47	0.31	4.38	0.37	9.47	0.41	12.97	0.49	27.91	0.57	50.49	0.59	59.91
.0011	909.1	0.24	1.55	0.32	4.60	0.39	9.94	0.43	13.61	0.52	29.29	0.60	52.98	0.62	62.87
.0012	833.3	0.26	1.62	0.34	4.81	0.41	10.39	0.44	14.22	0.54	30.60	0.62	55.36	0.65	65.69
.0013	769.2	0.27	1.68	0.35	5.01	0.43	10.82	0.46	14.81	0.56	31.87	0.65	57.64	0.68	68.40
.0014	714.3	0.28	1.75	0.37	5.20	0.44	11.23	0.48	15.38	0.58	33.09	0.67	59.84	0.70	71.01
.0015	666.7	0.29	1.81	0.38	5.39	0.46	11.63	0.50	15.93	0.60	34.26	0.70	61.96	0.73	73.53
.0016	625.0	0.30	1.87	0.39	5.57	0.48	12.02	0.51	16.46	0.62	35.40	0.72	64.01	0.75	75.96
.0017	588.2	0.31	1.93	0.40	5.74	0.49	12.39	0.53	16.97	0.64	36.50	0.74	66.00	0.77	78.32
.0018	555.6	0.31	1.99	0.42	5.91	0.50	12.76	0.55	17.47	0.66	37.56	0.76	67.93	0.80	80.61
.0019	526.3	0.32	2.04	0.43	6.07	0.52	13.11	0.56	17.95	0.68	38.60	0.79	69.81	0.82	82.83
.0020	500.0	0.33	2.10	0.44	6.23	0.53	13.46	0.58	18.42	0.70	39.62	0.81	71.64	0.84	85.00
.0022	454.5	0.35	2.20	0.46	6.54	0.56	14.12	0.60	19.33	0.73	41.57	0.85	75.16	0.88	89.18
.0024	416.7	0.36	2.30	0.48	6.84	0.58	14.76	0.63	20.20	0.76	43.43	0.88	78.53	0.92	93.18
.0026	384.6	0.38	2.40	0.50	7.12	0.61	15.36	0.66	21.03	0.80	45.22	0.92	81.76	0.96	97.01
.0028	357.1	0.39	2.49	0.52	7.39	0.63	15.95	0.68	21.84	0.83	46.94	0.96	84.87	1.00	100.70
.0030	333.3	0.41	2.58	0.54	7.66	0.65	16.52	0.71	22.61	0.85	48.60	0.99	87.87	1.16	117.23
.0032	312.5	0.42	2.66	0.56	7.91	0.68	17.06	0.73	23.36	0.88	50.21	1.15	102.17	1.20	121.13
.0034	294.1	0.43	2.75	0.57	8.16	0.70	17.59	0.75	24.08	0.91	51.77	1.19	105.36	1.24	124.90
.0036	277.8	0.45	2.83	0.59	8.40	0.72	18.11	0.77	24.79	0.94	53.28	1.22	108.45	1.27	128.57
.0038	263.2	0.46	2.91	0.61	8.63	0.74	18.61	0.80	25.47	0.96	54.75	1.25	111.46	1.31	132.14
.0040	250.0	0.47	2.98	0.62	8.85	0.76	19.10	0.82	26.14	0.99	56.18	1.29	114.39	1.34	135.61
.0042	238.1	0.48	3.06	0.64	9.08	0.77	19.57	0.84	26.79	1.14	65.07	1.32	117.25	1.38	139.00
.0044	227.3	0.50	3.13	0.65	9.29	0.79	20.04	0.86	27.43	1.17	66.62	1.35	120.05	1.41	142.31
.0046	217.4	0.51	3.20	0.67	9.50	0.81	20.49	0.88	28.05	1.20	68.14	1.38	122.78	1.44	145.54
.0048	208.3	0.52	3.27	0.68	9.71	0.83	20.94	0.90	28.65	1.22	69.62	1.41	125.45	1.47	148.71
.0050	200.0	0.53	3.34	0.70	9.91	0.85	21.37	0.91	29.25	1.25	71.08	1.44	128.06	1.62	163.88
.0055	181.8	0.55	3.51	0.73	10.40	0.89	22.42	0.96	30.69	1.31	74.59	1.63	145.18	1.70	172.02
.0060	166.7	0.58	3.66	0.76	10.87	0.93	23.43	1.14	36.43	1.37	77.95	1.71	151.75	1.78	179.81
.0065	153.8	0.60	3.81	0.80	11.31	0.97	24.39	1.19	37.94	1.43	81.17	1.78	158.05	1.85	187.27
.0070	142.9	0.63	3.96	0.83	11.74	1.14	28.84	1.23	39.39	1.48	84.26	1.85	164.12	1.92	194.46
.0075	133.3	0.65	4.10	0.86	12.16	1.18	29.86	1.28	40.79	1.66	94.50	1.91	169.97	1.99	201.39
.0080	125.0	0.67	4.24	0.88	12.56	1.22	30.86	1.32	42.15	1.72	97.66	1.98	175.64	2.06	208.09
.0085	117.6	0.69	4.37	0.91	12.95	1.26	31.82	1.36	43.46	1.77	100.72	2.04	181.13	2.12	214.59
.0090	111.1	0.71	4.50	0.94	13.33	1.30	32.75	1.40	44.74	1.82	103.69	2.10	186.46	2.19	220.90
.0095	105.3	0.73	4.62	0.96	13.70	1.33	33.66	1.44	45.97	1.87	106.57	2.16	191.64	2.25	227.04
.0100	100.0	0.75	4.74	0.99	14.06	1.37	34.55	1.48	47.18	1.92	109.39	2.21	196.69	2.31	233.02
.0110	90.9	0.79	4.97	1.19	16.91	1.43	36.25	1.68	53.81	2.02	114.81	2.32	206.42	2.42	244.55
.0120	83.3	0.82	5.20	1.24	17.67	1.50	37.88	1.76	56.24	2.11	119.99	2.43	215.72	2.53	255.56
.0130	76.9	0.86	5.41	1.29	18.40	1.70	42.94	1.83	58.58	2.20	124.96	2.53	224.64	2.63	266.13
.0140	71.4	0.89	5.62	1.34	19.10	1.76	44.59	1.90	60.83	2.28	129.75	2.63	233.23	2.73	276.29
.0150	66.7	0.92	5.82	1.39	19.78	1.83	46.18	1.97	63.00	2.36	134.36	2.72	241.51	2.83	286.10
.0160	62.5	0.95	6.01	1.44	20.44	1.89	47.72	2.04	65.10	2.44	138.83	2.81	249.52	2.92	295.59
.0170	58.8	0.98	6.19	1.48	21.07	1.95	49.21	2.10	67.13	2.52	143.15	2.90	257.29	3.02	304.78
.0180	55.6	1.17	7.38	1.67	23.70	2.00	50.66	2.16	69.10	2.59	147.36	2.98	264.83	3.10	313.71
.0190	52.6	1.20	7.59	1.71	24.36	2.06	52.07	2.22	71.03	2.66	151.44	3.06	272.16	3.19	322.39
.0200	50.0	1.23	7.79	1.76	25.00	2.11	53.44	2.28	72.90	2.73	155.42	3.14	279.31	3.27	330.85
.0220	45.5	1.29	8.17	1.85	26.24	2.22	56.09	2.39	76.50	2.87	163.10	3.30	293.08	3.43	347.16
.0240	41.7	1.35	8.54	1.93	27.43	2.32	58.61	2.50	79.95	3.00	170.43	3.45	306.24	3.59	362.74
.0260	38.5	1.41	8.89	2.01	28.57	2.42	61.04	2.60	83.25	3.12	177.46	3.59	318.86	3.74	377.68
.0280	35.7	1.46	9.23	2.09	29.66	2.51	63.37	2.70	86.43	3.24	184.23	3.73	331.00	3.88	392.06
.0300	33.3	1.66	10.50	2.16	30.72	2.60	65.63	2.80	89.50	3.35	190.76	3.86	342.72	4.02	405.94
.0320	31.2	1.72	10.85	2.23	31.74	2.68	67.81	2.89	92.47	3.47	197.07	3.99	354.05	4.15	419.36
.0340	29.4	1.77	11.19	2.30	32.73	2.77	69.92	2.98	95.35	3.57	203.20	4.11	365.04	4.28	432.37
.0360	27.8	1.82	11.52	2.37	33.69	2.85	71.97	3.07	98.14	3.68	209.14	4.23	375.70	4.40	445.00
.0380	26.3	1.87	11.84	2.44	34.63	2.93	73.96	3.15	100.86	3.78	214.92	4.35	386.08	4.52	457.28
.0400	25.0	1.92	12.16	2.50	35.54	3.00	75.90	3.24	103.51	3.88	220.55	4.46	396.18	4.64	469.25
.0420	23.8	1.97	12.46	2.56	36.43	3.08	77.80	3.32	106.09	3.98	226.04	4.57	406.04	4.76	480.92
.0440	22.7	2.02	12.76	2.62	37.29	3.15	79.65	3.40	108.61	4.07	231.41	4.68	415.66	4.87	492.31
.0460	21.7	2.07	13.05	2.68	38.14	3.22	81.46	3.47	111.07	4.16	236.65	4.78	425.07	4.98	503.45
.0480	20.8	2.11	13.33	2.74	38.97	3.29	83.22	3.55	113.48	4.25	241.78	4.89	434.27	5.09	514.35
.0500	20.0	2.15	13.61	2.80	39.79	3.36	84.96	3.62	115.85	4.34	246.80	4.99	443.29	5.19	525.02
.0550	18.2	2.26	14.29	2.94	41.75	3.53	89.14	3.80	121.55	4.55	258.94	5.23	465.07	5.45	550.81
.0600	16.7	2.36	14.93	3.07	43.63	3.69	93.14	3.97	127.00	4.76	270.54	5.47	485.88	5.69	575.45
.0650	15.4	2.46	15.55	3.20	45.43	3.84	96.98	4.13	132.23	4.95	281.66	5.69	505.84	5.93	599.09
.0700	14.3	2.56	16.14	3.32	47.16	3.98	100.67	4.29	137.26	5.14	292.36	5.91	525.04	6.15	621.83
.0750	13.3	2.65	16.72	3.43	48.83	4.12	104.23	4.44	142.11	5.32	302.69	6.12	543.57	6.37	643.77
.0800	12.5	2.73	17.27	3.55	50.45	4.26	107.68	4.59	146.81	5.50	312.68	6.32	561.50	6.58	664.99
.0850	11.8	2.82	17.81	3.66	52.01	4.39	111.02	4.73	151.36	5.67	322.36	6.52	578.87	6.78	685.56
.0900	11.1	2.90	18.33	3.77	53.53	4.52	114.26	4.87	155.78	5.83	331.76	6.71	595.74	6.98	705.53
.0950	10.5	2.98	18.84	3.87	55.01	4.65	117.42	5.00	160.08	6.00	340.90	6.89	612.14	7.17	724.96

TABLE B3 *(continued)* **PIPE FLOWING AT A PROPORTIONAL DEPTH OF 0.75**

k_s = 1.5mm for velocities less than or equal to 1.0m/s
k_s = 0.6mm for velocities greater than 1.0m/s less than or equal to 1.5m/s
k_s = 0.3mm for velocities greater than 1.5m/s

450mm to 1000mm Nominal Bore

Nominal Bore mm		450		500		600		700		800		900		1000	
Hydraulic Gradient	1 in	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s
.0010	1000.0	0.64	81.87	0.69	108.21	0.77	175.25	0.85	263.30	0.93	374.47	1.00	510.75	1.18	747.57
.0011	909.1	0.67	85.90	0.72	113.54	0.81	183.88	0.89	276.25	0.97	392.87	1.16	595.08	1.24	784.54
.0012	833.3	0.70	89.76	0.75	118.64	0.84	192.12	0.93	288.62	1.13	456.50	1.22	621.90	1.30	819.86
.0013	769.2	0.73	93.46	0.78	123.52	0.88	200.03	0.97	300.49	1.18	475.40	1.27	647.61	1.35	853.74
.0014	714.3	0.76	97.02	0.81	128.22	0.91	207.63	1.12	347.56	1.22	493.58	1.31	672.36	1.40	886.34
.0015	666.7	0.79	100.45	0.84	132.76	0.95	214.97	1.16	359.92	1.26	511.12	1.36	696.24	1.45	917.79
.0016	625.0	0.81	103.77	0.87	137.15	0.98	222.07	1.20	371.88	1.31	528.09	1.41	719.34	1.61	1014.83
.0017	588.2	0.84	106.99	0.90	141.40	1.12	255.71	1.24	383.48	1.35	544.54	1.45	741.72	1.66	1046.63
.0018	555.6	0.86	110.12	0.92	145.53	1.16	263.22	1.28	394.73	1.39	560.51	1.49	763.46	1.71	1077.50
.0019	526.3	0.88	113.16	0.95	149.55	1.19	270.53	1.31	405.68	1.42	576.04	1.64	840.61	1.75	1107.53
.0020	500.0	0.91	116.12	0.97	153.46	1.22	277.65	1.34	416.35	1.46	591.17	1.69	862.83	1.80	1136.79
.0022	454.5	0.95	121.83	1.14	180.35	1.28	291.38	1.41	436.90	1.65	665.31	1.77	905.68	1.89	1193.18
.0024	416.7	0.99	127.29	1.19	188.48	1.34	304.49	1.47	456.55	1.72	695.42	1.85	946.62	1.97	1247.08
.0026	384.6	1.16	148.72	1.24	196.28	1.39	317.07	1.65	510.47	1.79	724.30	1.93	985.89	2.06	1298.77
.0028	357.1	1.21	154.41	1.29	203.78	1.45	329.18	1.71	530.09	1.86	752.09	2.00	1023.69	2.13	1348.51
.0030	333.3	1.25	159.90	1.34	211.02	1.50	340.86	1.77	549.01	1.93	778.91	2.07	1060.16	2.21	1396.51
.0032	312.5	1.29	165.21	1.38	218.02	1.67	378.71	1.83	567.32	1.99	804.86	2.14	1095.43	2.28	1442.94
.0034	294.1	1.33	170.35	1.42	224.81	1.72	390.57	1.89	585.06	2.05	830.00	2.21	1129.62	2.36	1487.94
.0036	277.8	1.37	175.35	1.47	231.40	1.77	402.09	1.95	602.29	2.11	854.42	2.27	1162.82	2.42	1531.64
.0038	263.2	1.41	180.21	1.62	256.14	1.82	413.29	2.00	619.05	2.17	878.16	2.34	1195.11	2.49	1574.14
.0040	250.0	1.45	184.94	1.66	262.91	1.87	424.21	2.05	635.37	2.23	901.30	2.40	1226.56	2.56	1615.54
.0042	238.1	1.48	189.56	1.71	269.52	1.91	434.85	2.10	651.29	2.28	923.86	2.46	1257.24	2.62	1655.91
.0044	227.3	1.64	209.27	1.75	275.97	1.96	445.24	2.15	666.84	2.34	945.89	2.52	1287.20	2.68	1695.34
.0046	217.4	1.67	214.06	1.79	282.28	2.00	455.40	2.20	682.04	2.39	967.42	2.57	1316.48	2.74	1733.88
.0048	208.3	1.71	218.74	1.83	288.45	2.05	465.35	2.25	696.91	2.44	988.50	2.63	1345.14	2.80	1771.60
.0050	200.0	1.75	223.33	1.86	294.50	2.09	475.08	2.30	711.48	2.50	1009.14	2.68	1373.20	2.86	1808.53
.0055	181.8	1.83	234.42	1.96	309.11	2.19	498.61	2.41	746.67	2.62	1059.00	2.82	1441.00	3.00	1897.77
.0060	166.7	1.92	245.01	2.05	323.06	2.29	521.09	2.52	780.29	2.74	1106.65	2.94	1505.79	3.14	1983.04
.0065	153.8	1.99	255.17	2.13	336.45	2.39	542.65	2.62	812.54	2.85	1152.35	3.06	1567.93	3.27	2064.82
.0070	142.9	2.07	264.95	2.21	349.33	2.48	563.40	2.72	843.58	2.96	1196.33	3.18	1627.72	3.39	2143.52
.0075	133.3	2.14	274.39	2.29	361.76	2.57	583.42	2.82	873.53	3.06	1238.76	3.29	1685.42	3.51	2219.46
.0080	125.0	2.22	283.51	2.37	373.79	2.65	602.79	2.92	902.49	3.17	1279.81	3.40	1741.22	3.63	2292.91
.0085	117.6	2.29	292.36	2.44	385.44	2.73	621.56	3.01	930.57	3.26	1319.59	3.51	1795.31	3.74	2364.09
.0090	111.1	2.35	300.95	2.51	396.76	2.81	639.78	3.09	957.83	3.36	1358.22	3.61	1847.83	3.85	2433.22
.0095	105.3	2.42	309.30	2.58	407.76	2.89	657.51	3.18	984.34	3.45	1395.79	3.71	1898.91	3.96	2500.45
.0100	100.0	2.48	317.44	2.65	418.48	2.97	674.77	3.26	1010.17	3.54	1432.38	3.81	1948.67	4.06	2565.93
.0110	90.9	2.60	333.13	2.78	439.15	3.11	708.06	3.42	1059.95	3.72	1502.92	4.00	2044.58	4.26	2692.16
.0120	83.3	2.72	348.12	2.91	458.90	3.25	739.86	3.58	1107.52	3.88	1570.33	4.17	2136.23	4.45	2812.78
.0130	76.9	2.83	362.50	3.03	477.84	3.39	770.37	3.72	1153.15	4.04	1634.98	4.35	2224.13	4.64	2928.47
.0140	71.4	2.94	376.33	3.14	496.06	3.52	799.72	3.87	1197.05	4.20	1697.19	4.51	2308.71	4.81	3039.79
.0150	66.7	3.05	389.68	3.25	513.65	3.64	828.05	4.00	1239.42	4.35	1757.21	4.67	2390.33	4.98	3147.20
.0160	62.5	3.15	402.60	3.36	530.66	3.76	855.44	4.14	1280.39	4.49	1815.27	4.83	2469.27	5.15	3251.09
.0170	58.8	3.24	415.11	3.46	547.15	3.88	881.99	4.26	1320.11	4.63	1871.54	4.97	2545.77	5.31	3351.78
.0180	55.6	3.34	427.27	3.57	563.16	3.99	907.78	4.39	1358.67	4.76	1926.18	5.12	2620.06	5.46	3449.55
.0190	52.6	3.43	439.09	3.66	578.73	4.10	932.85	4.51	1396.17	4.90	1979.33	5.26	2692.32	5.61	3544.65
.0200	50.0	3.52	450.60	3.76	593.89	4.21	957.28	4.63	1432.71	5.02	2031.09	5.40	2762.69	5.76	3637.27
.0220	45.5	3.70	472.79	3.95	623.13	4.42	1004.36	4.86	1503.13	5.27	2130.87	5.66	2898.36	6.04	3815.81
.0240	41.7	3.86	494.00	4.12	651.06	4.61	1049.35	5.07	1570.41	5.51	2226.21	5.92	3027.98	6.31	3986.41
.0260	38.5	4.02	514.34	4.29	677.86	4.80	1092.50	5.28	1634.95	5.73	2317.65	6.16	3152.31	6.57	4150.04
.0280	35.7	4.17	533.91	4.45	703.64	4.99	1134.02	5.48	1697.05	5.95	2405.64	6.39	3271.94	6.82	4307.49
.0300	33.3	4.32	552.79	4.61	728.52	5.16	1174.08	5.68	1756.97	6.16	2490.54	6.62	3387.38	7.06	4459.41
.0320	31.2	4.46	571.06	4.76	752.58	5.33	1212.83	5.86	1814.93	6.36	2572.66	6.84	3499.02	7.29	4606.34
.0340	29.4	4.60	588.76	4.91	775.90	5.50	1250.39	6.04	1871.10	6.56	2652.25	7.05	3607.23	7.52	4748.76
.0360	27.8	4.74	605.95	5.06	798.54	5.66	1286.85	6.22	1925.64	6.75	2729.53	7.25	3712.31	7.74	4887.04
.0380	26.3	4.87	622.67	5.20	820.56	5.81	1322.32	6.39	1978.69	6.94	2804.69	7.45	3814.50	7.95	5021.53
.0400	25.0	4.99	638.96	5.33	842.02	5.97	1356.87	6.56	2030.36	7.12	2877.90	7.65	3914.03	8.16	5152.53
.0420	23.8	5.12	654.84	5.46	862.94	6.11	1390.56	6.72	2080.75	7.29	2949.30	7.84	4011.11	8.36	5280.29
.0440	22.7	5.24	670.35	5.59	883.37	6.26	1423.46	6.88	2129.96	7.47	3019.02	8.02	4105.90	8.56	5405.05
.0460	21.7	5.36	685.51	5.72	903.34	6.40	1455.62	7.04	2178.06	7.63	3087.18	8.20	4198.57	8.75	5527.00
.0480	20.8	5.47	700.34	5.84	922.88	6.54	1487.09	7.19	2225.12	7.80	3153.87	8.38	4289.24	8.94	5646.33
.0500	20.0	5.59	714.87	5.96	942.02	6.67	1517.91	7.34	2271.22	7.96	3219.18	8.55	4378.04	9.12	5763.20
.0550	18.2	5.86	749.97	6.26	988.25	7.00	1592.37	7.70	2382.58	8.35	3376.96	8.97	4592.56	9.57	6045.52
.0600	16.7	6.12	783.50	6.54	1032.43	7.31	1663.51	8.04	2488.98	8.72	3527.72	9.37	4797.53	10.00	6315.29
.0650	15.4	6.38	815.67	6.80	1074.80	7.61	1731.75	8.37	2591.03	9.08	3672.32	9.76	4994.13	10.41	6574.02
.0700	14.3	6.62	846.62	7.06	1115.57	7.90	1797.40	8.69	2689.23	9.43	3811.46	10.13	5183.30	10.80	6822.99
.0750	13.3	6.85	876.49	7.31	1154.91	8.18	1860.76	8.99	2783.98	9.76	3945.71	10.49	5365.83	11.18	7063.21
.0800	12.5	7.08	905.37	7.55	1192.95	8.45	1922.03	9.29	2875.63	10.08	4075.56	10.83	5542.37	11.55	7295.55
.0850	11.8	7.30	933.37	7.79	1229.83	8.71	1981.42	9.58	2964.45	10.39	4201.41	11.16	5713.48	11.90	7520.74
.0900	11.1	7.51	960.55	8.01	1265.64	8.97	2039.08	9.85	3050.69	10.69	4323.61	11.49	5879.62	12.25	7739.39
.0950	10.5	7.71	986.99	8.23	1300.47	9.21	2095.17	10.13	3134.58	10.99	4442.46	11.80	6041.21	12.59	7952.06

TABLE B4 PIPE FLOWING FULL

k_s = 1.5mm for velocities less than or equal to 1.0m/s
k_s = 0.6mm for velocities greater than 1.0m/s less than or equal to 1.5m/s
k_s = 0.3mm for velocities greater than 1.5m/s

100mm to 400mm Nominal Bore

Nominal Bore mm		100		150		200		225		300		375		400	
Hydraulic Gradient	1 in	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s
.0010	1000.0	0.21	1.62	0.27	4.82	0.33	10.42	0.36	14.27	0.43	30.70	0.50	55.54	0.52	65.91
.0011	909.1	0.22	1.70	0.29	5.06	0.35	10.93	0.38	14.97	0.46	32.22	0.53	58.28	0.55	69.16
.0012	833.3	0.23	1.78	0.30	5.29	0.36	11.43	0.39	15.65	0.48	33.67	0.55	60.90	0.58	72.27
.0013	769.2	0.24	1.85	0.31	5.51	0.38	11.90	0.41	16.30	0.50	35.06	0.57	63.41	0.60	75.25
.0014	714.3	0.24	1.92	0.32	5.72	0.39	12.36	0.43	16.92	0.51	36.40	0.60	65.83	0.62	78.12
.0015	666.7	0.25	1.99	0.34	5.93	0.41	12.80	0.44	17.52	0.53	37.69	0.62	68.16	0.64	80.89
.0016	625.0	0.26	2.06	0.35	6.12	0.42	13.22	0.46	18.10	0.55	38.94	0.64	70.42	0.66	83.56
.0017	588.2	0.27	2.12	0.36	6.32	0.43	13.63	0.47	18.67	0.57	40.15	0.66	72.61	0.69	86.16
.0018	555.6	0.28	2.19	0.37	6.50	0.45	14.03	0.48	19.22	0.58	41.33	0.68	74.73	0.71	88.68
.0019	526.3	0.29	2.25	0.38	6.68	0.46	14.42	0.50	19.75	0.60	42.47	0.70	76.80	0.73	91.13
.0020	500.0	0.29	2.31	0.39	6.86	0.47	14.80	0.51	20.27	0.62	43.58	0.71	78.81	0.74	93.51
.0022	454.5	0.31	2.42	0.41	7.20	0.49	15.53	0.53	21.27	0.65	45.73	0.75	82.68	0.78	98.11
.0024	416.7	0.32	2.53	0.43	7.52	0.52	16.23	0.56	22.22	0.68	47.78	0.78	86.39	0.82	102.51
.0026	384.6	0.34	2.64	0.44	7.83	0.54	16.90	0.58	23.14	0.70	49.75	0.81	89.94	0.85	106.72
.0028	357.1	0.35	2.74	0.46	8.13	0.56	17.55	0.60	24.02	0.73	51.64	0.85	93.36	0.88	110.78
.0030	333.3	0.36	2.84	0.48	8.42	0.58	18.17	0.63	24.87	0.76	53.47	0.88	96.66	0.91	114.69
.0032	312.5	0.37	2.93	0.49	8.70	0.60	18.77	0.65	25.70	0.78	55.24	0.90	99.85	0.94	118.48
.0034	294.1	0.38	3.02	0.51	8.97	0.62	19.35	0.67	26.49	0.81	56.95	0.93	102.95	0.97	122.15
.0036	277.8	0.40	3.11	0.52	9.24	0.63	19.92	0.69	27.27	0.83	58.61	0.96	105.95	1.13	141.44
.0038	263.2	0.41	3.20	0.54	9.49	0.65	20.47	0.70	28.02	0.85	60.23	0.99	108.87	1.16	145.36
.0040	250.0	0.42	3.28	0.55	9.74	0.67	21.01	0.72	28.76	0.87	61.81	1.14	125.85	1.19	149.19
.0042	238.1	0.43	3.36	0.57	9.98	0.69	21.53	0.74	29.47	0.90	63.34	1.17	128.99	1.22	152.91
.0044	227.3	0.44	3.44	0.58	10.22	0.70	22.04	0.76	30.17	0.92	64.84	1.20	132.06	1.25	156.55
.0046	217.4	0.45	3.52	0.59	10.45	0.72	22.54	0.78	30.85	0.94	66.31	1.22	135.07	1.27	160.11
.0048	208.3	0.46	3.60	0.60	10.68	0.73	23.03	0.79	31.52	0.96	67.74	1.25	138.00	1.30	163.59
.0050	200.0	0.47	3.67	0.62	10.90	0.75	23.51	0.81	32.18	0.98	69.15	1.28	140.88	1.33	167.00
.0055	181.8	0.49	3.86	0.65	11.44	0.79	24.67	0.85	33.76	1.16	82.06	1.34	147.83	1.39	175.24
.0060	166.7	0.51	4.03	0.68	11.95	0.82	25.77	0.89	35.27	1.21	85.75	1.40	154.48	1.46	183.11
.0065	153.8	0.53	4.20	0.70	12.45	0.85	26.83	0.92	36.72	1.26	89.29	1.46	160.85	1.64	206.02
.0070	142.9	0.55	4.36	0.73	12.92	0.89	27.85	0.96	38.12	1.31	92.70	1.63	180.55	1.70	213.92
.0075	133.3	0.57	4.51	0.76	13.38	0.92	28.84	0.99	39.46	1.36	95.99	1.69	186.99	1.76	221.55
.0080	125.0	0.59	4.66	0.78	13.82	0.95	29.79	1.17	46.37	1.40	99.17	1.75	193.22	1.82	228.93
.0085	117.6	0.61	4.80	0.81	14.25	0.98	30.71	1.20	47.81	1.45	102.25	1.80	199.26	1.88	236.08
.0090	111.1	0.63	4.95	0.83	14.66	1.15	36.03	1.24	49.21	1.49	105.25	1.86	205.12	1.93	243.02
.0095	105.3	0.65	5.08	0.85	15.07	1.18	37.03	1.27	50.58	1.66	117.24	1.91	210.82	1.99	249.77
.0100	100.0	0.66	5.22	0.87	15.46	1.21	38.00	1.31	51.91	1.70	120.34	1.96	216.38	2.04	256.35
.0110	90.9	0.70	5.47	0.92	16.22	1.27	39.88	1.37	54.47	1.79	126.30	2.06	227.09	2.14	269.03
.0120	83.3	0.73	5.72	0.96	16.95	1.33	41.67	1.43	56.91	1.87	132.01	2.15	237.32	2.24	281.15
.0130	76.9	0.76	5.95	1.00	17.64	1.38	43.39	1.49	59.26	1.94	137.47	2.24	247.13	2.33	292.77
.0140	71.4	0.79	6.18	1.19	21.02	1.43	45.05	1.68	66.92	2.02	142.74	2.32	256.58	2.42	303.95
.0150	66.7	0.81	6.40	1.23	21.76	1.48	46.65	1.74	69.30	2.09	147.81	2.41	265.69	2.50	314.74
.0160	62.5	0.84	6.61	1.27	22.48	1.67	52.49	1.80	71.61	2.16	152.72	2.49	274.50	2.59	325.18
.0170	58.8	0.87	6.81	1.31	23.18	1.72	54.13	1.86	73.85	2.23	157.49	2.56	283.05	2.67	335.29
.0180	55.6	0.89	7.01	1.35	23.86	1.77	55.73	1.91	76.02	2.29	162.11	2.64	291.34	2.75	345.12
.0190	52.6	0.92	7.21	1.39	24.52	1.82	57.28	1.97	78.14	2.36	166.60	2.71	299.41	2.82	354.67
.0200	50.0	0.94	7.39	1.42	25.17	1.87	58.79	2.02	80.19	2.42	170.98	2.78	307.27	2.90	363.98
.0220	45.5	0.99	7.76	1.49	26.41	1.96	61.70	2.12	84.16	2.54	179.42	2.92	322.42	3.04	381.91
.0240	41.7	1.20	9.39	1.71	30.17	2.05	64.48	2.21	87.95	2.65	187.49	3.05	336.89	3.18	399.05
.0260	38.5	1.25	9.78	1.78	31.43	2.14	67.15	2.30	91.59	2.76	195.23	3.18	350.78	3.31	415.49
.0280	35.7	1.29	10.15	1.85	32.63	2.22	69.72	2.39	95.09	2.87	202.67	3.30	364.14	3.43	431.31
.0300	33.3	1.34	10.51	1.91	33.79	2.30	72.20	2.48	98.46	2.97	209.86	3.41	377.03	3.55	446.58
.0320	31.2	1.38	10.86	1.98	34.92	2.37	74.59	2.56	101.73	3.07	216.80	3.53	389.50	3.67	461.34
.0340	29.4	1.43	11.20	2.04	36.01	2.45	76.92	2.64	104.89	3.16	223.54	3.64	401.58	3.79	475.65
.0360	27.8	1.47	11.53	2.10	37.06	2.52	79.17	2.72	107.97	3.25	230.08	3.74	413.32	3.90	489.55
.0380	26.3	1.66	13.03	2.16	38.09	2.59	81.36	2.79	110.96	3.34	236.44	3.85	424.73	4.00	503.06
.0400	25.0	1.70	13.37	2.21	39.10	2.66	83.50	2.86	113.87	3.43	242.63	3.95	435.84	4.11	516.22
.0420	23.8	1.75	13.71	2.27	40.07	2.72	85.59	2.94	116.71	3.52	248.67	4.04	446.69	4.21	529.06
.0440	22.7	1.79	14.04	2.32	41.03	2.79	87.62	3.01	119.48	3.60	254.57	4.14	457.27	4.31	541.60
.0460	21.7	1.83	14.36	2.37	41.96	2.85	89.61	3.07	122.19	3.68	260.34	4.23	467.62	4.41	553.85
.0480	20.8	1.87	14.67	2.43	42.87	2.91	91.56	3.14	124.85	3.76	265.98	4.33	477.75	4.50	565.84
.0500	20.0	1.91	14.98	2.48	43.77	2.98	93.46	3.21	127.44	3.84	271.51	4.42	487.67	4.60	577.58
.0550	18.2	2.00	15.72	2.60	45.93	3.12	98.07	3.36	133.72	4.03	284.86	4.63	511.62	4.82	605.95
.0600	16.7	2.09	16.43	2.72	47.99	3.26	102.47	3.51	139.72	4.21	297.62	4.84	534.52	5.04	633.06
.0650	15.4	2.18	17.11	2.83	49.97	3.40	106.69	3.66	145.47	4.38	309.86	5.04	556.48	5.24	659.06
.0700	14.3	2.26	17.76	2.94	51.88	3.53	110.75	3.80	151.00	4.55	321.63	5.23	577.60	5.44	684.08
.0750	13.3	2.34	18.39	3.04	53.72	3.65	114.67	3.93	156.34	4.71	332.99	5.41	597.99	5.64	708.22
.0800	12.5	2.42	19.00	3.14	55.50	3.77	118.46	4.06	161.51	4.87	343.98	5.59	617.71	5.82	731.56
.0850	11.8	2.49	19.59	3.24	57.22	3.89	122.13	4.19	166.51	5.02	354.63	5.77	636.82	6.00	754.19
.0900	11.1	2.57	20.17	3.33	58.89	4.00	125.70	4.31	171.37	5.16	364.97	5.93	655.37	6.18	776.17
.0950	10.5	2.64	20.73	3.42	60.52	4.11	129.17	4.43	176.10	5.31	375.03	6.10	673.42	6.35	797.54

TABLE B4 *(continued)*   **PIPE FLOWING FULL**

k_s = 1.5mm for velocities less than or equal to 1.0m/s
k_s = 0.6mm for velocities greater than 1.0m/s less than or equal to 1.5m/s
k_s = 0.3mm for velocities greater than 1.5m/s

450mm to 1000mm Nominal Bore

Nominal Bore mm		450		500		600		700		800		900		1000	
Hydraulic Gradient	1 in	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s
.0010	1000.0	0.57	90.06	0.61	119.04	0.68	192.80	0.75	289.66	0.82	411.96	0.88	561.88	0.94	741.52
.0011	909.1	0.59	94.50	0.64	124.91	0.72	202.29	0.79	303.91	0.86	432.21	0.93	589.49	0.99	777.93
.0012	833.3	0.62	98.75	0.66	130.51	0.75	211.35	0.83	317.52	0.90	451.55	0.97	615.86	1.15	901.93
.0013	769.2	0.65	102.82	0.69	135.89	0.78	220.05	0.86	330.57	0.94	470.11	1.12	712.45	1.20	939.20
.0014	714.3	0.67	106.73	0.72	141.06	0.81	228.42	0.89	343.14	0.97	487.97	1.16	739.67	1.24	975.07
.0015	666.7	0.69	110.51	0.74	146.05	0.84	236.49	0.92	355.26	1.12	562.29	1.20	765.94	1.29	1009.67
.0016	625.0	0.72	114.16	0.77	150.88	0.86	244.30	0.95	366.99	1.16	580.96	1.24	791.35	1.33	1043.15
.0017	588.2	0.74	117.71	0.79	155.56	0.89	251.87	0.98	378.35	1.19	599.05	1.28	815.98	1.37	1075.59
.0018	555.6	0.76	121.14	0.82	160.10	0.92	259.22	1.13	434.25	1.23	616.62	1.32	839.89	1.41	1107.09
.0019	526.3	0.78	124.49	0.84	164.52	0.94	266.37	1.16	446.29	1.26	633.71	1.36	863.15	1.45	1137.73
.0020	500.0	0.80	127.75	0.86	168.82	0.97	273.34	1.19	458.03	1.29	650.35	1.39	885.80	1.49	1167.57
.0022	454.5	0.84	134.03	0.90	177.12	1.13	320.55	1.25	480.64	1.36	682.44	1.46	929.47	1.67	1312.63
.0024	416.7	0.88	140.03	0.94	185.05	1.18	334.98	1.31	502.25	1.42	713.10	1.64	1041.39	1.75	1371.92
.0026	384.6	0.92	145.79	0.98	192.65	1.23	348.81	1.36	522.98	1.48	742.51	1.70	1084.59	1.82	1428.79
.0028	357.1	0.95	151.32	1.14	224.18	1.28	362.13	1.41	542.93	1.65	827.39	1.77	1126.17	1.89	1483.51
.0030	333.3	0.99	156.67	1.18	232.14	1.33	374.98	1.46	562.18	1.70	856.89	1.83	1166.29	1.96	1536.32
.0032	312.5	1.14	181.75	1.22	239.85	1.37	387.41	1.62	624.11	1.76	885.43	1.89	1205.09	2.02	1587.39
.0034	294.1	1.18	187.41	1.26	247.31	1.41	399.45	1.67	643.63	1.82	913.09	1.95	1242.71	2.08	1636.90
.0036	277.8	1.21	192.90	1.30	254.56	1.45	411.15	1.72	662.59	1.87	939.95	2.01	1279.23	2.15	1684.97
.0038	263.2	1.25	198.25	1.33	261.61	1.49	422.53	1.77	681.02	1.92	966.08	2.07	1314.75	2.20	1731.73
.0040	250.0	1.28	203.46	1.37	268.48	1.65	466.67	1.82	698.98	1.97	991.52	2.12	1349.36	2.26	1777.27
.0042	238.1	1.31	208.54	1.40	275.18	1.69	478.38	1.86	716.50	2.02	1016.34	2.17	1383.10	2.32	1821.69
.0044	227.3	1.34	213.50	1.43	281.72	1.73	489.82	1.91	733.60	2.07	1040.58	2.23	1416.06	2.37	1865.06
.0046	217.4	1.37	218.35	1.47	288.11	1.77	500.99	1.95	750.32	2.12	1064.27	2.28	1448.27	2.43	1907.46
.0048	208.3	1.40	223.09	1.50	294.37	1.81	511.93	1.99	766.68	2.16	1087.46	2.33	1479.80	2.48	1948.95
.0050	200.0	1.43	227.74	1.65	323.98	1.85	522.64	2.03	782.70	2.21	1110.16	2.37	1510.67	2.53	1989.59
.0055	181.8	1.62	257.88	1.73	340.05	1.94	548.52	2.13	821.42	2.32	1165.02	2.49	1585.26	2.66	2087.76
.0060	166.7	1.69	269.54	1.81	355.40	2.03	573.25	2.23	858.41	2.42	1217.44	2.60	1656.53	2.78	2181.56
.0065	153.8	1.77	280.72	1.89	370.13	2.11	596.97	2.32	893.89	2.52	1267.71	2.71	1724.89	2.89	2271.53
.0070	142.9	1.83	291.47	1.96	384.30	2.19	619.80	2.41	928.03	2.62	1316.09	2.81	1790.67	3.00	2358.11
.0075	133.3	1.90	301.85	2.03	397.98	2.27	641.83	2.50	960.98	2.71	1362.78	2.91	1854.15	3.11	2441.65
.0080	125.0	1.96	311.90	2.09	411.21	2.35	663.13	2.58	992.84	2.80	1407.93	3.01	1915.54	3.21	2522.45
.0085	117.6	2.02	321.63	2.16	424.03	2.42	683.78	2.66	1023.73	2.89	1451.69	3.10	1975.04	3.31	2600.76
.0090	111.1	2.08	331.08	2.22	436.48	2.49	703.83	2.74	1053.72	2.97	1494.19	3.20	2032.82	3.41	2676.81
.0095	105.3	2.14	340.27	2.28	448.58	2.56	723.33	2.81	1082.89	3.05	1535.52	3.28	2089.02	3.50	2750.77
.0100	100.0	2.20	349.22	2.34	460.38	2.63	742.33	2.89	1111.30	3.13	1575.78	3.37	2143.75	3.59	2822.81
.0110	90.9	2.30	366.48	2.46	483.11	2.75	778.94	3.03	1166.06	3.29	1653.38	3.54	2249.27	3.77	2961.67
.0120	83.3	2.41	382.97	2.57	504.84	2.88	813.93	3.17	1218.40	3.44	1727.53	3.69	2350.09	3.94	3094.37
.0130	76.9	2.51	398.79	2.68	525.67	3.00	847.49	3.30	1268.59	3.58	1798.66	3.85	2446.79	4.10	3221.64
.0140	71.4	2.60	414.01	2.78	545.73	3.11	879.78	3.42	1316.89	3.71	1867.09	3.99	2539.84	4.26	3344.10
.0150	66.7	2.70	428.70	2.88	565.07	3.22	910.94	3.54	1363.50	3.85	1933.13	4.13	2629.63	4.41	3462.27
.0160	62.5	2.78	442.90	2.97	583.79	3.33	941.08	3.66	1408.57	3.97	1997.00	4.27	2716.46	4.55	3576.56
.0170	58.8	2.87	456.67	3.07	601.92	3.43	970.29	3.77	1452.26	4.10	2058.90	4.40	2800.63	4.69	3687.33
.0180	55.6	2.96	470.04	3.16	619.53	3.53	998.65	3.88	1494.69	4.22	2119.01	4.53	2882.36	4.83	3794.89
.0190	52.6	3.04	483.04	3.24	636.66	3.63	1026.24	3.99	1535.95	4.33	2177.48	4.66	2961.85	4.96	3899.50
.0200	50.0	3.12	495.71	3.33	653.35	3.72	1053.11	4.10	1576.13	4.45	2234.42	4.78	3039.27	5.09	4001.40
.0220	45.5	3.27	520.12	3.49	685.51	3.91	1104.91	4.30	1653.60	4.66	2344.19	5.01	3188.51	5.34	4197.81
.0240	41.7	3.42	543.45	3.65	716.24	4.08	1154.40	4.49	1727.63	4.87	2449.07	5.24	3331.11	5.58	4385.49
.0260	38.5	3.56	565.83	3.80	745.72	4.25	1201.87	4.67	1798.63	5.07	2549.67	5.45	3467.89	5.81	4565.50
.0280	35.7	3.69	587.36	3.94	774.08	4.41	1247.55	4.85	1866.94	5.26	2646.47	5.66	3599.50	6.03	4738.71
.0300	33.3	3.82	608.13	4.08	801.45	4.57	1291.62	5.02	1932.86	5.45	2739.87	5.86	3726.49	6.25	4905.84
.0320	31.2	3.95	628.23	4.22	827.92	4.72	1334.25	5.19	1996.62	5.63	2830.21	6.05	3849.31	6.45	5067.49
.0340	29.4	4.07	647.70	4.35	853.57	4.87	1375.56	5.35	2058.41	5.80	2917.77	6.24	3968.35	6.65	5224.16
.0360	27.8	4.19	666.62	4.47	878.48	5.01	1415.68	5.50	2118.41	5.97	3002.78	6.42	4083.94	6.85	5376.28
.0380	26.3	4.31	685.01	4.60	902.71	5.14	1454.70	5.66	2176.77	6.14	3085.47	6.60	4196.37	7.03	5524.24
.0400	25.0	4.42	702.92	4.72	926.31	5.28	1492.71	5.80	2233.61	6.30	3166.01	6.77	4305.87	7.22	5668.35
.0420	23.8	4.53	720.40	4.83	949.33	5.41	1529.77	5.95	2289.05	6.45	3244.56	6.94	4412.66	7.40	5808.90
.0440	22.7	4.64	737.46	4.95	971.80	5.54	1565.97	6.09	2343.19	6.61	3321.26	7.10	4516.95	7.57	5946.15
.0460	21.7	4.74	754.13	5.06	993.77	5.66	1601.35	6.23	2396.10	6.76	3396.24	7.26	4618.89	7.74	6080.31
.0480	20.8	4.84	770.45	5.17	1015.27	5.79	1635.97	6.36	2447.88	6.90	3469.60	7.42	4718.63	7.91	6211.58
.0500	20.0	4.94	786.44	5.28	1036.32	5.91	1669.87	6.49	2498.59	7.05	3541.45	7.57	4816.32	8.07	6340.15
.0550	18.2	5.19	825.05	5.54	1087.18	6.20	1751.78	6.81	2621.10	7.39	3715.03	7.94	5052.32	8.47	6650.74
.0600	16.7	5.42	861.94	5.78	1135.78	6.47	1830.05	7.11	2738.15	7.72	3880.88	8.30	5277.81	8.85	6947.51
.0650	15.4	5.64	897.33	6.02	1182.39	6.74	1905.11	7.41	2850.42	8.04	4039.96	8.64	5494.09	9.21	7232.15
.0700	14.3	5.86	931.38	6.25	1227.25	6.99	1977.34	7.69	2958.45	8.34	4193.03	8.96	5702.20	9.56	7506.04
.0750	13.3	6.06	964.23	6.47	1270.52	7.24	2047.04	7.96	3062.69	8.64	4340.72	9.28	5903.01	9.89	7770.31
.0800	12.5	6.26	996.01	6.68	1312.38	7.48	2114.45	8.22	3163.51	8.92	4483.57	9.58	6097.22	10.22	8025.91
.0850	11.8	6.46	1026.80	6.89	1352.95	7.71	2179.78	8.47	3261.22	9.20	4622.01	9.88	6285.45	10.53	8273.64
.0900	11.1	6.64	1056.71	7.09	1392.34	7.93	2243.22	8.72	3356.10	9.46	4756.45	10.17	6468.23	10.84	8514.19
.0950	10.5	6.83	1085.79	7.29	1430.65	8.15	2304.92	8.96	3448.38	9.72	4887.20	10.45	6645.99	11.14	8748.14

Nominal Bore mm		100		150		200		225		300		375		400	
Hydraulic Gradient	1 in	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s
.0010	1000.0	0.23	1.84	0.31	5.45	0.37	11.74	0.40	16.06	0.49	34.45	0.56	62.19	0.59	73.75
.0011	909.1	0.25	1.93	0.32	5.73	0.39	12.33	0.42	16.87	0.51	36.18	0.59	65.29	0.62	77.43
.0012	833.3	0.26	2.02	0.34	5.99	0.41	12.90	0.44	17.64	0.54	37.83	0.62	68.26	0.64	80.95
.0013	769.2	0.27	2.11	0.35	6.24	0.43	13.44	0.46	18.38	0.56	39.41	0.64	71.11	0.67	84.32
.0014	714.3	0.28	2.19	0.37	6.49	0.44	13.96	0.48	19.09	0.58	40.93	0.67	73.84	0.70	87.57
.0015	666.7	0.29	2.27	0.38	6.72	0.46	14.46	0.50	19.78	0.60	42.40	0.69	76.49	0.72	90.70
.0016	625.0	0.30	2.35	0.39	6.95	0.48	14.95	0.51	20.44	0.62	43.82	0.72	79.04	0.75	93.73
.0017	588.2	0.31	2.43	0.41	7.17	0.49	15.42	0.53	21.09	0.64	45.20	0.74	81.52	0.77	96.66
.0018	555.6	0.32	2.50	0.42	7.39	0.51	15.88	0.55	21.71	0.66	46.53	0.76	83.93	0.79	99.51
.0019	526.3	0.33	2.57	0.43	7.59	0.52	16.33	0.56	22.32	0.68	47.83	0.78	86.27	0.81	102.29
.0020	500.0	0.34	2.64	0.44	7.80	0.53	16.76	0.58	22.92	0.69	49.10	0.80	88.55	0.84	104.99
.0022	454.5	0.35	2.77	0.46	8.19	0.56	17.60	0.61	24.06	0.73	51.54	0.84	92.94	0.88	110.19
.0024	416.7	0.37	2.90	0.48	8.56	0.59	18.40	0.63	25.15	0.76	53.88	0.88	97.14	0.92	115.17
.0026	384.6	0.38	3.02	0.50	8.92	0.61	19.17	0.66	26.20	0.79	56.12	0.92	101.17	0.95	119.94
.0028	357.1	0.40	3.14	0.52	9.27	0.63	19.91	0.68	27.21	0.82	58.27	0.95	105.04	0.99	124.53
.0030	333.3	0.41	3.25	0.54	9.60	0.66	20.62	0.71	28.18	0.85	60.35	0.98	108.78	1.03	128.97
.0032	312.5	0.43	3.36	0.56	9.92	0.68	21.31	0.73	29.13	0.88	62.36	1.02	112.40	1.06	133.25
.0034	294.1	0.44	3.47	0.58	10.24	0.70	21.98	0.76	30.04	0.91	64.31	1.05	115.91	1.09	137.41
.0036	277.8	0.45	3.57	0.60	10.54	0.72	22.63	0.78	30.92	0.94	66.20	1.08	119.31	1.13	141.44
.0038	263.2	0.47	3.67	0.61	10.83	0.74	23.26	0.80	31.79	0.96	68.04	1.11	122.62	1.16	145.36
.0040	250.0	0.48	3.77	0.63	11.12	0.76	23.88	0.82	32.63	0.99	69.83	1.14	125.85	1.19	149.19
.0042	238.1	0.49	3.87	0.65	11.40	0.78	24.48	0.84	33.44	1.01	71.58	1.17	128.99	1.22	152.91
.0044	227.3	0.50	3.96	0.66	11.68	0.80	25.06	0.86	34.24	1.04	73.29	1.20	132.06	1.25	156.55
.0046	217.4	0.52	4.05	0.68	11.94	0.82	25.64	0.88	35.03	1.06	74.96	1.22	135.07	1.27	160.11
.0048	208.3	0.53	4.14	0.69	12.20	0.83	26.20	0.90	35.79	1.08	76.59	1.25	138.00	1.30	163.59
.0050	200.0	0.54	4.23	0.71	12.46	0.85	26.75	0.92	36.54	1.11	78.19	1.28	140.88	1.33	167.00
.0055	181.8	0.57	4.44	0.74	13.08	0.89	28.07	0.96	38.35	1.16	82.06	1.34	147.83	1.39	175.24
.0060	166.7	0.59	4.64	0.77	13.67	0.93	29.34	1.01	40.08	1.21	85.75	1.40	154.48	1.46	183.11
.0065	153.8	0.62	4.84	0.81	14.24	0.97	30.56	1.05	41.74	1.26	89.29	1.46	160.85	1.52	190.66
.0070	142.9	0.64	5.02	0.84	14.79	1.01	31.73	1.09	43.34	1.31	92.70	1.51	166.98	1.58	197.93
.0075	133.3	0.66	5.20	0.87	15.32	1.05	32.85	1.13	44.88	1.36	95.99	1.57	172.90	1.63	204.94
.0080	125.0	0.68	5.38	0.90	15.83	1.08	33.95	1.17	46.37	1.40	99.17	1.62	178.62	1.68	211.72
.0085	117.6	0.71	5.55	0.92	16.32	1.11	35.00	1.20	47.81	1.45	102.25	1.67	184.16	1.74	218.29
.0090	111.1	0.73	5.71	0.95	16.80	1.15	36.03	1.24	49.21	1.49	105.25	1.72	189.55	1.79	224.67
.0095	105.3	0.75	5.87	0.98	17.27	1.18	37.03	1.27	50.58	1.53	108.16	1.76	194.79	1.84	230.88
.0100	100.0	0.77	6.02	1.00	17.72	1.21	38.00	1.31	51.91	1.57	110.99	1.81	199.89	1.89	236.92
.0110	90.9	0.81	6.32	1.05	18.60	1.27	39.88	1.37	54.47	1.65	116.46	1.90	209.72	1.98	248.57
.0120	83.3	0.84	6.61	1.10	19.44	1.33	41.67	1.43	56.91	1.72	121.68	1.98	219.12	2.07	259.71
.0130	76.9	0.88	6.88	1.15	20.24	1.38	43.39	1.49	59.26	1.79	126.69	2.07	228.13	2.15	270.39
.0140	71.4	0.91	7.15	1.19	21.02	1.43	45.05	1.55	61.52	1.86	131.51	2.14	236.80	2.23	280.66
.0150	66.7	0.94	7.40	1.23	21.76	1.48	46.65	1.60	63.70	1.93	136.17	2.22	245.17	2.31	290.58
.0160	62.5	0.97	7.65	1.27	22.48	1.53	48.19	1.66	65.81	1.99	140.67	2.29	253.27	2.39	300.17
.0170	58.8	1.00	7.89	1.31	23.18	1.58	49.69	1.71	67.85	2.05	145.03	2.36	261.11	2.46	309.46
.0180	55.6	1.03	8.12	1.35	23.86	1.63	51.14	1.76	69.83	2.11	149.26	2.43	268.73	2.53	318.49
.0190	52.6	1.06	8.34	1.39	24.52	1.67	52.56	1.80	71.76	2.17	153.38	2.50	276.13	2.60	327.26
.0200	50.0	1.09	8.56	1.42	25.17	1.72	53.93	1.85	73.64	2.23	157.39	2.57	283.35	2.67	335.81
.0220	45.5	1.14	8.99	1.49	26.41	1.80	56.59	1.94	77.26	2.34	165.12	2.69	297.26	2.80	352.29
.0240	41.7	1.20	9.39	1.56	27.59	1.88	59.12	2.03	80.73	2.44	172.51	2.81	310.55	2.93	368.04
.0260	38.5	1.25	9.78	1.63	28.73	1.96	61.56	2.11	84.05	2.54	179.60	2.93	323.30	3.05	383.15
.0280	35.7	1.29	10.15	1.69	29.83	2.03	63.90	2.19	87.24	2.64	186.42	3.04	335.56	3.16	397.68
.0300	33.3	1.34	10.51	1.75	30.88	2.11	66.16	2.27	90.32	2.73	193.00	3.15	347.40	3.28	411.70
.0320	31.2	1.38	10.86	1.81	31.90	2.18	68.34	2.35	93.30	2.82	199.36	3.25	358.84	3.38	425.27
.0340	29.4	1.43	11.20	1.86	32.89	2.24	70.46	2.42	96.19	2.91	205.53	3.35	369.94	3.49	438.41
.0360	27.8	1.47	11.53	1.92	33.85	2.31	72.51	2.49	99.00	2.99	211.52	3.45	380.71	3.59	451.17
.0380	26.3	1.51	11.85	1.97	34.79	2.37	74.51	2.56	101.73	3.07	217.34	3.54	391.19	3.69	463.59
.0400	25.0	1.55	12.16	2.02	35.70	2.43	76.46	2.63	104.39	3.15	223.01	3.63	401.39	3.79	475.68
.0420	23.8	1.59	12.46	2.07	36.59	2.49	78.36	2.69	106.98	3.23	228.55	3.72	411.35	3.88	487.47
.0440	22.7	1.62	12.76	2.12	37.45	2.55	80.22	2.75	109.51	3.31	233.95	3.81	421.06	3.97	498.99
.0460	21.7	1.66	13.05	2.17	38.30	2.61	82.03	2.82	111.98	3.38	239.23	3.90	430.56	4.06	510.25
.0480	20.8	1.70	13.33	2.21	39.13	2.67	83.80	2.88	114.40	3.46	244.40	3.98	439.86	4.15	521.26
.0500	20.0	1.73	13.61	2.26	39.94	2.72	85.54	2.94	116.78	3.53	249.46	4.06	448.96	4.23	532.05
.0550	18.2	1.82	14.28	2.37	41.90	2.86	89.74	3.08	122.50	3.70	261.69	4.26	470.96	4.44	558.11
.0600	16.7	1.90	14.92	2.48	43.78	2.98	93.75	3.22	127.98	3.87	273.37	4.45	491.97	4.64	583.01
.0650	15.4	1.98	15.53	2.58	45.58	3.11	97.60	3.35	133.23	4.03	284.58	4.64	512.13	4.83	606.89
.0700	14.3	2.05	16.12	2.68	47.31	3.22	101.30	3.48	138.28	4.18	295.36	4.81	531.52	5.01	629.87
.0750	13.3	2.13	16.69	2.77	48.98	3.34	104.87	3.60	143.15	4.33	305.76	4.98	550.24	5.19	652.05
.0800	12.5	2.20	17.24	2.86	50.59	3.45	108.32	3.72	147.87	4.47	315.82	5.15	568.34	5.36	673.49
.0850	11.8	2.26	17.78	2.95	52.16	3.55	111.67	3.83	152.44	4.61	325.58	5.30	585.88	5.52	694.28
.0900	11.1	2.33	18.30	3.04	53.68	3.66	114.92	3.95	156.87	4.74	335.05	5.46	602.91	5.69	714.46
.0950	10.5	2.39	18.80	3.12	55.15	3.76	118.09	4.05	161.19	4.87	344.26	5.61	619.48	5.84	734.09

Nominal Bore mm		450		500		600		700		800		900		1000	
Hydraulic Gradient	1 in	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s
.0010	1000.0	0.63	100.66	0.68	132.91	0.76	214.87	0.84	322.34	0.91	457.85	0.98	623.79	1.05	822.41
.0011	909.1	0.66	105.67	0.71	139.52	0.80	225.54	0.88	338.33	0.96	480.53	1.03	654.66	1.10	863.08
.0012	833.3	0.69	110.46	0.74	145.84	0.83	235.74	0.92	353.60	1.00	502.20	1.08	684.15	1.15	901.93
.0013	769.2	0.72	115.06	0.77	151.90	0.87	245.52	0.96	368.25	1.04	522.99	1.12	712.45	1.20	939.20
.0014	714.3	0.75	119.48	0.80	157.74	0.90	254.93	0.99	382.35	1.08	542.99	1.16	739.67	1.24	975.07
.0015	666.7	0.78	123.75	0.83	163.36	0.93	264.01	1.03	395.95	1.12	562.29	1.20	765.94	1.29	1009.67
.0016	625.0	0.80	127.88	0.86	168.81	0.96	272.79	1.06	409.11	1.16	580.96	1.24	791.35	1.33	1043.15
.0017	588.2	0.83	131.88	0.89	174.09	0.99	281.31	1.10	421.86	1.19	599.05	1.28	815.98	1.37	1075.59
.0018	555.6	0.85	135.77	0.91	179.21	1.02	289.58	1.13	434.25	1.23	616.62	1.32	839.89	1.41	1107.09
.0019	526.3	0.88	139.54	0.94	184.19	1.05	297.62	1.16	446.29	1.26	633.71	1.36	863.15	1.45	1137.73
.0020	500.0	0.90	143.23	0.96	189.05	1.08	305.45	1.19	458.03	1.29	650.35	1.39	885.80	1.49	1167.57
.0022	454.5	0.95	150.32	1.01	198.41	1.13	320.55	1.25	480.64	1.36	682.44	1.46	929.47	1.56	1225.10
.0024	416.7	0.99	157.10	1.06	207.35	1.18	334.98	1.31	502.25	1.42	713.10	1.53	971.20	1.63	1280.07
.0026	384.6	1.03	163.61	1.10	215.92	1.23	348.81	1.36	522.98	1.48	742.51	1.59	1011.23	1.70	1332.79
.0028	357.1	1.07	169.87	1.14	224.18	1.28	362.13	1.41	542.93	1.53	770.80	1.65	1049.74	1.76	1383.53
.0030	333.3	1.11	175.90	1.18	232.14	1.33	374.98	1.46	562.18	1.59	798.11	1.71	1086.90	1.82	1432.48
.0032	312.5	1.14	181.75	1.22	239.85	1.37	387.41	1.51	580.79	1.64	824.52	1.77	1122.85	1.88	1479.83
.0034	294.1	1.18	187.41	1.26	247.31	1.41	399.45	1.56	598.83	1.69	850.11	1.82	1157.68	1.94	1525.72
.0036	277.8	1.21	192.90	1.30	254.56	1.45	411.15	1.60	616.35	1.74	874.97	1.87	1191.51	2.00	1570.28
.0038	263.2	1.25	198.25	1.33	261.61	1.49	422.53	1.65	633.39	1.79	899.14	1.92	1224.41	2.05	1613.62
.0040	250.0	1.28	203.46	1.37	268.48	1.53	433.61	1.69	649.99	1.84	922.68	1.98	1256.46	2.11	1655.83
.0042	238.1	1.31	208.54	1.40	275.18	1.57	444.41	1.73	666.18	1.88	945.65	2.02	1287.71	2.16	1697.00
.0044	227.3	1.34	213.50	1.43	281.72	1.61	454.97	1.77	681.98	1.93	968.07	2.07	1318.23	2.21	1737.21
.0046	217.4	1.37	218.35	1.47	288.11	1.65	465.28	1.81	697.43	1.97	989.99	2.12	1348.06	2.26	1776.51
.0048	208.3	1.40	223.09	1.50	294.37	1.68	475.38	1.85	712.55	2.01	1011.44	2.16	1377.26	2.31	1814.96
.0050	200.0	1.43	227.74	1.53	300.50	1.72	485.26	1.89	727.36	2.05	1032.45	2.21	1405.85	2.36	1852.62
.0055	181.8	1.50	238.96	1.61	315.30	1.80	509.15	1.98	763.13	2.15	1083.19	2.32	1474.91	2.47	1943.60
.0060	166.7	1.57	249.69	1.68	329.45	1.88	531.97	2.07	797.31	2.25	1131.68	2.42	1540.91	2.59	2030.53
.0065	153.8	1.63	259.98	1.75	343.01	1.96	553.85	2.16	830.10	2.34	1178.19	2.52	1604.21	2.69	2113.92
.0070	142.9	1.70	269.88	1.81	356.07	2.03	574.92	2.24	861.64	2.43	1222.94	2.62	1665.11	2.79	2194.15
.0075	133.3	1.76	279.43	1.88	368.66	2.11	595.24	2.32	892.08	2.52	1266.12	2.71	1723.88	2.89	2271.56
.0080	125.0	1.82	288.67	1.94	380.85	2.17	614.89	2.39	921.52	2.60	1307.89	2.80	1780.72	2.99	2346.44
.0085	117.6	1.87	297.63	2.00	392.66	2.24	633.94	2.47	950.05	2.68	1348.36	2.89	1835.82	3.08	2419.01
.0090	111.1	1.93	306.32	2.06	404.12	2.31	652.44	2.54	977.76	2.76	1387.67	2.97	1889.31	3.17	2489.47
.0095	105.3	1.98	314.78	2.11	415.27	2.37	670.43	2.61	1004.71	2.84	1425.90	3.05	1941.34	3.26	2558.01
.0100	100.0	2.03	323.01	2.17	426.14	2.43	687.96	2.68	1030.96	2.91	1463.13	3.13	1992.01	3.34	2624.76
.0110	90.9	2.13	338.89	2.28	447.07	2.55	721.74	2.81	1081.55	3.05	1534.90	3.28	2089.70	3.51	2753.44
.0120	83.3	2.23	354.06	2.38	467.08	2.67	754.01	2.94	1129.89	3.19	1603.48	3.43	2183.04	3.66	2876.39
.0130	76.9	2.32	368.62	2.48	486.27	2.78	784.97	3.06	1176.26	3.32	1669.26	3.57	2272.56	3.81	2994.32
.0140	71.4	2.41	382.62	2.57	504.73	2.88	814.76	3.17	1220.88	3.45	1732.55	3.71	2358.70	3.96	3107.79
.0150	66.7	2.49	396.13	2.66	522.55	2.98	843.50	3.28	1263.93	3.57	1793.63	3.84	2441.82	4.10	3217.28
.0160	62.5	2.57	409.20	2.75	539.78	3.08	871.30	3.39	1305.57	3.69	1852.69	3.96	2522.21	4.23	3323.17
.0170	58.8	2.65	421.86	2.83	556.48	3.18	898.25	3.50	1345.92	3.80	1909.94	4.09	2600.13	4.36	3425.81
.0180	55.6	2.73	434.16	2.92	572.70	3.27	924.41	3.60	1385.11	3.91	1965.53	4.21	2675.78	4.49	3525.46
.0190	52.6	2.81	446.12	3.00	588.47	3.36	949.85	3.70	1423.22	4.02	2019.59	4.32	2749.36	4.61	3622.39
.0200	50.0	2.88	457.77	3.08	603.84	3.45	974.64	3.79	1460.34	4.12	2072.25	4.43	2821.03	4.73	3716.80
.0220	45.5	3.02	480.23	3.23	633.45	3.62	1022.41	3.98	1531.90	4.32	2173.76	4.65	2959.19	4.96	3898.78
.0240	41.7	3.15	501.69	3.37	661.75	3.78	1068.06	4.16	1600.27	4.52	2270.75	4.86	3091.19	5.19	4072.67
.0260	38.5	3.28	522.27	3.51	688.89	3.93	1111.85	4.33	1665.85	4.70	2363.78	5.06	3217.80	5.40	4239.45
.0280	35.7	3.41	542.07	3.64	715.00	4.08	1153.98	4.49	1728.95	4.88	2453.30	5.25	3339.63	5.60	4399.93
.0300	33.3	3.53	561.18	3.77	740.20	4.23	1194.63	4.65	1789.83	5.05	2539.67	5.43	3457.18	5.80	4554.77
.0320	31.2	3.64	579.67	3.89	764.57	4.36	1233.94	4.80	1848.72	5.22	2623.20	5.61	3570.88	5.99	4704.53
.0340	29.4	3.76	597.58	4.01	788.19	4.50	1272.05	4.95	1905.79	5.38	2704.17	5.79	3681.07	6.17	4849.68
.0360	27.8	3.87	614.97	4.13	811.13	4.63	1309.05	5.10	1961.21	5.54	2782.78	5.95	3788.06	6.35	4990.63
.0380	26.3	3.97	631.89	4.24	833.43	4.76	1345.04	5.24	2015.11	5.69	2859.24	6.12	3892.13	6.53	5127.71
.0400	25.0	4.08	648.36	4.36	855.16	4.88	1380.09	5.37	2067.61	5.84	2933.72	6.28	3993.49	6.70	5261.22
.0420	23.8	4.18	664.43	4.46	876.35	5.00	1414.28	5.51	2118.81	5.98	3006.35	6.43	4092.34	6.86	5391.44
.0440	22.7	4.28	680.13	4.57	897.04	5.12	1447.66	5.64	2168.81	6.12	3077.28	6.58	4188.87	7.03	5518.59
.0460	21.7	4.37	695.47	4.67	917.27	5.24	1480.29	5.76	2217.68	6.26	3146.61	6.73	4283.23	7.18	5642.89
.0480	20.8	4.47	710.47	4.77	937.06	5.35	1512.22	5.89	2265.50	6.39	3214.45	6.88	4375.56	7.34	5764.51
.0500	20.0	4.56	725.17	4.87	956.45	5.46	1543.49	6.01	2312.34	6.53	3280.89	7.02	4465.98	7.49	5883.62
.0550	18.2	4.78	760.68	5.11	1003.27	5.73	1619.03	6.30	2425.48	6.85	3441.39	7.36	4684.43	7.86	6171.37
.0600	16.7	5.00	794.62	5.34	1048.01	5.98	1691.21	6.58	2533.59	7.15	3594.76	7.69	4893.16	8.21	6446.31
.0650	15.4	5.20	827.16	5.56	1090.93	6.23	1760.44	6.85	2637.28	7.44	3741.85	8.01	5093.35	8.54	6710.02
.0700	14.3	5.40	858.47	5.77	1132.22	6.46	1827.06	7.11	2737.06	7.73	3883.39	8.31	5285.98	8.87	6963.76
.0750	13.3	5.59	888.69	5.97	1172.06	6.69	1891.33	7.36	2833.33	8.00	4019.95	8.60	5471.85	9.18	7208.60
.0800	12.5	5.77	917.91	6.17	1210.60	6.91	1953.50	7.60	2926.44	8.26	4152.04	8.88	5651.61	9.48	7445.40
.0850	11.8	5.95	946.24	6.36	1247.95	7.12	2013.75	7.84	3016.68	8.51	4280.06	9.16	5825.85	9.77	7674.91
.0900	11.1	6.12	973.74	6.54	1284.21	7.33	2072.26	8.07	3104.31	8.76	4404.36	9.42	5995.03	10.06	7897.76
.0950	10.5	6.29	1000.49	6.72	1319.48	7.53	2129.16	8.29	3189.53	9.00	4525.26	9.68	6159.57	10.33	8114.50

Nominal Bore mm		100		150		200		225		300		375		400	
Hydraulic Gradient	1 in	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s
.0010	1000.0	0.21	1.62	0.27	4.82	0.33	10.42	0.36	14.27	0.43	30.70	0.50	55.54	0.52	65.91
.0011	909.1	0.22	1.70	0.29	5.06	0.35	10.93	0.38	14.97	0.46	32.22	0.53	58.28	0.55	69.16
.0012	833.3	0.23	1.78	0.30	5.29	0.36	11.43	0.39	15.65	0.48	33.67	0.55	60.90	0.58	72.27
.0013	769.2	0.24	1.85	0.31	5.51	0.38	11.90	0.41	16.30	0.50	35.06	0.57	63.41	0.60	75.25
.0014	714.3	0.24	1.92	0.32	5.72	0.39	12.36	0.43	16.92	0.51	36.40	0.60	65.83	0.62	78.12
.0015	666.7	0.25	1.99	0.34	5.93	0.41	12.80	0.44	17.52	0.53	37.69	0.62	68.16	0.64	80.89
.0016	625.0	0.26	2.06	0.35	6.12	0.42	13.22	0.46	18.10	0.55	38.94	0.64	70.42	0.66	83.56
.0017	588.2	0.27	2.12	0.36	6.32	0.43	13.63	0.47	18.67	0.57	40.15	0.66	72.61	0.69	86.16
.0018	555.6	0.28	2.19	0.37	6.50	0.45	14.03	0.48	19.22	0.58	41.33	0.68	74.73	0.71	88.68
.0019	526.3	0.29	2.25	0.38	6.68	0.46	14.42	0.50	19.75	0.60	42.47	0.70	76.80	0.73	91.13
.0020	500.0	0.29	2.31	0.39	6.86	0.47	14.80	0.51	20.27	0.62	43.58	0.71	78.81	0.74	93.51
.0022	454.5	0.31	2.42	0.41	7.20	0.49	15.53	0.53	21.27	0.65	45.73	0.75	82.68	0.78	98.11
.0024	416.7	0.32	2.53	0.43	7.52	0.52	16.23	0.56	22.22	0.68	47.78	0.78	86.39	0.82	102.51
.0026	384.6	0.34	2.64	0.44	7.83	0.54	16.90	0.58	23.14	0.70	49.75	0.81	89.94	0.85	106.72
.0028	357.1	0.35	2.74	0.46	8.13	0.56	17.55	0.60	24.02	0.73	51.64	0.85	93.36	0.88	110.78
.0030	333.3	0.36	2.84	0.48	8.42	0.58	18.17	0.63	24.87	0.76	53.47	0.88	96.66	0.91	114.69
.0032	312.5	0.37	2.93	0.49	8.70	0.60	18.77	0.65	25.70	0.78	55.24	0.90	99.85	0.94	118.48
.0034	294.1	0.38	3.02	0.51	8.97	0.62	19.35	0.67	26.49	0.81	56.95	0.93	102.95	0.97	122.15
.0036	277.8	0.40	3.11	0.52	9.24	0.63	19.92	0.69	27.27	0.83	58.61	0.96	105.95	1.00	125.71
.0038	263.2	0.41	3.20	0.54	9.49	0.65	20.47	0.70	28.02	0.85	60.23	0.99	108.87	1.03	129.18
.0040	250.0	0.42	3.28	0.55	9.74	0.67	21.01	0.72	28.76	0.87	61.81	1.01	111.72	1.05	132.55
.0042	238.1	0.43	3.36	0.57	9.98	0.69	21.53	0.74	29.47	0.90	63.34	1.04	114.49	1.08	135.84
.0044	227.3	0.44	3.44	0.58	10.22	0.70	22.04	0.76	30.17	0.92	64.84	1.06	117.20	1.11	139.06
.0046	217.4	0.45	3.52	0.59	10.45	0.72	22.54	0.78	30.85	0.94	66.31	1.09	119.85	1.13	142.20
.0048	208.3	0.46	3.60	0.60	10.68	0.73	23.03	0.79	31.52	0.96	67.74	1.11	122.44	1.16	145.27
.0050	200.0	0.47	3.67	0.62	10.90	0.75	23.51	0.81	32.18	0.98	69.15	1.13	124.98	1.18	148.28
.0055	181.8	0.49	3.86	0.65	11.44	0.79	24.67	0.85	33.76	1.03	72.54	1.19	131.11	1.24	155.56
.0060	166.7	0.51	4.03	0.68	11.95	0.82	25.77	0.89	35.27	1.07	75.79	1.24	136.97	1.29	162.51
.0065	153.8	0.53	4.20	0.70	12.45	0.85	26.83	0.92	36.72	1.12	78.90	1.29	142.59	1.35	169.17
.0070	142.9	0.55	4.36	0.73	12.92	0.89	27.85	0.96	38.12	1.16	81.90	1.34	148.00	1.40	175.59
.0075	133.3	0.57	4.51	0.76	13.38	0.92	28.84	0.99	39.46	1.20	84.78	1.39	153.22	1.45	181.78
.0080	125.0	0.59	4.66	0.78	13.82	0.95	29.79	1.03	40.76	1.24	87.58	1.43	158.26	1.49	187.76
.0085	117.6	0.61	4.80	0.81	14.25	0.98	30.71	1.06	42.03	1.28	90.29	1.48	163.15	1.54	193.57
.0090	111.1	0.63	4.95	0.83	14.66	1.01	31.61	1.09	43.25	1.31	92.92	1.52	167.90	1.59	199.20
.0095	105.3	0.65	5.08	0.85	15.07	1.03	32.48	1.12	44.44	1.35	95.47	1.56	172.52	1.63	204.68
.0100	100.0	0.66	5.22	0.87	15.46	1.06	33.32	1.15	45.60	1.39	97.97	1.60	177.02	1.67	210.01
.0110	90.9	0.70	5.47	0.92	16.22	1.11	34.96	1.20	47.84	1.45	102.77	1.68	185.69	1.75	220.30
.0120	83.3	0.73	5.72	0.96	16.95	1.16	36.52	1.26	49.98	1.52	107.36	1.76	193.98	1.83	230.13
.0130	76.9	0.76	5.95	1.00	17.64	1.21	38.02	1.31	52.03	1.58	111.76	1.83	201.93	1.91	239.56
.0140	71.4	0.79	6.18	1.04	18.31	1.26	39.46	1.36	54.00	1.64	115.99	1.90	209.58	1.98	248.63
.0150	66.7	0.81	6.40	1.07	18.96	1.30	40.86	1.41	55.91	1.70	120.08	1.96	216.96	2.05	257.38
.0160	62.5	0.84	6.61	1.11	19.59	1.34	42.20	1.45	57.75	1.75	124.03	2.03	224.09	2.12	265.85
.0170	58.8	0.87	6.81	1.14	20.19	1.38	43.51	1.50	59.53	1.81	127.86	2.09	231.01	2.18	274.05
.0180	55.6	0.89	7.01	1.18	20.78	1.43	44.77	1.54	61.27	1.86	131.58	2.15	237.73	2.24	282.02
.0190	52.6	0.92	7.21	1.21	21.35	1.46	46.01	1.58	62.95	1.91	135.20	2.21	244.26	2.31	289.77
.0200	50.0	0.94	7.39	1.24	21.91	1.50	47.21	1.62	64.59	1.96	138.72	2.27	250.62	2.37	297.32
.0220	45.5	0.99	7.76	1.30	22.99	1.58	49.52	1.70	67.76	2.06	145.51	2.38	262.89	2.48	311.87
.0240	41.7	1.03	8.10	1.36	24.01	1.65	51.73	1.78	70.78	2.15	152.00	2.49	274.61	2.59	325.77
.0260	38.5	1.07	8.44	1.41	25.00	1.71	53.85	1.85	73.68	2.24	158.22	2.59	285.85	2.70	339.10
.0280	35.7	1.12	8.76	1.47	25.94	1.78	55.89	1.92	76.47	2.32	164.21	2.69	296.66	2.80	351.93
.0300	33.3	1.15	9.07	1.52	26.86	1.84	57.86	1.99	79.16	2.40	169.99	2.78	307.10	2.90	364.31
.0320	31.2	1.19	9.37	1.57	27.74	1.90	59.76	2.06	81.77	2.48	175.58	2.87	317.19	2.99	376.28
.0340	29.4	1.23	9.66	1.62	28.60	1.96	61.61	2.12	84.29	2.56	181.00	2.96	326.97	3.09	387.89
.0360	27.8	1.27	9.94	1.67	29.43	2.02	63.40	2.18	86.74	2.63	186.26	3.05	336.47	3.18	399.15
.0380	26.3	1.30	10.21	1.71	30.24	2.07	65.14	2.24	89.12	2.71	191.37	3.13	345.71	3.26	410.11
.0400	25.0	1.33	10.48	1.76	31.03	2.13	66.84	2.30	91.45	2.78	196.36	3.21	354.71	3.35	420.79
.0420	23.8	1.37	10.74	1.80	31.80	2.18	68.49	2.36	93.71	2.85	201.21	3.29	363.48	3.43	431.20
.0440	22.7	1.40	10.99	1.84	32.55	2.23	70.11	2.41	95.92	2.91	205.96	3.37	372.05	3.51	441.36
.0460	21.7	1.43	11.24	1.88	33.28	2.28	71.69	2.47	98.08	2.98	210.60	3.44	380.43	3.59	451.30
.0480	20.8	1.46	11.48	1.92	34.00	2.33	73.23	2.52	100.20	3.04	215.14	3.52	388.63	3.67	461.02
.0500	20.0	1.49	11.72	1.96	34.71	2.38	74.75	2.57	102.27	3.11	219.58	3.59	396.66	3.74	470.54
.0550	18.2	1.57	12.29	2.06	36.40	2.50	78.41	2.70	107.27	3.26	230.32	3.77	416.05	3.93	493.55
.0600	16.7	1.64	12.84	2.15	38.03	2.61	81.90	2.82	112.05	3.40	240.58	3.93	434.58	4.10	515.53
.0650	15.4	1.70	13.37	2.24	39.59	2.71	85.25	2.93	116.64	3.54	250.42	4.10	452.35	4.27	536.61
.0700	14.3	1.77	13.88	2.32	41.08	2.82	88.48	3.04	121.05	3.68	259.89	4.25	469.45	4.43	556.89
.0750	13.3	1.83	14.36	2.41	42.53	2.92	91.59	3.15	125.31	3.81	269.03	4.40	485.95	4.59	576.47
.0800	12.5	1.89	14.84	2.49	43.93	3.01	94.60	3.26	129.42	3.93	277.87	4.54	501.91	4.74	595.40
.0850	11.8	1.95	15.29	2.56	45.28	3.10	97.52	3.36	133.41	4.05	286.43	4.68	517.38	4.88	613.75
.0900	11.1	2.00	15.74	2.64	46.60	3.19	100.35	3.45	137.29	4.17	294.75	4.82	532.40	5.03	631.56
.0950	10.5	2.06	16.17	2.71	47.88	3.28	103.11	3.55	141.06	4.28	302.84	4.95	547.01	5.16	648.89

Nominal Bore mm		450		500		600		700		800		900		1000	
Hydraulic Gradient	1 in	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s	velocity m/s	discharge l/s
.0010	1000.0	0.57	90.06	0.61	119.04	0.68	192.80	0.75	289.66	0.82	411.96	0.88	561.88	0.94	741.52
.0011	909.1	0.59	94.50	0.64	124.91	0.72	202.29	0.79	303.91	0.86	432.21	0.93	589.49	0.99	777.93
.0012	833.3	0.62	98.75	0.66	130.51	0.75	211.35	0.83	317.52	0.90	451.55	0.97	615.86	1.03	812.73
.0013	769.2	0.65	102.82	0.69	135.89	0.78	220.05	0.86	330.57	0.94	470.11	1.01	641.16	1.08	846.10
.0014	714.3	0.67	106.73	0.72	141.06	0.81	228.42	0.89	343.14	0.97	487.97	1.05	665.51	1.12	878.22
.0015	666.7	0.69	110.51	0.74	146.05	0.84	236.49	0.92	355.26	1.01	505.20	1.08	689.00	1.16	909.20
.0016	625.0	0.72	114.16	0.77	150.88	0.86	244.30	0.95	366.99	1.04	521.86	1.12	711.71	1.20	939.17
.0017	588.2	0.74	117.71	0.79	155.56	0.89	251.87	0.98	378.35	1.07	538.02	1.15	733.73	1.23	968.22
.0018	555.6	0.76	121.14	0.82	160.10	0.92	259.22	1.01	389.38	1.10	553.70	1.19	755.12	1.27	996.42
.0019	526.3	0.78	124.49	0.84	164.52	0.94	266.37	1.04	400.12	1.13	568.95	1.22	775.91	1.30	1023.86
.0020	500.0	0.80	127.75	0.86	168.82	0.97	273.34	1.07	410.57	1.16	583.81	1.25	796.16	1.34	1050.58
.0022	454.5	0.84	134.03	0.90	177.12	1.01	286.76	1.12	430.72	1.22	612.45	1.31	835.21	1.40	1102.08
.0024	416.7	0.88	140.03	0.94	185.05	1.06	299.58	1.17	449.97	1.27	639.82	1.37	872.51	1.47	1151.29
.0026	384.6	0.92	145.79	0.98	192.65	1.10	311.88	1.22	468.44	1.33	666.06	1.43	908.30	1.53	1198.49
.0028	357.1	0.95	151.32	1.02	199.97	1.14	323.72	1.26	486.21	1.38	691.32	1.48	942.73	1.58	1243.91
.0030	333.3	0.99	156.67	1.05	207.02	1.19	335.14	1.31	503.35	1.42	715.69	1.53	975.95	1.64	1287.74
.0032	312.5	1.02	161.84	1.09	213.85	1.22	346.19	1.35	519.94	1.47	739.26	1.58	1008.08	1.69	1330.12
.0034	294.1	1.05	166.85	1.12	220.47	1.26	356.89	1.39	536.01	1.52	762.10	1.63	1039.22	1.75	1371.20
.0036	277.8	1.08	171.71	1.16	226.89	1.30	367.29	1.43	551.61	1.56	784.28	1.68	1069.46	1.80	1411.09
.0038	263.2	1.11	176.44	1.19	233.14	1.33	377.40	1.47	566.79	1.60	805.86	1.73	1098.87	1.85	1449.89
.0040	250.0	1.14	181.05	1.22	239.23	1.37	387.25	1.51	581.58	1.65	826.87	1.77	1127.51	1.89	1487.67
.0042	238.1	1.17	185.54	1.25	245.17	1.40	396.85	1.55	596.00	1.69	847.36	1.82	1155.45	1.94	1524.53
.0044	227.3	1.19	189.93	1.28	250.96	1.44	406.23	1.59	610.07	1.73	867.38	1.86	1182.73	1.99	1560.52
.0046	217.4	1.22	194.22	1.31	256.63	1.47	415.40	1.62	623.84	1.76	886.94	1.90	1209.40	2.03	1595.69
.0048	208.3	1.25	198.42	1.34	262.18	1.50	424.37	1.66	637.30	1.80	906.08	1.94	1235.49	2.08	1630.12
.0050	200.0	1.27	202.53	1.36	267.61	1.53	433.15	1.69	650.49	1.84	924.82	1.98	1261.05	2.12	1663.83
.0055	181.8	1.34	212.46	1.43	280.72	1.61	454.38	1.77	682.36	1.93	970.11	2.08	1322.78	2.22	1745.27
.0060	166.7	1.40	221.95	1.49	293.26	1.68	474.66	1.85	712.80	2.02	1013.38	2.17	1381.77	2.32	1823.08
.0065	153.8	1.45	231.05	1.55	305.28	1.75	494.11	1.93	742.00	2.10	1054.88	2.26	1438.35	2.42	1897.72
.0070	142.9	1.51	239.81	1.61	316.85	1.81	512.82	2.00	770.10	2.18	1094.82	2.35	1492.79	2.51	1969.53
.0075	133.3	1.56	248.26	1.67	328.01	1.88	530.88	2.07	797.21	2.25	1133.35	2.43	1545.32	2.60	2038.82
.0080	125.0	1.61	256.43	1.73	338.81	1.94	548.35	2.14	823.43	2.33	1170.62	2.51	1596.13	2.68	2105.84
.0085	117.6	1.66	264.36	1.78	349.27	2.00	565.28	2.21	848.84	2.40	1206.74	2.59	1645.37	2.76	2170.80
.0090	111.1	1.71	272.05	1.83	359.43	2.06	581.72	2.27	873.52	2.47	1241.81	2.66	1693.18	2.84	2233.87
.0095	105.3	1.76	279.53	1.88	369.31	2.11	597.70	2.33	897.52	2.54	1275.92	2.73	1739.68	2.92	2295.22
.0100	100.0	1.80	286.82	1.93	378.94	2.17	613.27	2.39	920.89	2.60	1309.15	2.81	1784.98	3.00	2354.96
.0110	90.9	1.89	300.86	2.02	397.49	2.28	643.29	2.51	965.95	2.73	1373.20	2.94	1872.29	3.15	2470.14
.0120	83.3	1.98	314.28	2.11	415.22	2.38	671.97	2.62	1009.01	2.85	1434.39	3.07	1955.71	3.29	2580.19
.0130	76.9	2.06	327.15	2.20	432.22	2.47	699.48	2.73	1050.30	2.97	1493.08	3.20	2035.72	3.42	2685.74
.0140	71.4	2.13	339.54	2.28	448.58	2.57	725.95	2.83	1090.04	3.08	1549.56	3.32	2112.72	3.55	2787.30
.0150	66.7	2.21	351.49	2.37	464.37	2.66	751.49	2.93	1128.38	3.19	1604.06	3.44	2187.00	3.67	2885.30
.0160	62.5	2.28	363.05	2.44	479.63	2.75	776.19	3.03	1165.46	3.30	1656.76	3.55	2258.85	3.79	2980.08
.0170	58.8	2.35	374.25	2.52	494.43	2.83	800.13	3.12	1201.40	3.40	1707.84	3.66	2328.49	3.91	3071.94
.0180	55.6	2.42	385.13	2.59	508.80	2.91	823.37	3.21	1236.30	3.50	1757.45	3.77	2396.11	4.02	3161.14
.0190	52.6	2.49	395.71	2.66	522.78	2.99	845.98	3.30	1270.24	3.59	1805.69	3.87	2461.88	4.14	3247.89
.0200	50.0	2.55	406.01	2.73	536.39	3.07	868.01	3.39	1303.30	3.69	1852.67	3.97	2525.93	4.24	3332.39
.0220	45.5	2.68	425.88	2.87	562.63	3.22	910.46	3.55	1367.03	3.87	1943.25	4.16	2649.41	4.45	3495.27
.0240	41.7	2.80	444.86	2.99	587.70	3.36	951.02	3.71	1427.92	4.04	2029.79	4.35	2767.39	4.65	3650.91
.0260	38.5	2.91	463.06	3.12	611.74	3.50	989.92	3.86	1486.32	4.20	2112.80	4.53	2880.55	4.84	3800.18
.0280	35.7	3.02	480.58	3.23	634.88	3.63	1027.35	4.01	1542.52	4.36	2192.67	4.70	2989.43	5.02	3943.81
.0300	33.3	3.13	497.48	3.35	657.21	3.76	1063.47	4.15	1596.74	4.52	2269.74	4.86	3094.49	5.20	4082.40
.0320	31.2	3.23	513.83	3.46	678.80	3.88	1098.40	4.29	1649.18	4.66	2344.28	5.02	3196.10	5.37	4216.44
.0340	29.4	3.33	529.67	3.56	699.72	4.00	1132.26	4.42	1700.01	4.81	2416.52	5.18	3294.58	5.53	4346.36
.0360	27.8	3.43	545.05	3.67	720.05	4.12	1165.14	4.55	1749.36	4.95	2486.67	5.33	3390.21	5.69	4472.50
.0380	26.3	3.52	560.02	3.77	739.81	4.23	1197.11	4.67	1797.36	5.08	2554.89	5.48	3483.22	5.85	4595.19
.0400	25.0	3.61	574.59	3.87	759.06	4.34	1228.26	4.79	1844.11	5.21	2621.34	5.62	3573.81	6.00	4714.69
.0420	23.8	3.70	588.80	3.96	777.83	4.45	1258.63	4.91	1889.71	5.34	2686.15	5.76	3662.16	6.15	4831.24
.0440	22.7	3.79	602.68	4.05	796.17	4.56	1288.29	5.03	1934.24	5.47	2749.44	5.89	3748.43	6.30	4945.04
.0460	21.7	3.87	616.25	4.15	814.09	4.66	1317.28	5.14	1977.76	5.59	2811.30	6.02	3832.76	6.44	5056.29
.0480	20.8	3.96	629.52	4.24	831.62	4.76	1345.65	5.25	2020.35	5.71	2871.83	6.15	3915.28	6.58	5165.14
.0500	20.0	4.04	642.52	4.32	848.79	4.86	1373.43	5.36	2062.06	5.83	2931.11	6.28	3996.09	6.71	5271.75
.0550	18.2	4.24	673.93	4.53	890.28	5.09	1440.55	5.62	2162.82	6.12	3074.32	6.59	4191.33	7.04	5529.29
.0600	16.7	4.43	703.94	4.74	929.92	5.32	1504.69	5.87	2259.10	6.39	3211.16	6.88	4377.87	7.35	5775.37
.0650	15.4	4.61	732.73	4.93	967.94	5.54	1566.20	6.11	2351.44	6.65	3342.41	7.16	4556.79	7.65	6011.39
.0700	14.3	4.78	760.42	5.12	1004.53	5.75	1625.38	6.34	2440.29	6.90	3468.70	7.43	4728.95	7.94	6238.50
.0750	13.3	4.95	787.14	5.30	1039.83	5.95	1682.49	6.56	2526.02	7.14	3590.55	7.69	4895.07	8.22	6457.62
.0800	12.5	5.11	812.99	5.47	1073.97	6.15	1737.73	6.78	2608.94	7.38	3708.40	7.95	5055.73	8.49	6669.56
.0850	11.8	5.27	838.04	5.64	1107.06	6.34	1791.26	6.99	2689.31	7.60	3822.63	8.19	5211.45	8.75	6874.98
.0900	11.1	5.42	862.37	5.80	1139.19	6.52	1843.24	7.19	2767.34	7.83	3933.54	8.43	5362.65	9.01	7074.43
.0950	10.5	5.57	886.02	5.96	1170.43	6.70	1893.80	7.39	2843.24	8.04	4041.42	8.66	5509.70	9.25	7268.42

Table B7 – Proportional velocities and discharges in pipes running part full

Proportional Depth	Proportion of full-bore values	
	Velocity	Discharge
0.02	0.128	0.001
0.04	0.213	0.003
0.06	0.283	0.007
0.08	0.345	0.013
0.10	0.400	0.021
0.12	0.450	0.031
0.14	0.496	0.042
0.16	0.539	0.056
0.18	0.580	0.071
0.20	0.618	0.088
0.22	0.654	0.107
0.24	0.688	0.127
0.26	0.720	0.149
0.28	0.750	0.172
0.30	0.779	0.197
0.35	0.846	0.264
0.40	0.904	0.338
0.45	0.955	0.417
0.50	1.000	0.500
0.55	1.038	0.585
0.60	1.071	0.671
0.65	1.097	0.755
0.70	1.117	0.835
0.75	1.130	0.909
0.80	1.136	0.974
0.85	1.134	1.027
0.90	1.121	1.063
0.95	1.092	1.072

The values in this table have been extracted from Tables 35 and 36 of Hydraulics Research.
Tables for the Hydraulic Design of Pipes and Sewers, Fifth Edition, H.M.S.O. 1990.

Appendix C

General guidance on resistance to chemicals of vitrified clay pipes, fittings and joints to chemicals in effluents and contaminated ground

Introduction

Vitrified clay pipes, fittings and joints specified to BS EN 295-1[3] can carry all effluents acceptable to a sewage treatment works. They are unaffected by the acid conditions resulting from the presence of hydrogen sulphide in sewers and they can be safely laid in ground containing aggressive materials, such as sulphates. Pipes, fittings and joints will resist both effluents and groundwaters over the pH range 2-12 at the average temperatures found in public sewers in the UK of between 14° C and 19° C.

Most of the effluents emanating from general industry, garages, hospitals, laboratories, chemical works and other sources can be carried without damage. In some cases it may be necessary to select the materials from which the joints and seals are made, using the information given in the table in this appendix.

Service Conditions

In order to determine the pipe and joint system requirements, the actual service conditions should be examined, particularly in respect of the constituents, concentration, temperature and rate of discharge.

The chemical constituents of the effluent and surrounding ground or groundwater should be identified by their recognised chemical names rather than trade names, unless full details of their composition are known. Account should also be taken of the results of mixing the constituents.

Subsequent changes to plant or effluent content may produce different conditions to those designed for, and the system performance should then be re-assessed.

Concentration

For reference purposes the concentration of chemical constituents are best expressed as percentages, either as weight/volume (w/v) for solid in solution, volume/volume (v/v) for liquid in solution or weight/weight (w/w) for solid contamination. A pH level is also a useful guide when conditions are alkaline or acid.

The range of concentrations of discharges, including the accidental discharge of raw chemicals, should be considered along with the dilution of effluent by water. Where concentrated chemical effluents are encountered, they should, where possible be diluted before entering the drainage system. Some chemicals, such as hydrocarbons, are however not readily miscible with water unless deliberately agitated.

Temperature

The temperature of the effluent at the point at which it will enter the drainage system should be considered. This is necessary because, generally, the higher the temperature, the more reactive the chemicals will be. Hot chemical effluents should, where possible, be cooled before entering the drainage system. Where the temperature of the effluent remains in excess of 85° C for long periods of time, the manufacturer's advice should be sought on the effect of sustained high temperatures on the jointing materials. It should be noted that the information given in the Table is for effluent at 20° C.

If resin cement mortar joints are to be subjected to effluent temperatures greater than 50° C, the pipeline should be surrounded with a minimum thickness of 150 mm of concrete.

Thermal Shock

Whilst clay pipes can easily carry liquids at sustained high temperatures, a very rapid rise in internal temperature should be avoided in order to prevent a steep temperature gradient between the inside and outside of the pipe. Even more importantly, a clay pipeline carrying a hot effluent should not be suddenly cooled by a very large drop in effluent temperature.

It should be noted that effluent temperatures can be suddenly raised by plant 'wash-down', boiler 'blow-down' or by the discharge of an additional hot effluent. It may be appropriate to install a temperature equalisation tank to reduce such sudden changes in temperature.

Rate of Discharge

The volume of effluent, period of flow, frequency of discharge and likely retention time in the pipeline should be taken into consideration because of their effects on concentration and temperature at any pipeline position.

Caustic Soda and Hydrofluoric Acid

Vitrified clay pipes, factory jointed or unjointed, are known to be damaged by continuous exposure to hydrofluoric acid, hydrofluorsilic acid or hot concentrated caustic soda (sodium hydroxide). Therefore, they are not suitable for the continuous conveyance of these chemicals which have been known to cause damage to clay pipes with undiluted flows over extended periods.

Chemicals in the Ground

Ground conditions as well as effluents have to be considered, to check the suitability of pipes and joints. Many soils contain sulphates which are harmful to concrete and cement mortar, but which do no harm to clay pipes or normal flexible joints.
In many redevelopment areas the ground contains corrosive chemical residues from past activities on the site, such as old gas works. In these cases, checks should be made for the presence of harmful chemicals, particularly organic compounds, normally indicated by toluene extraction data.

Most of these chemical residues, which may attack some pipe joint materials complying with BS EN 295-1, are indicated in the Table.

Often, such redevelopment areas have structurally weak ground conditions. It is then necessary to lay a flexibly jointed pipeline to cope with anticipated ground movement, rather than use a rigid resin cement mortar joint. In particularly soft ground conditions it may be necessary to apply the method of construction given in Technical Note No. 1. Standard flexible joints can be protected from chemical attack in this situation by removing the contaminated ground or by wrapping them in protective tape or other suitable material. One type of protection with a high degree of strength and adhesion to the pipe is made from irradiated stretched polyethylene to BS EN 295-4 [34] which is heat-shrunk on to the pipes over the jointing area. It is available either as a sleeve, which can be placed over the pipes as they are laid, or as a wrap, which can be applied after laying. The resistance of this polyethylene to the chemicals present must be checked before use.

Subsequent Changes to Effluent Discharge

Subsequent changes to the effluent or to its temperature may produce different conditions to those for which the pipeline has been designed. The system performance should then be re-assessed.

Conclusion

Most chemical effluent and aggressive soil conditions can be successfully dealt with by flexibly jointed clay pipe systems specified to BS EN 295-1. In a few cases however, appropriate jointing materials or protection should be chosen from the available materials to avoid corrosion. The following table indicates where special care should be taken when sufficient knowledge exists of the chemicals likely to be encountered.

The following table gives guidance on the resistance of vitrified clay pipes, sealing rings and jointing materials to a wide variety of chemicals.

Where the symbol '**R**' appears for a material, it indicates that the material will resist long term exposure to the chemical up to a temperature of at least 20 ° C and up to any strength of solution unless otherwise specified.

The symbol '**E**' indicates that specialist advice should be sought from the pipe or joint manufacturer before the pipes are exposed to the chemical listed.

The symbol '**U**' indicates that the material is unsuitable for continuous exposure to that chemical.

The symbol '**ND**' indicates that there is no relevant published data and therefore further advice should be sought.

From the information given in the Table it is usually possible to select a pipe, joint material and sealing ring combination specified to BS EN 295-1. Where this is not the case, it is usually the joint material or sealing ring that is not suitable. If a suitable combination of the listed jointing materials from BS EN 295 cannot be found, normal or extra chemically resistant pipes, as appropriate, to BS 65 : 1991 [4] may be used with special jointing compounds.

The materials for joint rings and joint materials are coded as follows:-

SBR = Styrene-butadiene rubber

EPDM = Ethylene-propylene-diene modified

NBR = Nitrile-butadiene rubber

PP = Polypropylene

General guidance table

Chemical	Vitrified	Joint Rings			Joint Materials	
	Clay Pipes	SBR	EPDM	NBR	Polyester	PP
Acetaldehyde	R	E	R	E	E	E
Acetamide	R	U	R	R	ND	R
Acetic acid (10%)	R	R	R	R	R	R
Acetic Acid (glacial)	R	E	R	E	E	R
Acetic Anhydride	R	U	E	U	U	R
Acetone	R	E	R	E	E	R
Acetophenone	R	U	R	U	U	R
Acetyl Chloride	R	U	U	U	U	ND
Acetyl Salicylic Acid	R	R	R	R	R	R
Adipic Acid	R	ND	R	R	R	R
Alcohols (most fatty)	R	R	R	R	R	R
Aliphatic Esters	R	E	R	E	E	E
Alkazene	R	U	U	U	ND	ND
Allyl Alcohol	R	ND	ND	ND	ND	R
Alum	R	R	R	R	R	R
Aluminium Acetate	R	E	R	R	R	R
Aluminium Chloride	R	E	R	R	R	R
Aluminium Fluoride	R	R	R	R	R	R
Aluminium Hydroxide	R	R	R	R	R	R
Aluminium Nitrate	R	R	R	R	R	R
Aluminium Phosphate	R	R	R	R	R	R
Aluminium Sulphate	R	R	R	R	R	R
Ammonium Acetate	R	E	R	E	R	R
Ammonium Bicarbonate	R	R	R	E	R	R
Ammonium Carbonate	R	R	R	E	R	R
Ammonium Chloride	R	R	R	R	R	R
Ammonium Fluoride	R	E	R	E	R	R
Ammonium Hydroxide	R	E	R	E	E	R
Ammonium Nitrate	R	R	R	R	R	R
Ammonium Persulphate	R	E	R	E	R	R
Ammonium Phosphate	R	R	R	R	R	R
Ammonium Sulphate	R	E	R	R	R	R
Ammonium Sulphide	R	E	R	R	R	R
Amyl Acetate	R	U	R	U	U	E
Amyl Alcohol	R	U	R	U	R	R
Aniline	R	U	E	U	U	R
Aniline Hydrochloride	R	U	E	U	ND	U
Antimony Trichloride	R	R	R	ND	E	R
Arsenic Acid	R	R	R	R	R	R
Barium Carbonate	R	R	R	R	R	R
Barium Chloride	R	R	R	R	R	R
Barium Hydroxide	R	R	R	R	R	R
Barium Nitrate	R	R	R	R	R	R
Barium SulphateR	R	R	R	R	R	
Beer	R	R	R	R	R	R
Benzaldehyde	R	U	R	U	U	E
Benzene	R	U	U	U	U	U
Benzoic Acid	R	U	U	U	R	R
Benzyl Alcohol	R	U	E	U	U	E
Benzyl Chloride	R	U	U	U	U	ND

Chemical	Vitrified Clay Pipes	Joint Rings SBR	Joint Rings EPDM	Joint Rings NBR	Joint Materials Polyester	Joint Materials PP
Borax	R	E	R	R	R	R
Boric Acid	R	R	R	R	R	R
Brake Fluid	R	R	R	U	U	R
Brines (saturated)	R	R	R	R	R	R
Bromine	R	U	U	U	U	U
Bromobenzene	R	U	U	U	ND	U
Bromoform	R	ND	ND	ND	ND	U
Butadiene	R	U	E	U	ND	E
Butanol	R	R	R	R	R	R
Butyl Acetate	R	U	E	U	ND	R
Butyl Alcohol	R	R	R	R	R	R
Butyl Chloride	R	ND	ND	ND	ND	U
Butyric Acid	R	E	E	E	ND	E
Calcium Acetate	R	E	R	E	R	R
Calcium Carbonate	R	R	R	R	R	R
Calcium Chloride	R	R	R	R	R	R
Calcium Hydroxide (saturated aqueous)	R	R	R	R	R	R
Calcium Hypochlorite	R	E	R	E	R	R
Calcium Nitrate	R	R	R	R	R	R
Carbon Disulphide	R	U	U	U	U	E
Carbonic Acid	R	R	R	R	R	R
Carbon Tetrachloride	R	U	U	U	R	U
Castor Oil	R	R	U	R	R	R
Chloroacetic Acid	R	E	E	E	E	ND
Chlorobenzene	R	U	U	U	U	U
Chlorobutane	R	ND	ND	U	U	ND
Chloroform	R	U	U	E	E	U
Chlorosulphuric Acid	R	U	U	U	U	U
Chromic Acid (dilute)	R	R	R	R	R	R
Chromic Acid (higher concentrations)	E	E	E	E	E	E
Chromium Sulphate	R	R	R	R	R	R
Chromium Trioxide	R	E	E	E	ND	ND
Cider	R	R	R	R	R	R
Citric Acid	R	R	R	R	R	R
Cobalt Chloride	R	R	R	R	R	R
Cod Liver Oil	R	U	R	R	R	R
Copper Acetate	R	E	R	E	R	R
Copper Chloride	R	R	R	R	R	R
Copper Fluoride	R	R	R	R	R	R
Copper Nitrate	R	R	R	R	R	R
Copper Sulphate	R	E	R	R	R	R
Corn Oil	R	U	U	R	R	U
Creosote	R	U	U	R	ND	R
Cresylic Acid	R	U	U	U	U	ND
Crude Oil	R	U	U	U	ND	ND
Cuprous Chloride	R	R	R	R	R	R
Cutting Oil	R	U	U	R	R	R
Cyclohexane	R	U	U	R	R	U
Detergents (conc.)	R	E	R	R	R	R
Dibutyl Phthalate	R	U	E	U	ND	R
Dichloroethylene	R	ND	ND	ND	ND	U
Diesel Oil	R	U	U	R	R	R
Diethylamine	R	U	E	E	U	ND
Diethyl Ketone	R	ND	ND	ND	U	R
Dimethyl Aniline	R	U	U	U	U	ND
Diethylaniline	R	ND	ND	U	U	ND
Ether	R	E	E	E	E	E
Ethyl Acetate	R	E	R	E	E	E
Ethyl Alcohol	R	R	R	R	E	R
Ethyl Benzene	R	U	U	U	ND	U
Ethylene Dichloride	R	U	E	U	U	ND
Ethylene Glycol	R	R	R	R	R	R
Ethylene Oxide Liquor	R	E	E	E	E	E
Fatty Acids	R	E	E	R	R	R
Ferric Acetate	R	E	R	E	ND	ND

Chemical	Vitrified Clay Pipes	Joint Rings SBR	Joint Rings EPDM	Joint Rings NBR	Joint Materials Polyester	Joint Materials PP
Ferric Chloride	R	R	R	R	R	R
Ferric Nitrate	R	R	R	R	R	R
Ferric Sulphate	R	R	R	R	R	R
Ferrous Chloride	R	R	R	R	R	R
Ferrous Nitrate	R	R	R	R	R	R
Ferrous Sulphate	R	R	R	R	R	R
Fish Oil	R	U	U	R	R	R
Formaldehyde	R	R	R	R	R	R
Formic Acid	R	R	R	E	R	R
Furfural	R	U	E	U	U	U
Fruit Juices	R	R	R	R	R	R
Fuel Oil	R	U	U	R	R	R
Furfuryl Alcohol	R	U	U	U	ND	ND
Gallic Acid	R	E	E	E	ND	ND
Gelatine	R	R	R	R	R	R
Glucose	R	R	R	R	R	R
Glycerine/Glycerol	R	R	R	R	R	R
Glycols	R	R	R	R	R	R
Glycollic Acid	R	ND	R	ND	ND	ND
Heptane (C_7H_{16})	R	U	U	R	ND	U
Hexamine	R	R	ND	U	ND	ND
Hexane (C_6H_{14})	R	U	U	R	R	R
Hydraulic Oil	R	U	U	R	R	R
Hydrazine	R	E	R	R	ND	E
Hydrobromic Acid	R	E	R	E	R	R
Hydrochloric Acid (dilute)	R	R	R	R	R	R
Hydrochloric Acid (higher concentrations)	E	E	E	E	E	E
Hydrocyanic Acid	R	R	R	R	R	R
Hydrofluoric Acid	U	U	E	U	U	E
Hydrofluosilicic Acid	U	ND	R	R	ND	ND
Hydrogen Peroxide	R	R	E	R	E	R
Hydrogen Sulphide	R	R	R	R	R	R
Hydroquinone	R	E	E	E	E	E
Iodine Solution	R	E	E	E	E	R
Isobutyl Alcohol	R	U	R	U	R	R
Isopropanol	R	E	R	E	ND	R
Iso-octane	R	U	U	R	ND	U
Kerosene	R	U	U	R	R	U
Lactic Acid	R	R	R	R	R	R
Lanolin (wool fat)	R	ND	ND	ND	ND	R
Lead Acetate	R	R	R	E	R	R
Lead Chloride	R	R	R	R	R	R
Lead Nitrate	R	R	R	R	R	R
Lead Sulphate	R	R	R	R	R	R
Linseed Oil	R	U	E	R	R	R
Lubricating Oils	R	U	U	R	R	R
Magnesium Bicarbonate	R	R	R	R	R	R
Magnesium Carbonate	R	R	R	R	R	R
Magnesium Chloride	R	R	R	R	R	R
Magnesium Hydroxide	R	R	R	R	R	R
Magnesium Nitrate	R	R	R	R	R	R
Magnesium Perchlorate	R	R	R	R	R	R
Magnesium Sulphate	R	R	R	R	R	R
Malic Acid	R	E	E	R	ND	R
Maleic Acid	R	U	U	U	R	R
Meat Juices	R	R	R	R	R	R
Mercuric Chloride	R	R	R	R	R	R
Mercury	R	R	R	R	R	R
Methyl Alcohol	R	R	R	R	E	R
Methylated Spirit	R	R	R	R	E	R
Methyl Ethyl Ketone	R	U	R	U	U	R
Methyl-iso-butyl Ketone	R	U	E	U	U	R
Methylamine (aqueous)	R	R	R	E	ND	ND
Methylene Chloride	R	U	U	U	U	U
Methyl Salicylate	R	U	E	U	ND	ND

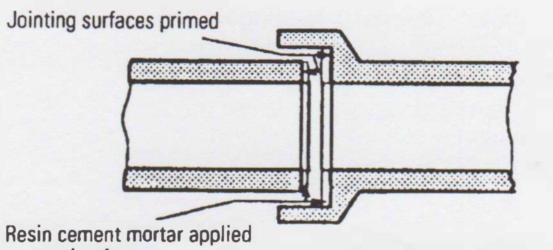
Chemical	Vitrified	Joint Rings			Joint Materials	
	Clay Pipes	SBR	EPDM	NBR	Polyester	PP
Milk and its products	R	R	R	R	R	R
Molasses	R	R	R	R	R	R
Naphtha	R	U	U	R	R	E
Napthalene	R	U	U	U	R	E
Nickel Acetate	R	E	R	E	R	R
Nickel Chloride	R	R	R	R	R	R
Nickel Nitrate	R	R	R	R	R	R
Nickel Sulphate	R	R	R	R	R	R
Nicotine Sulphate	R	ND	ND	ND	ND	R
Nitric Acid dilute	R	E	R	E	R	R
Nitric Acid (higher concentrations)	E	U	E	U	E	E
Nitrobenzene	R	U	U	U	U	U
Oleic Acid	R	U	E	U	ND	R
Oil (mineral)	R	U	U	R	R	E
Oil (veg and animal)	R	E	E	R	R	R
Olive Oil	R	U	U	R	R	R
Oxalic Acid	R	E	R	E	R	R
Palmitic Acid	R	U	U	R	ND	R
Paraffin	R	U	U	R	R	U
Paraffin Wax	R	R	R	R	R	R
Perchloric Acid (dilute)	R	E	R	E	R	R
Perchloric Acid (higher concentrations)	E	U	E	U	E	E
Petroleum	R	U	U	R	E	E
Petroleum Ether	R	U	U	R	U	R
Phenol	R	U	U	U	U	R
Phenylhydrazine	R	U	E	U	ND	ND
Phosphoric Acid (dilute)	R	R	R	R	R	R
Phosphoric Acid (higher concentrations)	E	E	E	E	E	E
Phosphorus Chlorides	R	U	U	U	U	ND
Phthalic Acid	R	R	E	R	R	R
Picric Acid	R	U	E	U	U	U
Potassium Acetate	R	E	R	E	R	R
Potassium Bisulphate	R	E	R	R	R	R
Potassium Borate	R	R	R	R	R	R
Potassium Bromide	R	R	R	R	R	R
Potassium Chlorate	R	R	R	R	R	R
Potassium Chloride	R	R	R	R	R	R
Potassium Chromate	R	R	R	R	R	R
Potassium Cyanide	R	R	R	R	R	R
Potassium Dichromate	R	R	R	R	R	R
Potassium Hydroxide (dilute)	R	R	R	R	R	R
Potassium Hydroxide (higher concentrations)	E	R	R	E	E	R
Potassium Nitrate	R	R	R	R	R	R
Potassium Perchlorate	R	R	R	R	R	R
Potassium Permanganate	R	E	R	E	R	R
Potassium Sulphate	R	R	R	R	R	R
Potassium Persulphate	R	R	R	R	R	ND
Iso-Propanol	R	E	R	E	ND	R
Propionic Acid	R	ND	R	ND	ND	R
Pyridine	R	E	E	E	E	R
Rapeseed Oil	R	U	R	U	R	R
Quinoline	R	ND	ND	ND	ND	R
Sal Ammoniac	R	R	R	R	R	R
Salicylic Acid	R	E	R	E	R	R
Sea Water	R	R	R	R	R	R
Silicic Acid	R	R	R	R	R	R
Silicone Fluids	R	ND	R	R	R	R
Silver Nitrate	R	R	R	R	R	R
Sodium Acetate	R	E	R	E	R	R
Sodium Benzoate	R	ND	R	R	ND	R
Sodium Bicarbonate	R	R	R	R	R	R
Sodium Bisulphate	R	E	R	R	R	R
Sodium Borate	R	R	R	R	R	R
Sodium Bromide	R	R	R	R	R	R
Sodium Carbonate	R	R	R	R	R	R
Sodium Chlorate	R	R	R	R	R	R
Sodium Chloride	R	R	R	R	R	R
Sodium Cyanide	R	R	R	R	R	R
Sodium Dichromate	R	R	R	R	R	R
Sodium Ferricyanide	R	ND	R	R	R	R
Sodium Fluoride	R	ND	ND	ND	ND	R
Sodium Hydroxide (dilute)	R	R	R	R	R	R
Sodium Hydroxide (higher concentrations)	E	R	R	E	E	R
Sodium Hypochlorite	R	E	R	E	E	E
Sodium Metaphosphate	R	R	R	R	R	R
Sodium Nitrate	R	R	R	R	R	R
Sodium Perborate	R	E	R	E	R	R
Sodium Phosphate	R	R	R	R	R	R
Sodium Silicate	R	R	R	R	R	R
Sodium Sulphate	R	R	R	R	R	R
Sodium Sulphide	R	E	R	R	R	R
Sodium Tetraborate	R	E	R	E	R	R
Sodium Thiosulphate	R	E	R	E	R	R
Stannic Chloride	R	R	E	R	R	R
Stannous Chloride	R	R	E	R	R	R
Starch	R	R	R	R	R	R
Stearic Acid	R	R	R	R	R	R
Styrene	R	U	U	U	U	ND
Succinic Acid	R	E	ND	R	R	R
Sugar, Syrup, Jam	R	R	R	R	R	R
Sulphamic Acid	R	ND	R	ND	ND	ND
Sulphites	R	R	R	R	R	R
Sulphonic Acids	R	ND	E	ND	R	ND
Sulphur	R	E	R	E	R	R
Sulphuric Acid (dilute)	R	R	R	R	R	R
Sulphuric Acid (higher concentrations)	E	E	E	E	E	E
Sulphur Chlorides	R	U	U	U	ND	ND
Sulphurous Acid R	E	E	E	E	E	
Tannic Acid	R	R	R	R	R	R
Tannic Liquors	R	ND	ND	ND	ND	R
Tartaric Acid	R	E	E	R	R	R
Tetrahydrofuran	R	U	E	U	R	U
Tetrahydronaphthalene	R	U	U	U	U	U
Thionyl Chloride	R	ND	U	ND	U	U
Toluene	R	U	U	U	U	U
Transformer Oil	R	U	U	R	R	R
Trichlorethylene	R	U	U	U	U	E
Trichloroacetic Acid	R	E	E	E	ND	E
Tricresyl Phosphate	R	U	R	U	ND	ND
Triethanolamine	R	U	E	U	ND	R
Turpentine Oil	R	U	U	R	R	U
Urine	R	R	R	R	R	R
Urea (aqueous)	R	R	R	R	R	R
Vinegar	R	R	R	R	R	R
White Spirit	R	U	U	R	R	E
Xylene	R	U	U	U	U	U
Yeast	R	R	R	R	R	R
Zinc Acetate	R	E	R	E	R	R
Zinc Chloride	R	R	R	R	R	R
Zinc Nitrate	R	R	R	R	R	R
Zinc Stearate	R	R	R	R	R	R
Zinc Sulphate	R	E	R	R	R	R

R - Resistant up to 20 ° C **E - Seek expert advice** **U - Unsuitable** **ND - No Data**

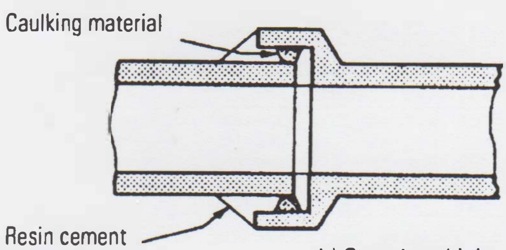
Resin Cement Mortar Joints

A number of proprietary chemically resistant mortars are available which can be used where factory-made joints are not suitable. These are generally based on furane resin cements, although other resins are also available. These jointing materials are used with normal or extra chemically resistant pipes specified to BS 65 : 1991 [4]. They produce a rigid joint so the pipeline must therefore be bedded on concrete. Full details of concrete beddings for vitrified clay pipes are given in the Construction section of this booklet.

The configuration of a typical chemically resistant mortar joint is illustrated in Figure 1. Specialist contractors are usually employed to joint pipes with these materials and detailed jointing instructions are available from the joint material manufacturers.



a) First stage in jointing.



b) Completed joint.

Figure C1 - Typical resin cement joint

Jointing procedure
The normal requirements and sequence of operations for jointing with resin cement mortars are given here as a guide. The specific requirements for any material used should always be confirmed with the material supplier.

1. The pipes should be checked for soundness before use by visual examination. They should also be tapped lightly with a hammer, which should produce a clear ringing tone if the pipe is not cracked. Any suspect pipes must be rejected.

2. The spigot and socket jointing faces must be clean and dry before the pipes can be properly jointed. In wet conditions the jointing area should be covered over and any wet jointing face wiped and then dried with warm air from a blower or a flame. When using a flame, care should be taken to avoid the danger of cracking the pipes by the sudden application of high temperature. The pipe should be allowed to cool before jointing is commenced. Drying must be thorough as latent moisture within the pipe body can prevent resin cements curing.

3. The pipes should be firmly supported, both during and after the jointing process so that no movement can take place.

4. Any glaze on the jointing surfaces should first be removed by wire brushing or grinding. All dust should be removed and a check made for cracks in the area of the joint. The recommended primer should then be applied, usually a weak mixture of the resin cement mortar, and allowed to become tacky, but not dry.

5. The face of the socket and the end of the adjacent spigot should be spread with resin cement mortar and the spigot pushed home into the socket, making sure that both pipes remain firmly supported.

6. About half the depth of the gap between spigot and socket should then be caulked with appropriate caulking material.

7. The remainder of the gap between spigot and socket should then be filled with the resin cement mortar and the external fillet formed. This should be carried out in stages until the joint is completely filled, using small quantities of mortar at each stage so that the weight of mortar does not cause it to fall from the joint .

8. Any mortar which has exuded from the joint inside the pipe should be cleaned off before proceeding to the next joint.

9. The joints should be protected from both water and hot sun during the curing period. The curing time is usually 24 hours but this may be reduced in very warm weather. Up to 72 hours may be required in cold weather. Heaters and de-humidifiers may have to be used in these circumstances. Some resin cements are supplied in alternative summer or winter grades.

10. The pipeline should not be tested with water until at least 8 days after the last joint has been made. This period may be reduced to 5 days in the hottest weather.

APPENDIX D - COST COMPARISONS AND COST SAVING CONSIDERATIONS

THE FACTS

The facts in this cost comparison are drawn from a report on the comparative costs of complete foul and rainwater drainage systems for two small housing developments carried out by an independent firm of chartered quantity surveyors. The developments are typical of the size and type of scheme being built in the late 1990's, one being of five terraced houses and the other of five detached houses.

The PVC-U prices are based on pipes laid with the normally used specification of a single size granular material surround with 100 mm cover over the crown of the pipe, using the Osmadrain Trade Price List dated 11th November 1996 and the Polypipe Trade Price List dated 29th September 1997.

Where PVC-U pipes are laid with single size aggregate only to the crown of the pipe, the total laid price will reduce by £534.84 for the terraced houses and £871.78 for the detached houses so as to cover the reduced costs of granular material and spoil removal from the trench.

The clay prices are based on pipes laid on a regulating granular bed using the Hepworth Building Products Price List dated 6th October 1997.

THE REASONS - Clay is cheaper because:-

1. The pipe is so strong that it does not require surrounding in granular material, resulting in large savings.
2. Fittings are competitively priced.
3. Less bedding means less spoil to remove from site - so no extra charges.
4. It's durability is proven so it will result in savings not allowed for in these costings. Over the life expectancy of the system, maintenance and repair costs will be lower.

THE CONCLUSIONS

If a drainage system is fully measured, then the true cost of each item of work can be counted up. Even using the illustrated excessive discounts for PVC-U of up to 57.5 % on Polypipe prices and 80 % on Osmadrain prices, which are unlikely to be readily offered or available ex-depot, as compared to typical merchant ex-depot prices for clay, such as 30 % from the list used here, it is still cheaper to lay a clay pipe system.

COST COMPARISON SUMMARY TABLE AS AT 1ST NOVEMBER 1997

System	Type of granular bedding	List price of pipes	List price of fittings	Laying of pipes and fittings	Trench excavation	Granular material	List price of small preformed inspection chambers	Laying of small preformed inspection chambers	List price of large preformed inspection chambers	Laying of large pre-formed inspection chambers	TOTAL
5 Terraced Houses											
FOUL AND RAINWATER DRAINAGE											
Clay Sleeve	Flat bed	£711.24	£685.06	£915.6	£1,194.05	£283.75	£412.16	£39.44	£357.80	£86.76	**£4,685.86**
Polypipe	Surround	£598.32	£274.00	£650.63	£1,459.98	£1,351.25	£205.48	£40.40	£203.16	£83.12	**£4,866.34**
Osmadrain	Surround	£908.82	£650.52	£688.84	£1,459.98	£1,351.25	£360.68	£31.44	£355.20	£86.62	**£5,893.35**
FOUL DRAINAGE											
Clay Sleeve	Flat bed	£411.99	£348.46	£429.15	£783.17	£165.71	£412.16	£39.44	£357.80	£86.76	**£3,034.64**
Polypipe	Surround	£349.71	£158.20	£302.92	£939.97	£789.13	£205.48	£40.40	£203.16	£83.12	**£3,072.09**
Osmadrain	Surround	£533.52	£398.92	£318.28	£939.97	£789.13	£360.68	£31.44	£355.20	£86.62	**£3,813.76**
RAINWATER DRAINAGE											
Clay Sleeve	Flat bed	£299.25	£336.60	£486.45	£410.88	£118.04	-	-	-	-	**£1,651.22**
Polypipe	Surround	£248.61	£115.80	£347.71	£520.01	£562.12	-	-	-	-	**£1,794.25**
Osmadrain	Surround	£375.30	£251.60	£370.56	£520.01	£562.12	-	-	-	-	**£2,079.59**
5 Detached Houses											
FOUL AND RAINWATER DRAINAGE							Concrete bed and surround				
Clay Sleeve	Flat bed	£1,390.98	£1,058.75	£1,613.47	£2,380.98	£458.54	£1,145.78		£1,687.20	£372.61	**£10,108.31**
Polypipe	Surround	£1,166.48	£460.45	£1,101.30	£2,841.52	£2,183.62	£1,071.88		£1,045.44	£365.15	**£10,235.84**
Osmadrain	Surround	£1,769.76	£1,067.37	£1,172.95	£2,841.52	£2,183.62	£1,071.88		£1,818.36	£383.25	**£12,308.71**
FOUL DRAINAGE											
Clay Sleeve	Flat bed	£844.71	£623.72	£937.60	£1,613.54	£242.89	£1,145.78		£1,687.20	£372.61	**£7,468.05**
Polypipe	Surround	£707.81	£258.62	£654.47	£1,861.04	£1,156.67	£1,071.88		£1,045.44	£365.15	**£7,121.08**
Osmadrain	Surround	£1,076.94	£639.59	£689.55	£1,861.04	£1,156.67	£1,071.88		£1,818.36	£383.25	**£8,697.28**
RAINWATER DRAINAGE											
Clay Sleeve	Flat bed	£546.27	£435.03	£675.87	£767.44	£215.65	-		-	-	**£2,640.26**
Polypipe	Surround	£458.67	£201.83	£446.83	£980.48	£1,026.95	-		-	-	**£3,114.76**
Osmadrain	Surround	£692.82	£427.78	£483.40	£980.48	£1,026.95	-		-	-	**£3,611.43**

METHOD OF CHECKING SPECIFIC LAID PRICES

Different trade discounts available can be applied to the list prices of the products used in these installations to fill in the table below and calculate the installed costs that would then be achieved.

5 TERRACED HOUSES	PVC-U (Polypipe)	PVC-U (Osmadrain)	CLAY
Total laid price:	£4,866.34	£5,893.35	£4,685.86
Total list price value	£1280.96	£2275.22	£2166.26
Less discount of	(%) =	(%) =	(%) =
Total laid price less discount			

5 DETACHED HOUSES	PVC-U (Polypipe)	PVC-U (Osmadrain)	CLAY
Total laid price:	£10,235.84	£12,308.71	£10,108.31
Total list price value	£2672.37	£4655.49	£4136.93
Less discount of	(%) =	(%) =	(%) =
Total laid price less discount			

TYPICAL LAID PRICES

5 TERRACED HOUSES	PVC-U (Polypipe)		PVC-U (Osmadrain)		CLAY	
Total laid price:		**£4,866.34**		**£5,893.35**		**£4,685.86**
List Price Value of:-						
Pipes	£598.32		£908.82		£711.24	
Fittings	£274.00		£650.52		£685.06	
Small pre-formed chambers	£205.48		£360.68		£412.16	
Large pre-formed chambers	£203.16		£355.20		£357.80	
Total list price value	£1,280.96		£2,275.22		£2,166.26	
Less discount of	57.5 %	£ 736.55	80 %	£1,820.18	30 %	£ 649.88
Total laid price less discount		**£4,129.79**		**£4,073.17**		**£4,035.98**

5 DETACHED HOUSES	PVC-U (Polypipe)		PVC-U (Osmadrain)		CLAY	
Total laid price:		**£10,235.84**		**£12,308.71**		**£10,108.31**
List Price Value of:-						
Pipes	£1166.48		£1769.76		£1390.98	
Fittings	£460.45		£1067.37		£1058.75	
Large pre-formed chambers	£1045.44		£1818.36		£1687.20	
Total list price value	£2,672.37		£4,655.49		£4,136.93	
Less discount of	50%	£1,336.19	72.5%	£3,375.23	30 %	£1,241.08
Total laid price less discount		**£8,899.65**		**£8,933.48**		**£8,867.23**

All PVC-U discounts are given as those necessary to even come close to the clay nett price. The discount for clay is representative of that given ex-depot by many builders merchants.

POINTS TO REMEMBER IN ORDER TO SAVE MONEY

1. Using a total granular surround is expensive and is rarely necessary as clay pipes have ample inherent strength at most depths encountered in building drainage and even for the majority of sewers.

2. If suitable material is available for sidefill and initial backfill, a flat bed of single sized or other granular material can be used to lay the pipe on. Suitable sidefill and initial backfill material may be available on site, either excavated from the trench or from other economic materials in use.

3. Overexcavation of either the depth or width of the trench should be avoided as it wastes bedding material.

4. Brickwork chambers are expensive to construct. Small clay or polypropylene chambers should be used where the depth of the drain is appropriate. The tables in BS EN 752-3 [13] show where each size of chamber can be used.

5. Material waste should be avoided as far as possible. Discarded cut-off lengths of sleeve jointed clay pipes can be used as rocker pipes without resorting to cutting precise lengths from new pipes.

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MEMBERS OF THE CLAY PIPE DEVELOPMENT ASSOCIATION

Hepworth Building Products Ltd.	Hazlehead, Crow Edge, Sheffield, South Yorkshire, S36 4HG	Tel: 01226 763561 Fax: 01226 764827
W.T. Knowles & Sons Ltd.	Ash Grove Sanitary Pipe Works, Elland, West Yorkshire, HX5 9JA	Tel: 01422 372833 Fax: 01422 370900
Naylor Drainage Ltd.	Clough Green, Cawthorne, Barnsley, South Yorkshire, S75 4AD	Tel: 01226 790591 Fax: 01226 790531

ASSOCIATE MEMBERS AND OVERSEAS ASSOCIATE MEMBERS

Building Products Company (A division of MCP Industries)	P.O. Box 18110, Phoenix, AZ 85005, U.S.A.	Tel: (1) 602 269 8314 Fax: (1) 602 269 7433
Can-Clay Corporation	402 Washington Street, P.O. Box 158, Cannelton, IN 47520, U.S.A.	Tel: (1) 812 547 3461 Fax: (1) 812 547 6514
Flemings Fireclays Ltd.	The Swan, Athy, Co. Kildare, Republic of Ireland	Tel: (353) 507 35513 Fax: (353) 507 35582
Fyfe Vitro	Potchefstroom Road, Vereeniging P.O. Box 49, Vereeniging 1930, Gauteng, South Africa.	Tel: (27) 16 88 1130 Fax: (27) 16 88 2301
GBH Ceramics Sdn. Bhd.	238 Jalan Segambut, 51200 Kuala Lumpur, Malaysia	Tel: (60) 3 6261055 Fax: (60) 3 6231630
Gladding, McBean, A division of Pacific Coast Building Products Ltd.,	3001 I Street, P.O. Box 160488, Sacremento, CA 95816, U.S.A.	Tel: (1) 916 444 9304 Fax: (1) 916 325 3697
Irish Stoneware & Fireclays Ltd.	Carrickmacross, Co. Monaghan, Republic of Ireland.	Tel: (353) 42 61256 Fax: (353) 42 62494
Johore Pipe Company	57th Mile, Jalan Johor, 86100 Air Hitam, Kluang, Johor, West Malaysia	Tel: (60) 7 7581253 Fax: (60) 7 7581175
The Logan Clay Products Company	P.O. Box 698, Logan, OH 43138-0698, U.S.A.	Tel: (1) 740 385 2184 Fax: (1) 740 385 9336
Misson Clay Products	P.O. Box 549, Corona, CA 91718, U.S.A.	Tel: (1) 909 277 4600 Fax: (1) 909 273 2708
Superior Clay Corporation	P.O. Box 352, Uhrichsville, OH 44683, U.S.A.	Tel:: (1) 614 922 4122 Fax: (1) 614 922 6626
Ulster Fireclays Ltd.	Coalisland, Dungannon, Co. Tyrone, Northern Ireland	Tel: 028 8774 0436 Fax: 028 8774 7430

For up to date contact information please use the Contact or Member links on the web site home page.