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Contents

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 60, an inside back cover and a back cover.

Foreword

Publishing information

This British Standard is published by BSI and came into effect on 31 March 2010. It was prepared by Technical Committee B/505, *Wastewater engineering* in consultation with Technical Committee B/504, *Water supply*. A list of organizations represented on these committees can be obtained on request to their secretaries.

Relationship with other publications

This British Standard is complementary to BS EN 1295-1:1997 and PD CEN/TR 1295-2:2005.

BS EN 1295-1:1997 specifies general requirements for the structural design of buried pipelines under various conditions of loading. Guidance is also given on the application of the nationally established methods of design declared by, and used in, CEN member countries at the time it was prepared. The established United Kingdom method is summarised in **B.2.12**, and National Annex A describes the calculation procedure in more detail.

PD CEN/TR 1295-2:2005 summarizes the nationally established methods of design made available to CEN and the United Kingdom method is described in **A.9**, which is consistent with BS EN 1295-1:1997, National Annex A, as corrected by Corrigendum No. 1 on 31 May 2006.

This British Standard gives further information to facilitate in full the structural design of buried pipelines under various conditions of loading using the established United Kingdom method; it does not alter any of the provisions of BS EN 1295-1:1997.

Whilst recognizing that the UK National Annex to EN 1295-1 might be reviewed in the future in respect of possible changes to current practice for the design of thermoplastics pipelines, it was agreed that this first edition of BS 9295 is specifically required to be a guide to the existing BS EN 1295-1.

Use of this document

As a guide, this British Standard takes the form of guidance and recommendations. It should not be quoted as if it was a specification or a code of practice and claims of compliance cannot be made to it.

Presentational conventions

The provisions in this standard are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is "should".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

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Introduction

The established United Kingdom method for the structural design of buried pipelines under various conditions of loading ("the UK method") is based on the "Marston" or "Computed load" method developed at the Iowa Engineering Experiment Station in the USA by Professor Anson Marston and his colleagues Professors Merlin G. Spangler and W.J. Shlick in the first half of the twentieth century. In 1951, at the request of the then Ministry of Housing and Local Government, a 10-year programme of experimental work was carried out at Garston by the Building Research Station (later the Building Research Establishment). The work was led by N.W.B. Clarke, supported by Oliver C. Young and J.H. Smith and in 1962 resulted in the publication of *Simplified tables of external loads on buried pipelines* [1], followed in 1966 by *Loading charts for the design of buried rigid pipes* [2] and in 1967 by *High-strength beddings for unreinforced concrete and clayware pipes* [3]. In 1970 an updated and revised *Simplified tables of external loads on buried pipelines* [4] was published.

Throughout the 1960s the Marston work was complemented by a programme of research on rigid pipe beddings at the British Ceramic Research Association at Stoke-on-Trent, sponsored by the Clay Pipe Development Association and led by John H. Walton. This phase of the Stoke-on-Trent investigations culminated in 1970 with the publication of *The structural design of the cross-section of buried vitrified clay pipelines* [5], but by then the work had moved on into minimum beddings for small diameter pipes. That research was led by Colin E.G. Bland, whose work in chairing the B/505 project group that developed this British Standard is acknowledged by both B/504 and B/505. In 1975 the use of minimum beddings for rigid pipes not exceeding DN225 was endorsed by the Department of the Environment's Working Party on Sewers and Water Mains in its First Report [6].

By 1983 the United Kingdom central role in this field had passed from the Building Research Station to the Transport and Road Research Laboratory (now the Transport Research Laboratory) and, based on work by Oliver C. Young and Myles P. O'Reilly, it published *A guide to design loadings for buried rigid pipes* [7]; there was no longer any limit on the size of rigid pipes that could be used with minimal bedding. In 1986 a further edition of *Simplified tables of external loads on buried pipelines* [8] was published, based on work by the same authors and Guy Brennan. BSI gratefully acknowledges the permission kindly granted by Her Majesty's Stationery Office to draw heavily on the texts of these two publications in the preparation of this British Standard.

In 1989 a joint working group of CEN/TC 164 *Water supply* and CEN/TC 165 *Wastewater engineering*, led by the latter, was created to develop a common method for the structural design of buried pipelines. The varying practices throughout Europe and the huge task of agreeing a common method led the group to adopt what became a three-stage approach. The first stage was to produce an EN specifying general requirements and giving guidance on the application of nationally established methods; this was achieved in 1997 and implemented by BSI as BS EN 1295-1:1997. The second stage was to collate and summarize the various nationally established methods of design that had been reported in Europe and this was published by BSI as PD CEN/TR 1295-2:2005.

It proved impossible to agree a common method and so in 2003 it was decided to stop work on an EN, since the human and financial resources necessary were no longer available. By then the draft had been distilled into two separate methods, broadly speaking those used in France and the Germanic countries, and so it was decided to publish these as what became CEN/TR 1295-3:2007. The United Kingdom recorded opposition to the proposed Technical Report at CEN formal vote stage because the two methods not only give widely varying results for the same input data for both rigid and flexible pipes, but neither produces equivalent results to the UK method described in BS EN 1295-1:1997, which has been proven both by research and practice correlating theory and practice for both rigid and flexible pipes.

More recent research work indicates a possible need for revision of the design method for buried thermoplastics pipes to be included in a future revision of BS EN 1295-1.

BSI is not obliged to publish CEN Technical Reports and so, on the advice of B/505, supported by B/504, did not do so in the case of CEN/TR 1295-3:2007.

The method for semi-rigid pipes in BS EN 1295-1:1997 was taken from published and unpublished work by C. Barrie Greatorex at Stanton plc.

The aim of this British Standard, therefore, is to consolidate and update the various documents that together describe the UK method. The opportunity has also been taken to expand on the published information and in this connection both B/504 and B/505 acknowledge the kind permission of MWH (Montgomery Watson Harza) UK Ltd. to incorporate work developed by the late Jonathan L. Olliff, for many years a member of both committees and principal UK expert in the CEN joint working group.

1 Scope

This British Standard gives information and guidance for the use of BS EN 1295-1:1997, National Annex A, the UK established method for the structural design of buried pipelines under various conditions of loading. The procedures are explained and, for situations where general assumptions can be made, loading tables are given.

NOTE The scope of BS EN 1295-1:1997 is restricted to the structural design of water supply pipelines, drains and sewers, and other water industry pipelines, whether operating at atmospheric, greater or lesser pressure.

The design for longitudinal effects is not covered (see BS EN 1295-1:1997, **5.4**).

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS EN 545, *Ductile iron pipes, fittings, accessories and their joints for water pipelines – Requirements and test methods*

BS EN 598:2007+A1:2009, *Ductile iron pipes, fittings, accessories and their joints for sewerage applications – Requirements and test methods*

BS EN 622-4:1997, *Fibreboards – Specifications – Part 4: Requirements for softboards*

BS EN 1295-1:1997, *Structural design of buried pipelines under various conditions of loading – Part 1: General requirements*

BS EN 1610:1998, *Construction and testing of drains and sewers*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this British Standard, the terms and definitions given in BS EN 1295-1:1997 apply.

3.2 Symbols

For the purposes of this British Standard, the following symbols apply.

B_c outside diameter of pipe

B_d effective width of trench

C_c soil load coefficient in wide trench (embankment) conditions

C_d soil load coefficient in narrow trench conditions

C_L soil modulus adjustment factor (Leonhardt's coefficient)

C_w water load coefficient

D mean diameter of pipe

D_f strain factor

D_L deflection lag factor

D_{Lsr} lag deflection factor for semi-rigid pipes

E flexural modulus of elasticity of pipe material

E_h hoop tensile modulus of elasticity of pipe material

E' overall modulus of soil reaction

E'_2 embedment soil modulus

E'_3 native soil modulus

F_m bedding factor

F_s factor of safety

F_{se} factor of safety for rigid pipe material (external load design)

F_{si} factor of safety for rigid pipe (internal pressure design)

H depth of cover to top of pipe

H_e height of plane of equal settlement above top of pipe

I second moment of area of unit length of pipe wall

K coefficient of active lateral earth pressure

K_x deflection coefficient

M_p modified Proctor density

m	Poisson's ratio
n	pipe-soil stiffness factor
P	vertical pressure due to soil and surcharge
P_{cr}	critical pressure for buckling of flexible pipes
P_{cra}	short-term critical pressure in air
P_{crl}	long-term critical pressure
P_{crs}	short-term critical pressure
P_e	vertical soil pressure
P_i	internal water pressure
P_s	surcharge pressure
P_u	ultimate bursting pressure
P_v	transient vacuum pressure from surge analysis
P_w	working pressure
p	projection ratio
r_{sd}	settlement deflection ratio
S_f	settlement of pipe invert
S_g	settlement of the natural ground
S_m	settlement of fill
t	pipe wall thickness
W_c	soil load per unit length of pipe in narrow trench conditions
W_c'	soil load per unit length of pipe in embankment or wide trench conditions
W_c''	load on a rigid pipe where there is no friction at the backfill/trench wall interface
W_{csu}	concentrated surcharge load per unit length of pipe
W_e	total design external load per unit length of pipe
W_p	proof crushing strength
W_t	crushing strength of rigid pipes (maximum load for concrete pipes)
W_t'	crushing strength of rigid pipes with internal pressure per unit length of pipe
W_w	equivalent external load due to weight of water in unit length of pipe
γ	unit weight of soil
γ_w	unit weight of water
Δ	pipe diameter change
ε_b	bending strain in pipe wall
ε_c	combined strain in pipe wall
μ	coefficient of friction within soil mass
μ'	coefficient of friction at trench wall
σ_{bs}	bending stress in pipe wall
σ_c	combined stress

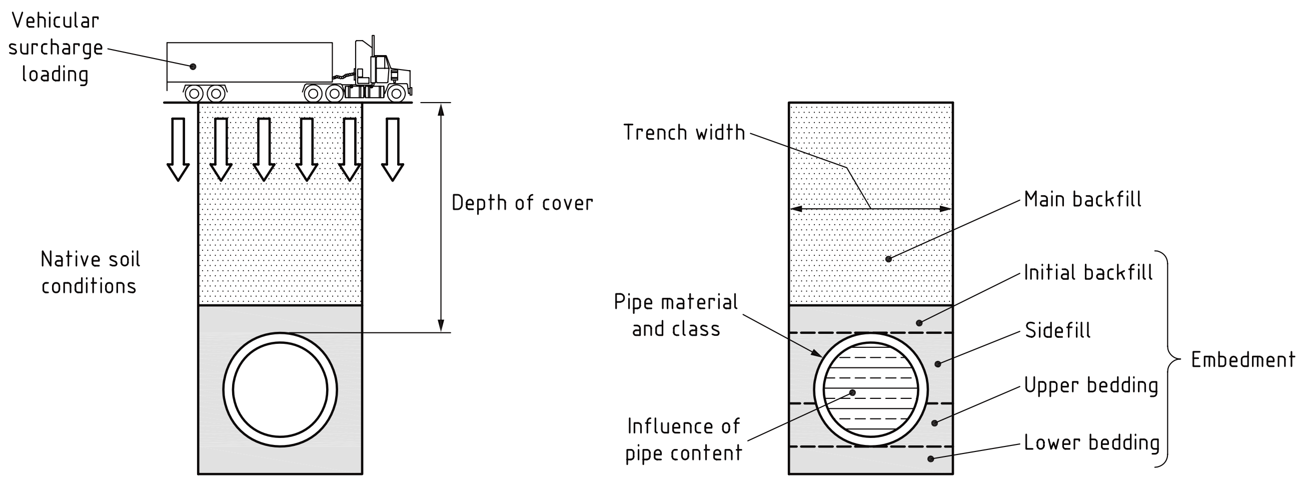
For ease of reference to BS EN 1295-1:1997, National Annex A, the equation numbers given in that standard are also used in this British Standard.

4 The structural design of pipelines

4.1 General

The purpose of the structural design of the cross-section of buried pipelines is to ensure that they are designed so that the optimum materials and embedments are selected for the given installation, whilst meeting all the necessary design criteria. For design considerations see Figure 1.

Figure 1 **Design considerations**



a) Factors to be considered in the design environment b) Factors to be considered – Designer controlled parameters

NOTE Definition of sidefill in BS EN 1295-1:1997 includes sidefill and upper bedding as shown in Figure 1.

4.2 Categories of structural behaviour

Pipe materials are divided for structural design purposes into three categories.

- Rigid (see Clause **5**);
- Semi-rigid (see Clause **6**);
- Flexible (see Clause **7**).

The behaviour of these materials depends upon both their inherent response to external loading and their interaction with surrounding soils.

Rigid pipe materials have a small deflection on loading, which is too small to develop any lateral earth pressures. Load is taken by the pipeline and bending moments are developed in the pipe walls. Rigid pipes also attract an amplified backfill load upon burial and obtain a reaction from their bedding in response. Semi-rigid pipe materials tend to exhibit a range of behaviour from rigid to flexible. Flexible pipe materials deflect towards an oval shape in response to loading and are able to develop significant lateral earth pressure from their surrounding embedment. BS EN 1295-1:1997, National Annex A uses the terms “soil load” and “backfill load” synonymously to describe the load imposed from the backfill after burial of the pipeline.

Pipes of different materials are classified in the UK according to the strength criterion required to be proven in testing or otherwise established in design. Where the strength of pipes is established in a crushing test, they are classified as rigid, see Table 1 for further classifications.

Table 1 **Pipe classification**

Type of pipe	Classification
Clay	Rigid
Concrete	Rigid
Reinforced concrete	Rigid
Ductile iron	Semi-rigid
Thick walled steel	Semi-rigid
Thermoplastics	Flexible
Glass reinforced plastics	Flexible
Thin walled steel	Flexible

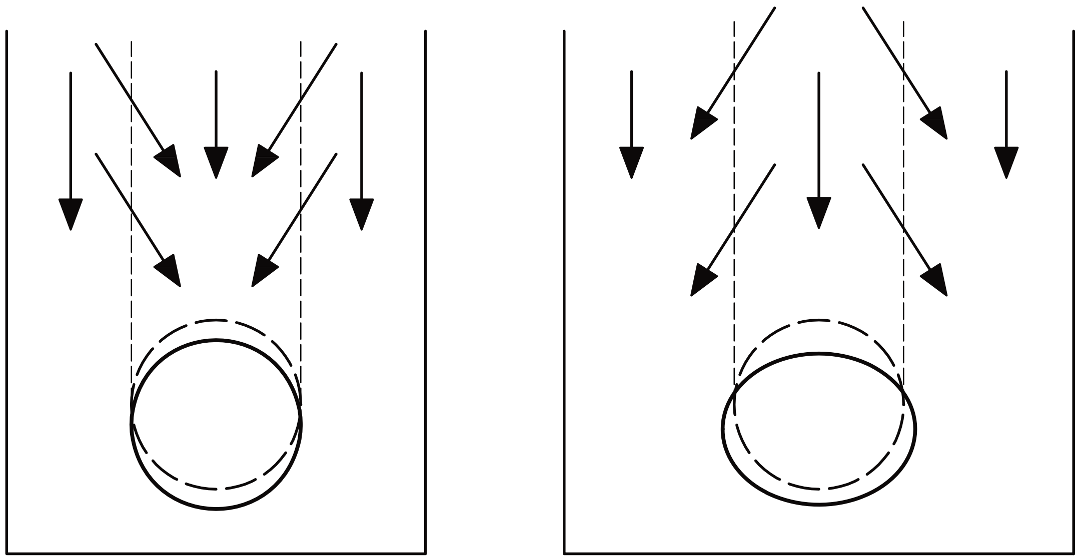
When a pipeline is installed, the ground is disturbed. Settlement of the disturbed soil occurs in the pipe trench even after backfilling is complete.

A rigid pipe is stiffer than the surrounding soil and when consolidation of the backfill takes place in the pipe zone, the soil to the sides of the pipe tends to settle more than the soil over the pipe. By friction, load is transferred to the column of soil over the pipe (geostatic load, γH) meaning that the pipe is attracting more load than just the geostatic load. In response to this, a rigid pipe might settle marginally into its bedding.

A flexible pipe is less stiff than the surrounding soil, so when buried, the column of soil over the flexible pipe settles more than the columns of soil to the sides. The effect of this is that the flexible pipe will deflect on loading, but will also tend to shed load away from itself. Figure 2 illustrates rigid and flexible pipe behaviour.

The set of equations for rigid and semi-rigid pipe given in BS EN 1295-1:1997 (equations 1, 2, 4, 12 and 14) and equation A.7 in this standard (Annex A, subclause **A.5**) together provide continuity of calculation for loads from fully flexible to fully rigid pipe.

Figure 2 **Rigid and flexible pipe behaviour**



a) Rigid b) Flexible

NOTE Displacement and deflection exaggerated for illustrative purposes.

Over time all these effects within the trench tend to disappear. From a backfill load point of view, the worst loading condition for a rigid pipe is when it is newly installed in the ground and the columns of soil to the sides of the pipe are transferring load onto the pipe. These factors are taken into account by the use of the coefficient C_c in the wide trench condition, equation 1, and C_d in the narrow trench condition, equation 4 (a description of wide and narrow trench conditions is given in **5.2**).

$$W'_c = C_c \gamma B_c^2 \qquad \text{(BS EN 1295-1:1997, equation 1)}$$

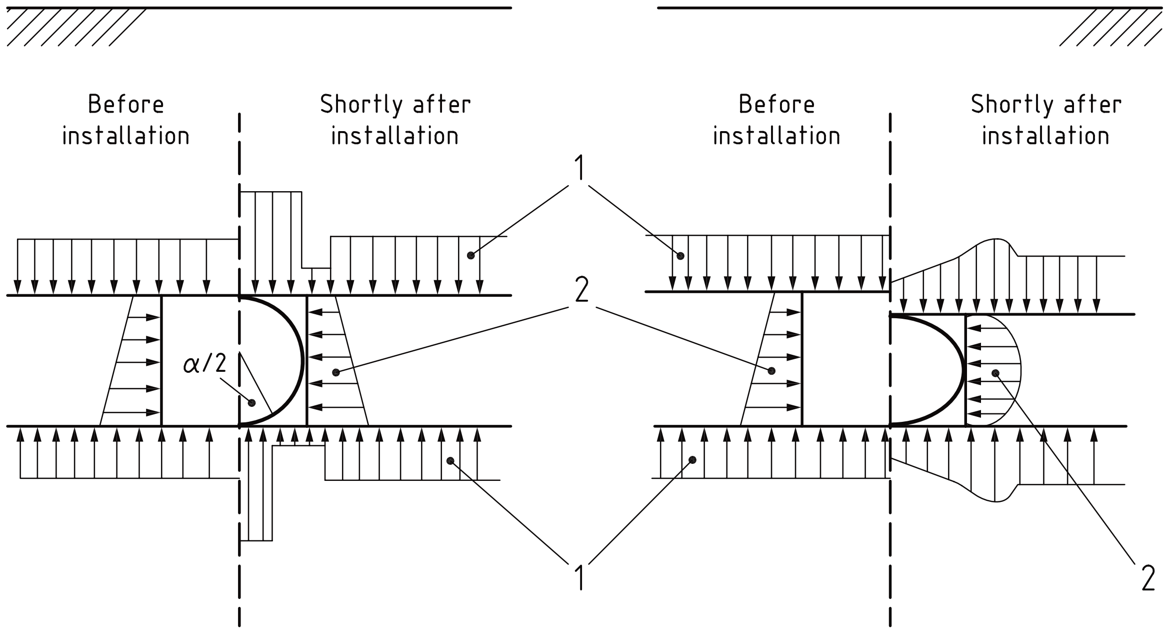
$$W_c = C_d \gamma B_d^2 \qquad \text{(BS EN 1295-1:1997, equation 4)}$$

Conversely, the highest predicted backfill load for a flexible pipe, according to BS EN 1295-1:1997, is after all the beneficial shedding of load has taken place, so the load used is just the geostatic value γH with no coefficients.

$$P_e = \gamma H \qquad \text{(BS EN 1295-1:1997, equation 20)}$$

Figure 3 shows a schematic diagram of the changes in the soil pressures following the burial of rigid and flexible pipes.

Figure 3 **Soil pressure changes**



a) Rigid pipes b) Flexible pipes

Key

1 Vertical pressure

2 Horizontal pressure

α Bedding angle

4.3 Native soil

The stiffness of the surrounding soil is measured in terms of the Spangler modulus *E′*, which is known as the modulus of soil reaction. This parameter is not a fundamental engineering property of the soil and cannot be directly measured. It is a semi-empirical parameter which is a function of the pipe and soil system (and not the soil alone).

The Spangler moduli for various native soils are given in BS EN 1295-1:1997, Table NA.1. Table NA.1 modulus values apply to shallow depths and with groundwater present; they are likely to be conservative for depths exceeding 1 m or above groundwater, or both.

Although it is not mentioned in Table NA.1, the values given are the E'_3 moduli for various native soils and are used in the calculation of the soil modulus adjustment factor C_L (Leonhardt's coefficient [9]).

$$C_L = \frac{0.985 + (0.544 B_d / B_c)}{\{1.985 - 0.456(B_d / B_c)\}(E'_2 / E'_3) - \{1 - (B_d / B_c)\}}$$

(BS EN 1295-1:1997, equation 17)

The E'_3 moduli are also referenced in BS EN 1295-1:1997, Table NA.4. Leonhardt's coefficient is a factor used to adjust the value of the embedment modulus, in order to establish an overall soil modulus value for design purposes (see **6.5**).

4.4 Vehicle loading

The vehicle loadings used in BS EN 1295-1:1997, National Annex A are given in BS 5400-2:1978. BS 5400-2:1978 has been revised, but the original loadings are still used in pipeline design and give a more conservative result than loadings derived from the newer standard. The loading configurations considered are shown in Figure 4 and Figure 5 and these are converted to pressure at the pipe crown using Newmark's integration of Boussinesq's formula, to give the resultant load at pipe crown level at a certain depth and distance away from the wheel loading.

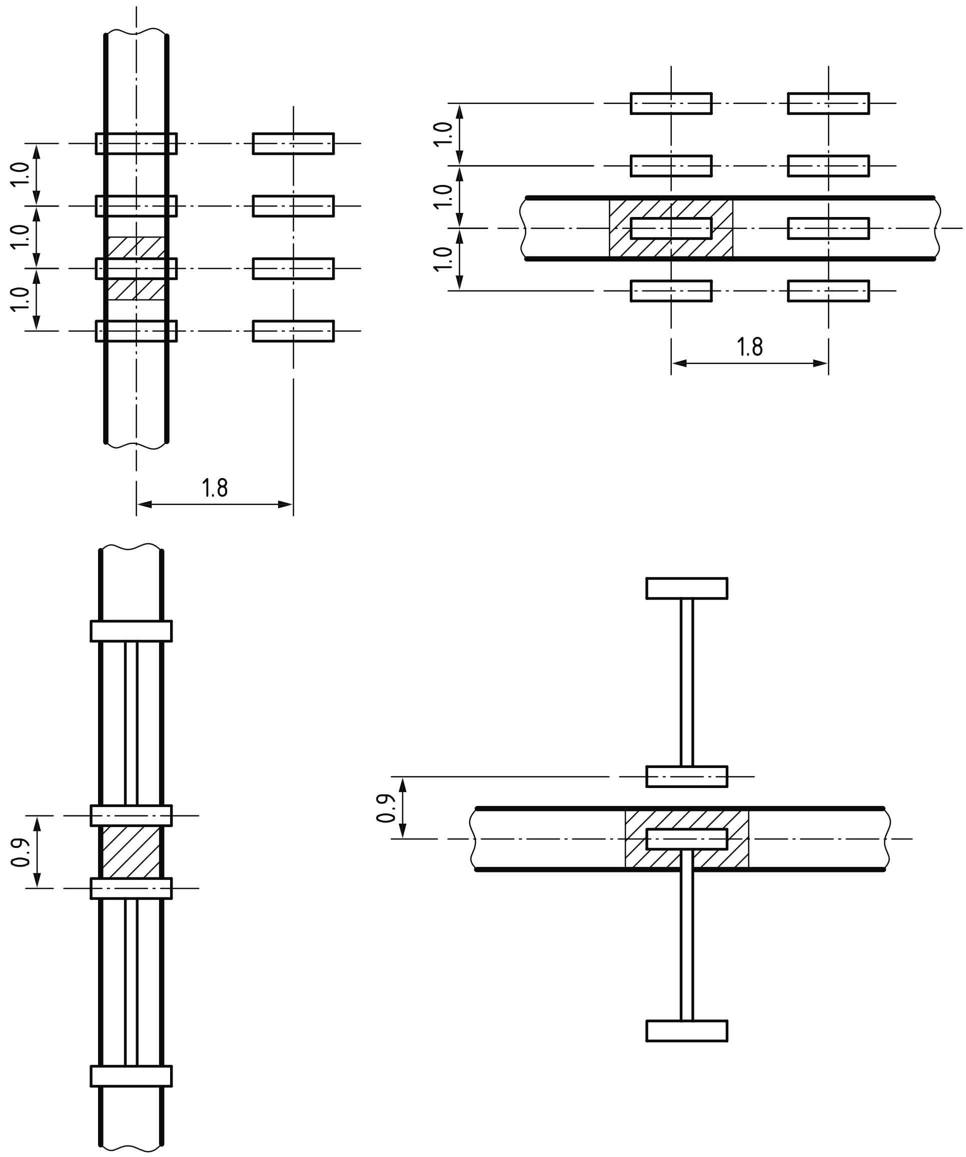
Figure 6 and Figure 7 indicate how backfill load increases with depth of cover whereas traffic load decreases. Further information on traffic loading, including simplified tables of vehicular loading, can be found in Annex A.

Graphs of surcharge pressure due to vehicle loads illustrated in Figure 4 are shown in BS EN 1295-1:1997, Figure NA.6. Similar graphs for other vehicles and railways are shown in BS EN 1295-1:1997, Figures NA.7, NA.8 and NA.9.

The maximum loading on a pipeline will depend upon its depth and diameter.

Figure 4 **Loading configurations**

Dimensions in metres



Main roads

8 × 112.5 kN wheel loads including impact factor of 1.3 (this corresponds to 45 units of HB loading according to BS 5400-2:1978)

Light trafficked roads

2 × 105 kN wheel loads including impact factor of 1.5

Fields

2 × 60 kN wheel loads, including impact factor of 2.0

Key

The effect of wheel loads is considered over a 1 m length of pipe as shown shaded.

Figure 5 **Schematics of the main road loading case**

Dimensions in millimetres

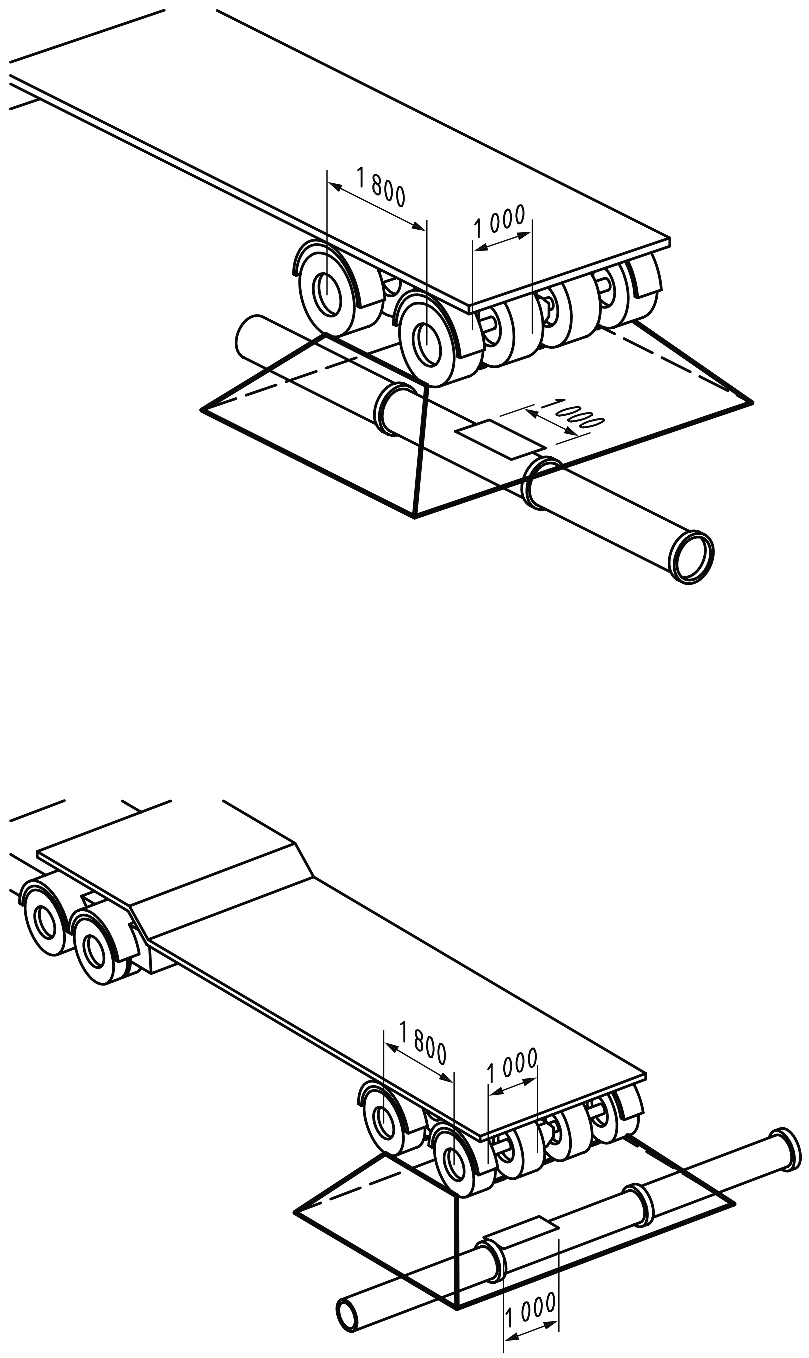


Figure 6 **Typical calculated backfill and main road traffic loadings on a DN300 rigid pipeline with an external diameter of 358 mm**

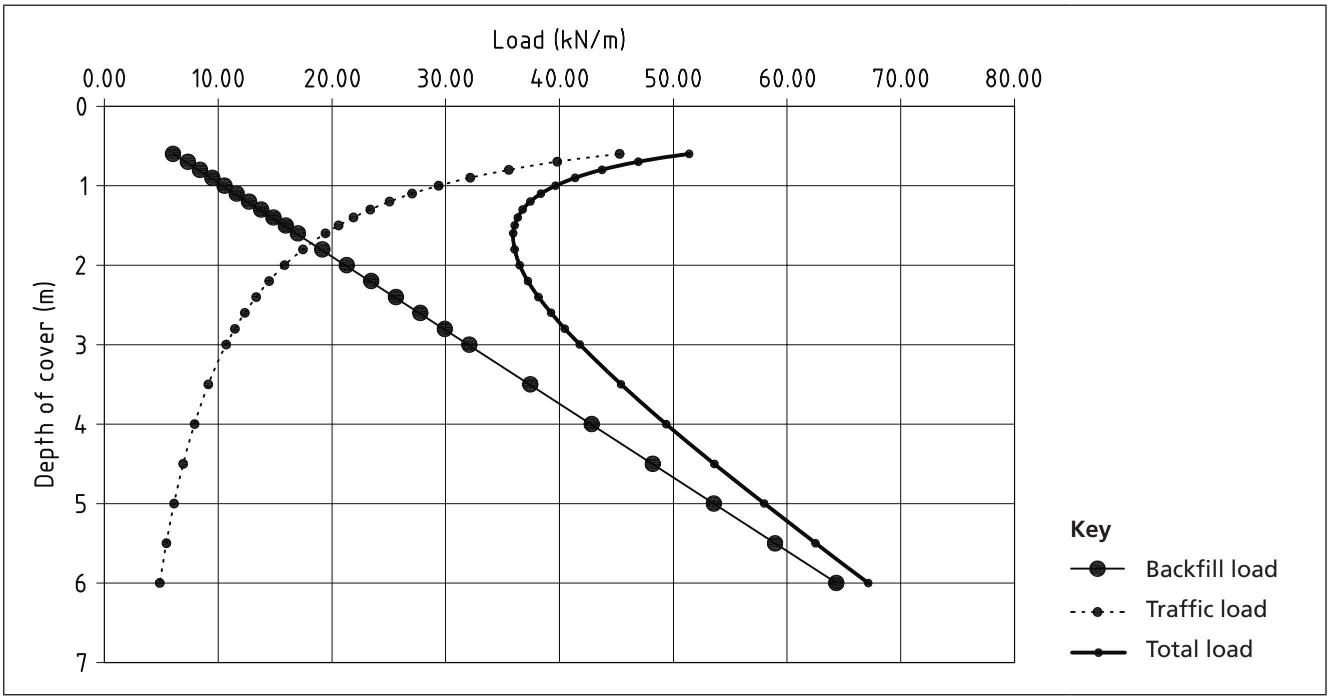
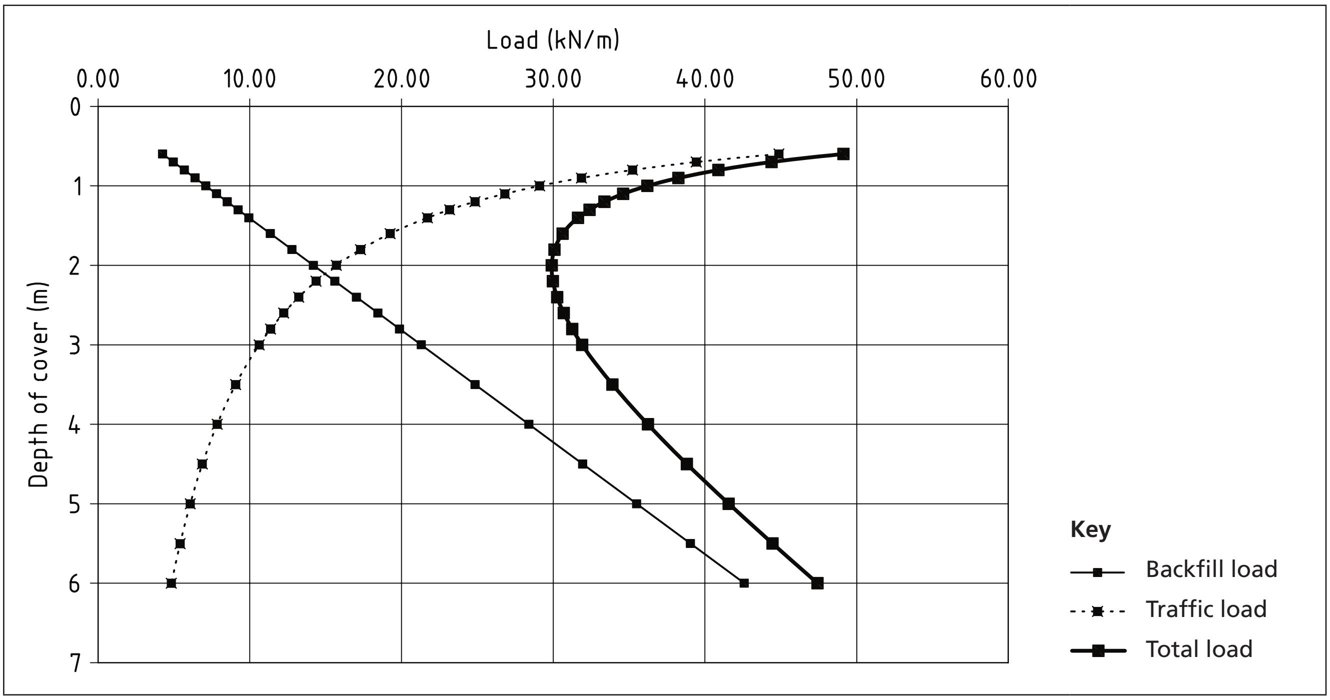


Figure 7 **Typical calculated backfill and main road traffic loadings on a DN355 external diameter flexible pipeline (for comparison purposes)**



5 The design of rigid pipelines

5.1 General

Rigid pipes rely on their embedment to distribute the loads imposed by backfill and traffic in order to reduce the circumferential bending moments in the pipe walls. Their response to the loading is to settle marginally into their supporting material until sufficient reaction is achieved (see **4.2**).

5.2 Wide and narrow trenches

In BS EN 1295-1:1997, **NA.4.1**, there are two broad sections: pipes installed in wide trenches or embankments (see BS EN 1295-1:1997, **NA.4.1.1**) and pipes installed in narrow trenches (see BS EN 1295-1:1997, **NA.4.1.2**). For all pipeline installations both conditions should be calculated and the lower of the two loads used in the design. In the absence of specific information it is safer to assume the trench is wide. The effective trench width is illustrated in Figure 8.

Figure 8 **Effective trench width, B_d**

Dimensions in millimetres

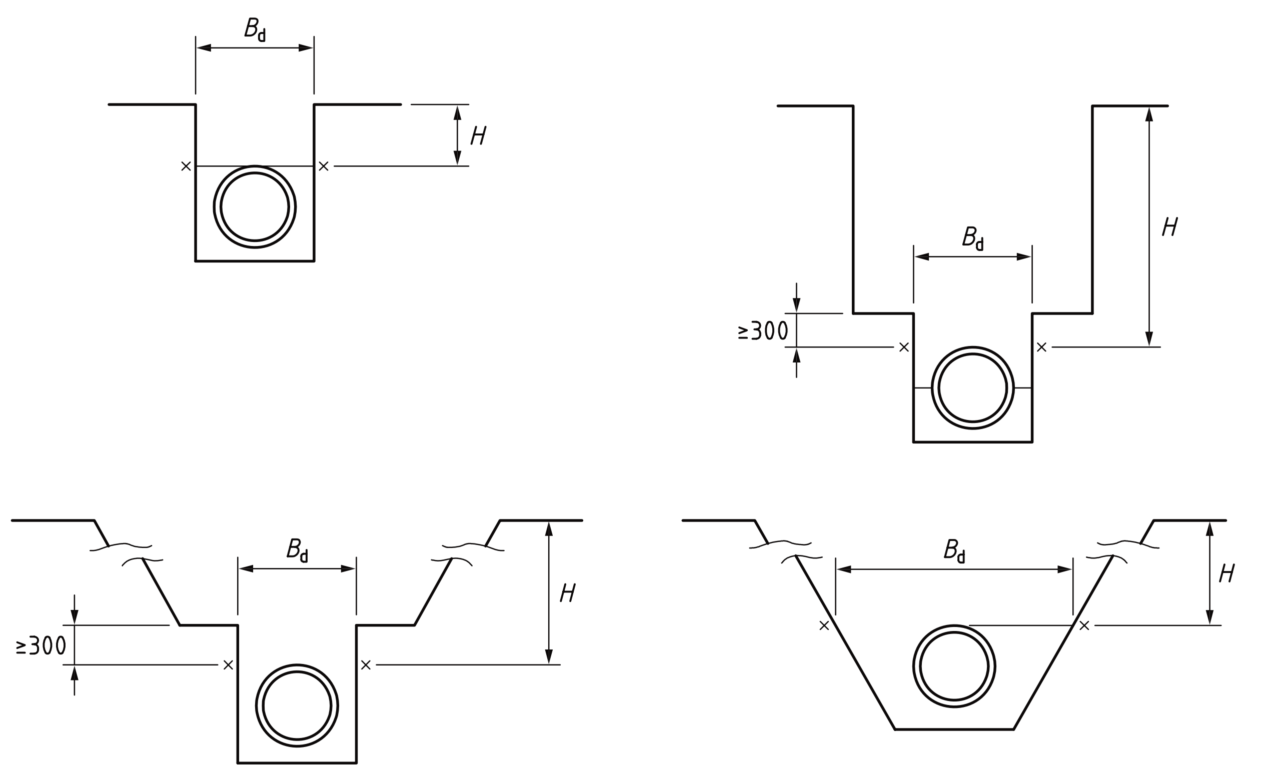


Figure 9 and Figure 10 illustrate what is known as the "transition width" and "transition depth". In the case of a narrow trench at a particular depth, the load W_c increases as the trench width increases, up to a maximum value of that given by the wide trench formula.

When the loads calculated by the two methods are equal, then the "transition width" is reached. Although the load calculated by the narrow trench formula increases beyond that width, in reality the pipeline will not experience a load greater than the wide trench load.

Similarly, in a trench of a particular width but varying depth, it is possible for wide trench conditions to apply in the shallower sections of the trench and narrow trench conditions to apply in the deeper sections. The depth at which the loads calculated by both formulae are equal is known as the "transition depth". At depths beyond the transition depth the narrow load will prevail (see Annex A and Annex B).

Figure 9 **Narrow to wide trench conditions (transition width)**

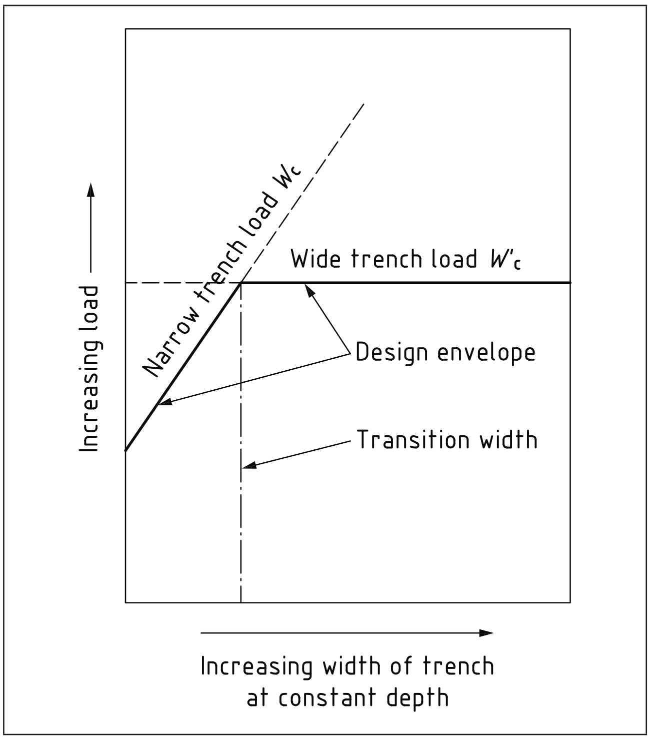
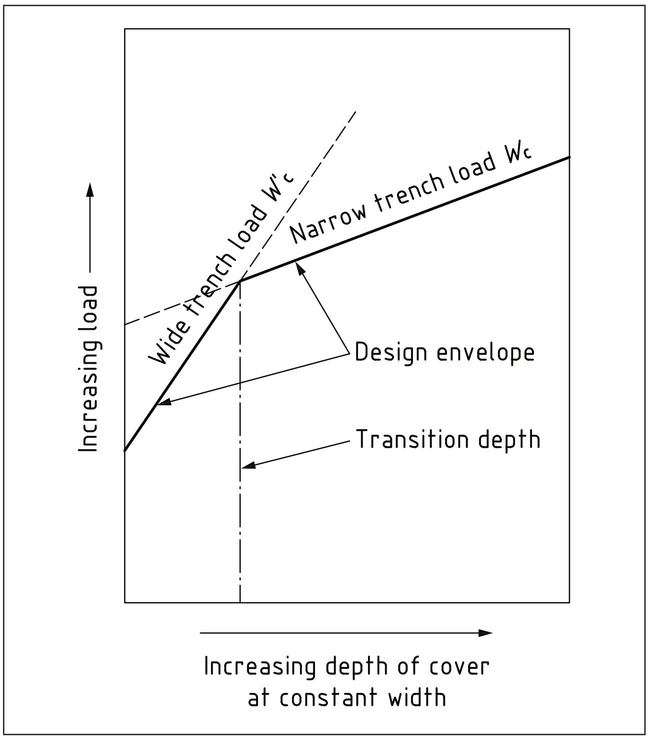


Figure 10 **Wide to narrow trench conditions (transition depth)**



For the wide trench condition (see Figure 9) the soil load coefficient C_c is used and takes into account the amplification of the backfill load on rigid pipes. There are two equations given, equation 2 for the wide trench complete projection case and equation 3 for the wide trench incomplete projection case (see **5.3** for descriptions of complete and incomplete projection). In the latter case, however, values for C_c are given in BS EN 1295-1:1997, Table NA.2, rather than being calculated using equation 3.

$$C_c = \frac{e^{2K\mu H/B_c} - 1}{2K\mu} \qquad \text{(BS EN 1295-1:1997, equation 2)}$$

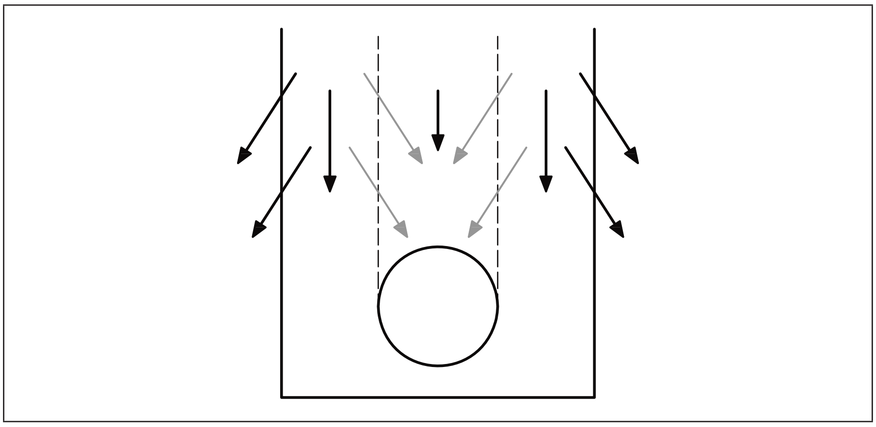
$$C_c = \left\{ \frac{e^{2K\mu H_e/B_c} - 1}{2K\mu} + \left(\frac{H}{B_c} - \frac{H_e}{B_c} \right) e^{2K\mu H_e/B_c} \right\}$$

(BS EN 1295-1:1997, equation 3)

NOTE See Annex A, subclause ***A.5****, for elaboration of equation 3, and equation A.7 for alternative calculation of C_c for the incomplete projection case.*

For the narrow trench condition (see Figure 10) the soil load coefficient C_d is used and takes account of what is known as the "silo effect" (see Figure 11). It is so called because the phenomenon was first observed in grain silos during the 19th century, where failures were occurring in the walls of these structures. The reason for this was that load was being transferred into the silo walls by the friction created from settling grain within. It was recognized that the same thing would happen in trenches when backfilled. This would have a beneficial effect in design if the walls of the trench were sufficiently close to the pipeline.

Figure 11 **The silo effect**

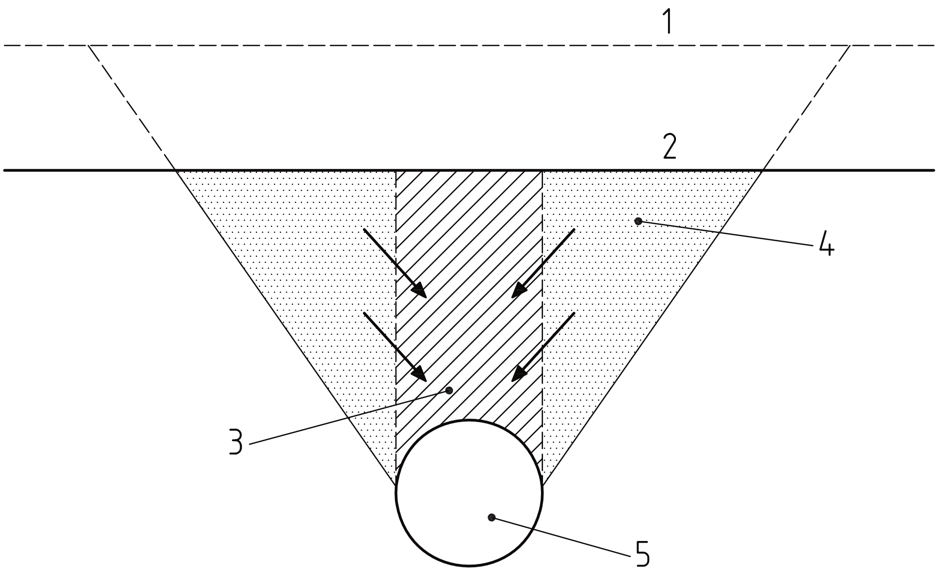


If, however, the walls of the trench are not close enough to have a beneficial effect, then the pipeline is designed as if in a wide trench. Designers should be mindful of how an installation is likely to be carried out on site and whether or not site supervision will be such that a narrow trench design can be relied upon (see Annex A and Annex B).

5.3 Complete and incomplete projection

Within the wide trench design, there is introduced the idea of complete and incomplete projection. These refer to a line known as the "plane of equal settlement" and to whether or not this line falls above ground level (complete projection, see Figure 12) or below (incomplete projection, see Figure 13). The plane of equal settlement refers to the point at which the settlements of soil to the sides of the pipeline and over the pipeline are equal (see **4.2**).

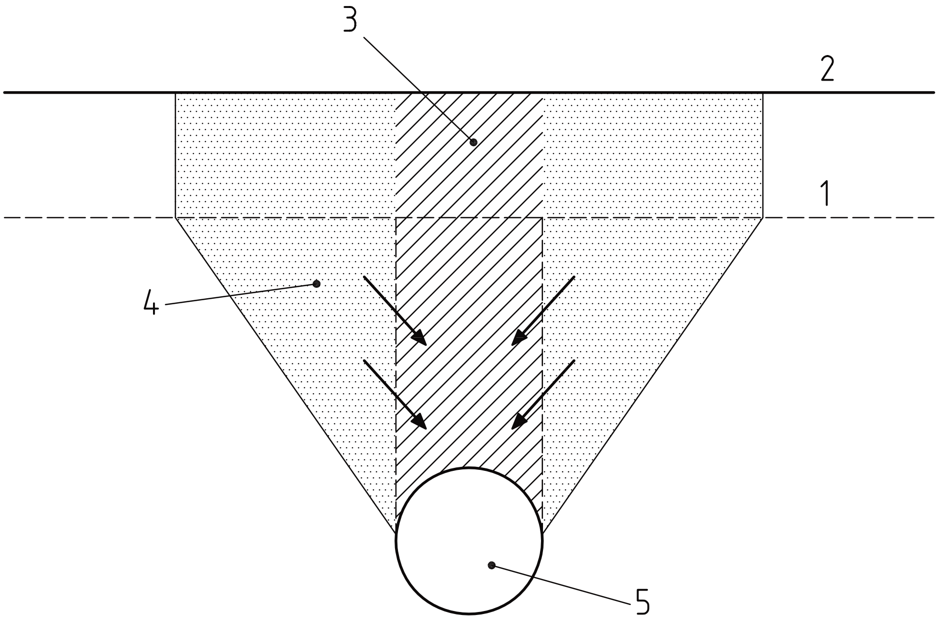
Figure 12 **Complete projection**



Key

1 Plane of equal settlement
2 Ground level
3 Soil load on the pipeline
4 Transferring of load by friction
5 Pipeline in a wide trench or embankment

Figure 13 **Incomplete projection**



Key

1 Plane of equal settlement
2 Ground level
3 Soil load on the pipeline
4 Transferring of load by friction
5 Pipeline in a wide trench or embankment

Loads should be calculated using both complete and incomplete projection formulae and the lesser of the two calculated loads used for design.

NOTE Generally this calculation will show that the incomplete projection case is the more common situation except for pipelines installed at a shallow depth of cover.

5.4 Backfill loads

The wide trench or embankment load formula is given as:

$$W'_c = C_c \gamma B_c^2 \qquad \text{(BS EN 1295-1:1997, equation 1)}$$

Where C_c is the lower value given by equation 2 or equation A.7.

The narrow trench formula is given as:

$$W_c = C_d \gamma B_d^2 \qquad \text{(BS EN 1295-1:1997, equation 4)}$$

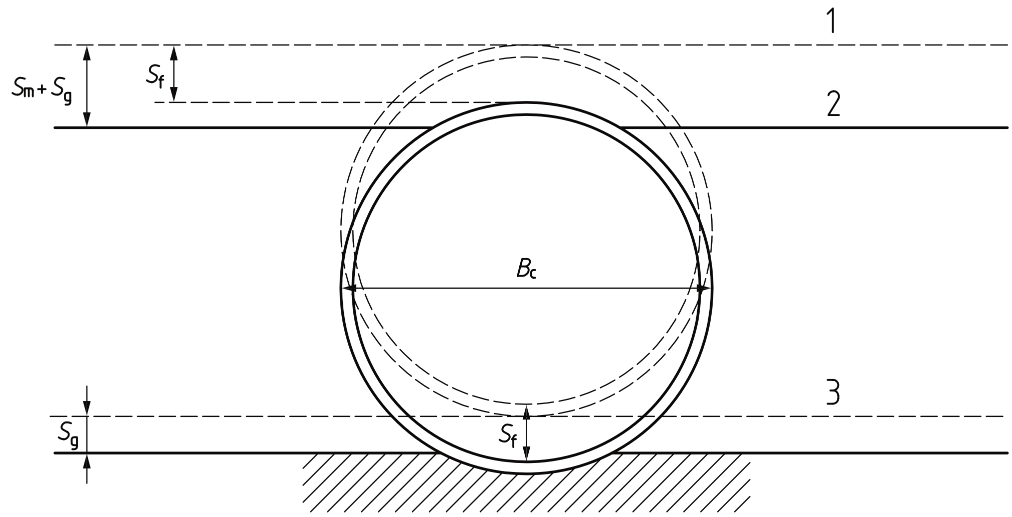
where

$$C_d = \frac{1 - e^{-2K\mu' H/B_d}}{2K\mu'}$$

5.5 Settlement deflection ratio, r_{sd}

The settlement deflection ratio for a positively projecting pipeline is given by the formula below Figure 14.

Figure 14 **Settlement deflection ratio**



Key

1 Critical plane (before loading)

2 Critical plane (after loading)

3 Natural ground (before loading)

$$r_{sd} = \frac{(S_m + S_g) - S_f}{S_m}$$

The settlement deflection ratio is evaluated by considering the situation of a pipe being laid on the surface of the ground, with the critical plane being at the pipe crown. Once loading occurs, the natural ground level goes down an amount S_g, the pipe goes down by the settlement of the pipe invert, S_f, and the critical plane goes down by the settlement of the fill, S_m, plus the settlement of the natural ground, S_g. The value of r_{sd} can vary between 0 and 1, with 0 being in very soft soils, and 1 being in rock (see Annex B and BS EN 1295-1:1997, **NA.4.3.2**).

5.6 Projection ratio, *p*

The projection ratio, *p*, is calculated as the proportion of the pipe external diameter that is above firm bedding level or the natural ground level. For class D, F and N beddings (see BS EN 1295-1:1997, Table NA.7) the value of *p* is unity. For all other granular and concrete beddings *p* equals 0.7.

5.7 Bedding factors

The load-bearing capacity of a rigid pipeline is the crushing strength of the pipe (given in European Standards) multiplied by the bedding factor (see BS EN 1295-1:1997, **NA.4.2**). BS EN 1295-1:1997, Table NA.7 shows that the bedding factor increases as more imported bedding material is provided to a rigid pipeline.

The purpose of the embedment is to distribute the vertical load (and its corresponding support reaction) around the pipe. By effectively distributing the loads the pipeline can carry more than the crushing strength load. A full embedment (bedding class S, see BS EN 1295-1:1997, Table NA.7) gives a bedding factor of 2.2, whereas a non-existent or minimal bedding (bedding class D or N) hardly distributes the loads at all, and results in a bedding factor of only 1.1.

The process of structural design is about effectively matching the loads to the load-bearing capacity of the pipe and its embedment to achieve an appropriate factor of safety.

Further information is given in Annex A and Annex B.

5.8 Crushing strength adjustments for pressure pipelines

Some rigid pipe materials, such as specially designed concrete, can be used for pressure situations. In this case it is necessary to make an adjustment to the crushing strength of the pipeline to account for the fact that as well as the backfill and traffic loading, some of the pipe's strength will also be required to contain the internal pressure within the pipeline.

For reinforced concrete pressure pipelines:

$$W_t' = W_t\left(1 - P_w / P_u\right) \qquad \text{(BS EN 1295-1:1997, equation 9)}$$

5.9 Minimum bedding factor and factor of safety

The required minimum bedding factor is obtained by using equation 8.

$$F_m \geqslant W_e F_{se} / W_t \left(\text{or } W_t'\right) \qquad \text{(BS EN 1295-1:1997, equation 8)}$$

The minimum factor of safety, F_{se}, is given in BS EN 1295-1:1997, Table NA.5.

Alternatively, given the crushing strength of the pipe, W_t, the total design external load, W_e, and the bedding factor, F_m, the actual design factor of safety can be calculated from the expression crushing strength, W_t, multiplied by bedding factor, F_m, divided by the total design external load W_e, and compared to the minimum factor of safety, F_{se}, given in BS EN 1295-1:1997, Table NA.5.

6 The design of semi-rigid pipelines

6.1 General

Semi-rigid pipes are those that display elements of both rigid and flexible pipe behaviour, i.e. they will both deflect and settle in response to loading. Typically the pipe materials that fall into this category are ductile iron and the thicker walled steels.

6.2 Pipe-soil stiffness factor, *n*

The pipe-soil stiffness factor, n, is obtained from equation 11 by considering the pipe surround material and its degree of compaction. In order to calculate this value, the deflection lag factor, D_L, (see **6.4**) needs to be selected from BS EN 1295-1:1997, Table NA.6 for the intended embedment and its compaction.

$$n = \frac{E' / D_L}{\left(105EI / D^3\right) + \left(0.8E' / D_L\right)} \qquad \text{(BS EN 1295-1:1997, equation 11)}$$

The overall modulus of soil reaction (E') is determined using equations 16 and 17 (see **6.5**).

Generally n has a value between 0 and 1. If the pipe stiffness (EI/D^3) is much greater than the soil stiffness (E'/D_L) then n tends to zero. Conversely, if the pipe stiffness is much lower than the soil stiffness then n tends to 1.25. For design purposes the maximum value of n is usually limited to 1.

6.3 Vertical soil pressure

The vertical soil pressure in wide trench or embankment installations is given by:

$$P_e = C_c \gamma B_c \qquad \text{(BS EN 1295-1:1997, equation 12)}$$

where

C_c is the lower of that given by equations 2 and 3 but with the settlement deflection ratio given by:

$$r_{sd} = 0.7\left(1 - n\right) \qquad \text{(BS EN 1295-1:1997, equation 13)}$$

When the pipe behaves as a rigid pipe (i.e. $n = 0$, from equation 11) then $r_{sd} = 0.7$, a value for a rigid pipe on a normal foundation. When the pipe is fully flexible ($n = 1$) then $r_{sd} = 0$ and the vertical pressure is the geostatic pressure, as used in flexible pipe design.

The vertical soil pressure for a narrow trench installation is given by:

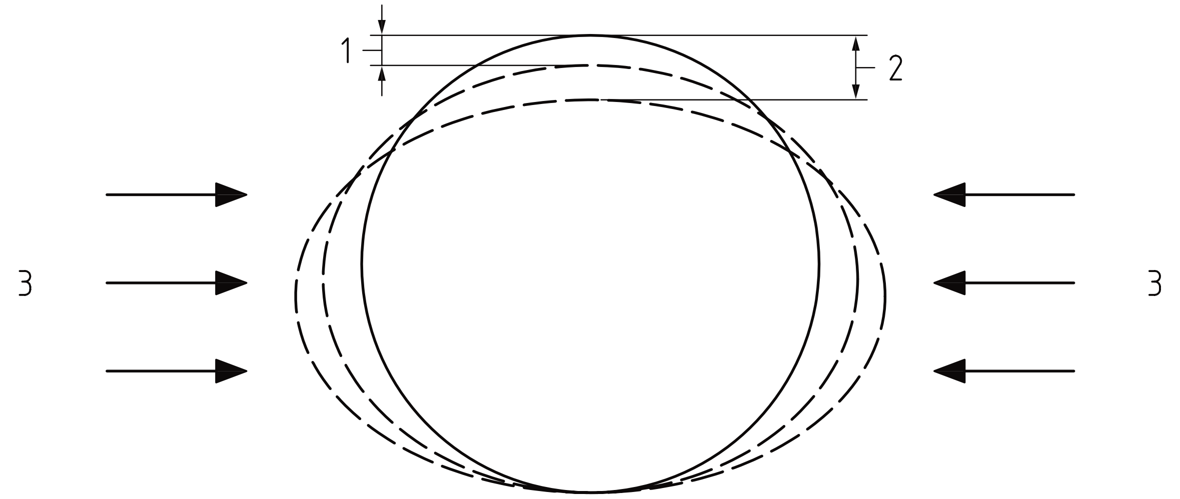
$$P_e = \frac{C_d \gamma {B_d}^2}{nB_d + \left(1 - n\right)B_c} \qquad \text{(BS EN 1295-1:1997, equation 14)}$$

Similarly, when $n = 0$ then the soil pressure is that for a rigid pipe and when $n = 1$ the equation gives the pressure acting on a flexible pipe according to Spangler [10].

6.4 Deflection lag factor, D_L

The deflection lag factor D_L (see Figure 15) takes account of the relaxation of the pressure of the sidefill over time resulting in further deflection of the pipe.

Figure 15 **Deflection lag factor**



Key

1 Initial deflection

2 Long-term deflection

3 Sidefill support

Ratio of long-term deflection to initial deflection = D_L

D_L gives an indication of the degree of compaction that occurs during the installation for a given embedment. It can be seen from BS EN 1295-1:1997, Table NA.6 that the greater the level of compaction, the lower the deflection lag factor. As the embedment becomes less favourable (for example Classes S5, B1 and B2) then the harder it is to achieve a low deflection lag factor.

The value of D_L is modified to D_{Lsr} when used in the semi-rigid ovalization analysis (see BS EN 1295-1:1997, **NA.5.2.3**) and leads to a ratio of initial to long-term deflection that is much lower than that for a flexible pipeline.

If the pipeline is to be pressurized with at least 3 bar [1)] working pressure within one year of burial, at a depth of less than 2.5 m then D_L can be taken as 1, since the internal water pressure will have the beneficial effect of preventing the long-term deflection from taking place.

6.5 Leonhardt's coefficient, C_L

Leonhardt's coefficient (soil modulus adjustment factor) is a way of evaluating the influence of the native modulus of soil reaction, E'_3, on the embedment modulus, E'_2, thereby arriving at an overall soil modulus value E'.

---

1) 1 bar = 100 kPa.

Leonhardt's coefficient, C_L, is calculated from equation 17 to obtain the effective pipe-soil stiffness factor.

$$C_L = \frac{0.985 + \left(0.544 B_d / B_c\right)}{\left\{1.985 - 0.456\left(B_d / B_c\right)\right\}\left(E_2' / E_3'\right) - \left\{1 - \left(B_d / B_c\right)\right\}}$$

(BS EN 1295-1:1997, equation 17)

The overall modulus of soil reaction, E', is then calculated from equation 16:

$$E' = E_2' C_L$$ (BS EN 1295-1:1997, equation 16)

If the trench is more than 4.3 times the external pipe diameter, then C_L does not need to be calculated and the overall modulus of soil reaction, E', can be taken as the embedment soil modulus, E_2'. This is because when the trench is so wide the native soil modulus has no effect on the embedment modulus in the pipe zone.

6.6 Ovalization, Δ/D

The ovalization or ring deflection of the pipeline (see BS EN 1295-1:1997, **NA.5.2.3** and **NA.6.2.4**) considers the backfill and traffic load placed upon it, which is resisted by the pipe stiffness and soil stiffness. Semi-rigid pipe materials exhibit different ovalization characteristics according to their stiffness. For metallic pipes, no creep of the material occurs, so the Young's modulus value, E, used in the stiffness calculation is constant. However, for plastics pipes (see BS EN 1295-1:1997, **NA.6.2.4**) a short-term value is used for the initial deflection, but when calculating long-term deflection, the creep factor of the material needs to be applied to the Young's modulus value.

Also considered is the beneficial re-rounding effect that comes from the presence of water pressure within the pipeline. This effect is said to be present provided the depth of cover to the pipeline is not more than 2.5 m. If the pipeline is buried at a greater depth, then the backfill pressure will be too great to allow re-rounding to occur.

The semi-rigid version includes the modified deflection lag factor D_{Lsr}, which is used in the equation for ovalization.

$$\frac{\Delta}{D} = \frac{K_x\left(D_{Lsr} P_e + P_s\right)}{8EI / D^3 + 0.061E'}$$ (BS EN 1295-1:1997, equation 18)

NOTE The initial deflection is obtained with the value of D_{Lsr} set at 1, and the long-term deflection with $D_{Lsr} = 1 + 0.8n(D_L - 1)$; *where D_L is the value obtained from BS EN 1295-1:1997, Table NA.6. If the working pressure is 3 bar or more and if the depth of cover does not exceed 2.5 m, the long term deflection can be reduced by the factor* $D_R = 1 - (P_i/40)$ *where P_i is the internal pressure in bars.*

6.7 Strain factor, D_f

The strain factor, D_f, was developed by Molin and is used in equation 19 and tabulated in BS EN 1295-1:1997, Table NA.6 for different pipe stiffnesses and embedments.

$$\sigma_{bs} = ED_f\left(\Delta / D\right)\left(t / D\right)$$ (BS EN 1295-1:1997, equation 19)

It can be seen that the higher the modulus of soil reaction and the stiffer the pipe, the lower the value of the strain factor. This is because less compactive energy is required to achieve the same embedment modulus. It is very important when choosing a pipe stiffness and embedment to consider the amount of compaction that will be required in the field to achieve the desired modulus of soil reaction.

6.8 Bending stress, σ_{bs}

The bending stress in the pipe walls due to the external load on the pipeline is calculated to ensure that the allowable bending stress is not exceeded. In the case of ductile iron pipes the allowable ovalization values are given in BS EN 545 and BS EN 598, and these limit the bending stresses. These standards also give values for the minimum stiffness (EI/D^3) for ductile iron pipes.

7 The design of flexible pipelines

7.1 General

It is important to remember that flexible pipes derive much of their structural strength from the embedment that is to the sides of the installed pipeline. Considering the response of flexible pipes to loading (see **4.2**) it can be appreciated that the embedment selection and compaction are very important where control of ovalization is required.

7.2 Vertical soil pressure

The backfill load on a flexible pipeline is given by the geostatic load, γH, with no other coefficients applied (see **4.2**).

$$P_e = \gamma H \qquad \text{(BS EN 1295-1:1997, equation 20)}$$

7.3 Embedment characteristics

Some flexible pipes will have fairly low stiffness and will be most at risk of absorbing energy from the embedment compaction in the effort to achieve the required modified Proctor density and modulus of soil reaction (see BS EN 1295-1:1997, Table NA.6) and so, for these pipes, the use of a self-compacting embedment such as a single sized gravel will achieve a high modulus with little compactive effort.

7.4 Critical pressure for buckling (long and short-term), P_{crl} and P_{crs}

The long-term and short-term critical buckling equations are identical except for the introduction of the creep factor in the long-term equation in the case of plastics pipes, turning the initial pipe stiffness into long-term stiffness. In the case of metallic pipes there is no creep to be considered, so the two equations are the same.

$$P_{cr} = 0.6\left(EI / D^3\right)^{0.33}\left(E'\right)^{0.67} \qquad \text{(BS EN 1295-1:1997, equation 21a)}$$

NOTE In equation 21a, the long and short-term values of the modulus (E) are used to calculate P_{crl} and P_{crs} respectively. (For metal pipes, the long and short-term moduli are identical.)

Where there is deemed to be no soil support, Timoshenko's critical buckling formula is used. It can be particularly necessary to consider this case where a pipeline has a shallow burial depth and could lose its side support if trenches for other utilities are dug nearby. Here the short-term stiffness value is adopted.

$$P_{cra} = 24EI / D^3 \qquad \text{(BS EN 1295-1:1997, equation 22a)}$$

7.5 Factor of safety against buckling, F_s

The equation for the factor of safety against buckling is given by equation 21.

$$F_s = 1/\left\{\left(P_e / P_{crl}\right) + \left(P_s + P_v\right) / P_{crs}\right\} \qquad \text{(BS EN 1295-1:1997, equation 21)}$$

The vertical soil pressure, P_e, is divided by the long-term critical buckling pressure, P_{crl}. This is because the earth load is always present. However, the surcharge pressure, P_s, and the vacuum pressure, P_v, (if present) are divided by the short-term critical buckling pressure, P_{crs}. This is because these are transient loads, to which the pipe's response will be with its short-term modulus.

7.6 Ovalization following re-rounding, $(\Delta/D)_R$

The ovalization or ring deflection of the pipeline (see BS EN 1295-1:1997, **NA.5.2.3** and **NA.6.2.4**) considers the backfill and traffic load placed upon it, which is resisted by the pipe stiffness and soil stiffness. For plastics pipes (see BS EN 1295-1:1997, **NA.6.2.4**) a short-term value is used for the initial deflection, but when calculating long-term deflection, the creep factor of the material needs to be applied to the Young's modulus value.

The beneficial re-rounding effect (see BS EN 1295-1:1997, **NA.6.2.5**) that comes from the presence of water pressure within the pipeline is said to be present provided the depth of cover to the pipeline is not more than 2.5 m, the pressure is greater than 3 bar and is applied within one year. If the pipeline is buried at a greater depth, then the backfill pressure will be too great to allow re-rounding to occur.

7.7 Combined stress in thermoplastics, σ_c

The combined stress equation (equation 25) calculates the net hoop stress generated, taking into account internal pressure and soil loading in the pipe walls by the presence of the internal pressure. This value is then compared against an allowable value for the pipe material.

$$\sigma_c = \left(P_i - P_e\right)D / 2t \qquad \text{(BS EN 1295-1:1997, equation 25)}$$

This equation is also used for the calculation of hoop stress in thin walled steel pipes.

7.8 Strain in GRP (glass reinforced plastics) pipes

Since GRP is a composite material, its response to loading is a little more complicated than for a homogeneous material.

For non-pressure pipelines the bending strain in the pipe walls (ε_b) is given by:

$$\varepsilon_b = D_f\left(\Delta / D\right)\left(t / D\right) \qquad \text{(BS EN 1295-1:1997, equation 26)}$$

In the case of pressure pipelines, the combined strain (ε_c) (see BS EN 1295-1:1997, **NA.6.2.7**) is given by:

$$\varepsilon_c = D_f \left(\Delta / D \right)_R \left(t / D \right) + P_i D / 2E_h t \quad \text{(BS EN 1295-1:1997, equation 27)}$$

Here the first term is the bending strain in the pipe walls, added to the hoop stress due to internal water pressure, divided by the hoop modulus of the pipe material.

The strain factor, D_f, was developed by Molin and is used in equations 26 and 27 (and tabulated in BS EN 1295-1:1997, Table NA.6 for different pipe stiffnesses and embedments). It can be seen that the higher the modulus of soil reaction and the stiffer the pipe, the lower the value of the strain factor. This is because less compactive energy is required to achieve the same embedment modulus. It is very important when choosing a pipe stiffness and embedment to consider the amount of compaction that will be required in the field to achieve the desired modulus of soil reaction.

Unlike thermoplastics, it is correct to add strains in thermoset pipe materials to ensure that the peak instantaneous, or long-term, strain value does not exceed a prescribed total. This is because failures in the walls of these pipes are normally due to excessive local strains (e.g. external impact can cause high tensile strains on the bore that later become a point of weakness). In contrast to the case with thermoplastics pipes, there is no stress relaxation of GRP under constant strain conditions (i.e. bending strain as the result of an applied ring deflection) in the walls of GRP pipes.

Annex A (informative) Other design considerations

A.1 Removal of trench support systems

The narrow trench load, as determined from equation 4, assumes that there will be relief of load due to friction at the fill/trench wall interface. However, should a trench be backfilled and compacted prior to the complete withdrawal of the trench support, the relieving friction at the interface may be substantially lost and the pipe load increased. In such cases the narrow trench load should be taken as equal to the total weight of the trench backfill.

Soil load for rigid pipes, see equation A.1:

$$W_c'' = H\gamma B_d \tag{A.1}$$

Soil pressure for semi-rigid pipes, see equation A.2:

$$P_e = H\gamma \frac{B_d}{B_c} \tag{A.2}$$

These narrow trench loads are then compared with the wide trench load (equation 1 for rigid, equation 12 for semi-rigid) and the lower value is used for the pipeline design.

For flexible pipes, the void formed by removing the trench support system between the trench wall and the backfill will reduce support from the native soil significantly and increase pipe deflection.

Where the pipe installation relies on the sidefill compaction then it should be carried out in layers and the trench support pulled progressively to enable the specified compaction to be achieved.

A.2 Uniformly distributed surcharge loads of large extent

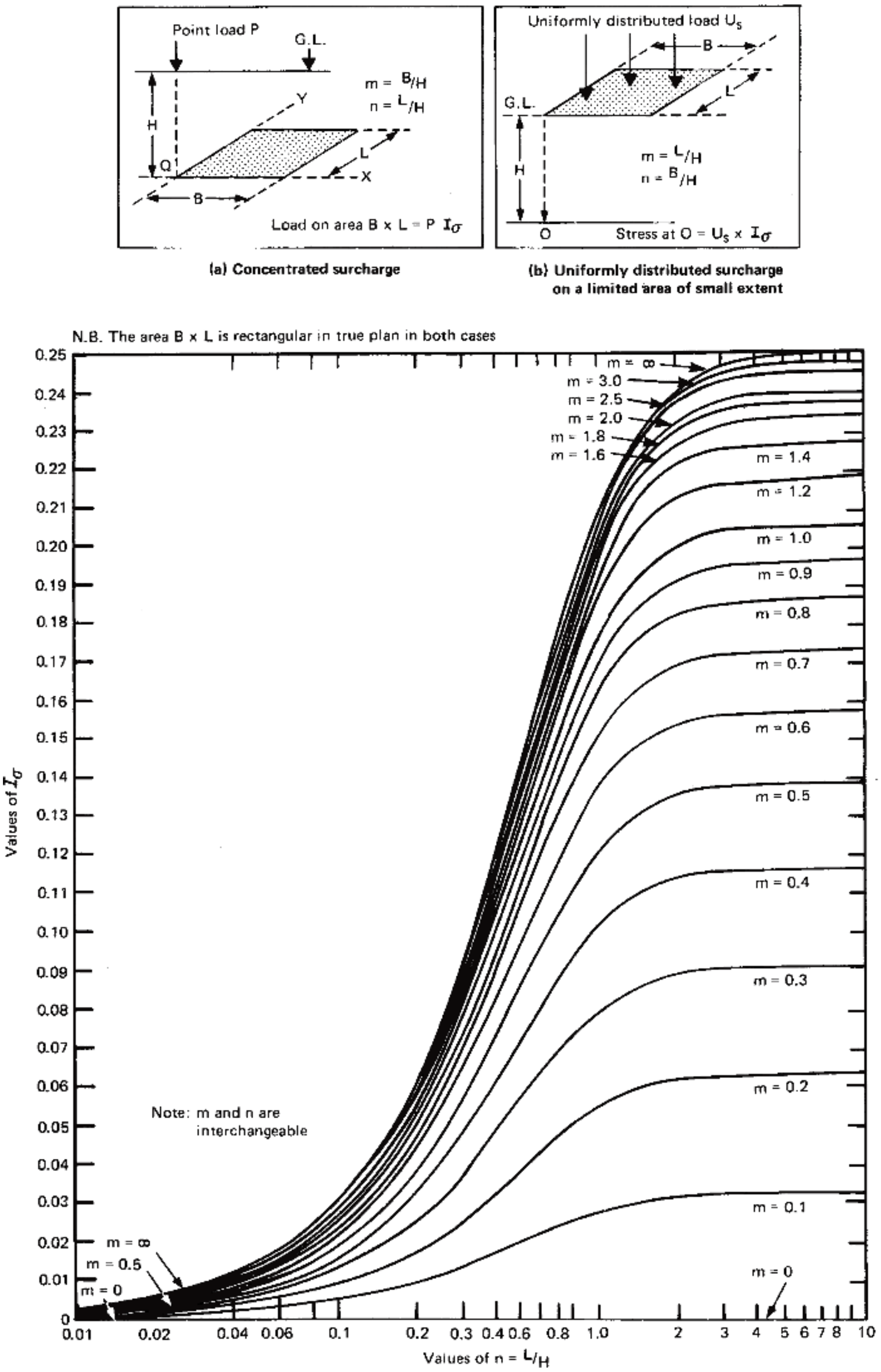
Such surcharges, often of a temporary nature, can occur through the raising of the ground surface level by filling with soil or other material. They can be allowed for in design by assuming a notional increase in the cover depth *H*. If the uniform surcharge is U_s kN/m^2 and unit weight of the soil is γ kN/m^3 then *H* is notionally assumed to be increased by U_s/γ metres.

The effect of vehicles operating on the raised surface will be diminished because of the increased cover depth. In calculating the total load on the pipes the true cover depth should be taken plus the increased fill load, unless the original fill load plus vehicle load was the greater.

A.3 Uniformly distributed surcharge loads of limited extent

The stress at a point below the ground surface [point O in Figure A.1(b)] is given by $U_s I_\sigma$, where the influence value I_σ can be found from Figure A.1. The surcharge may be in a fixed position in relation to the pipeline or it may be moveable. In the latter case it should be taken to be in the position giving greatest load on the pipe. This will generally be with the centre of gravity of the surcharge vertically above the pipe centre line. In general it will be necessary to divide the load into several rectangles as illustrated in Figure A.2, and obtain the answer by algebraic summation. Note that the point O, [see Figure A.1(b)] should always be vertically below one corner of the rectangle. Non-rectangular surcharges will need to be split into approximate rectangles. Having determined the vertical soil stress at the pipe crown the same stress is assumed to exist across the full breadth of the pipe and for unit run of pipeline, i.e. pipe load = stress × B_c per unit length. The procedure is approximate but errs on the safe side.

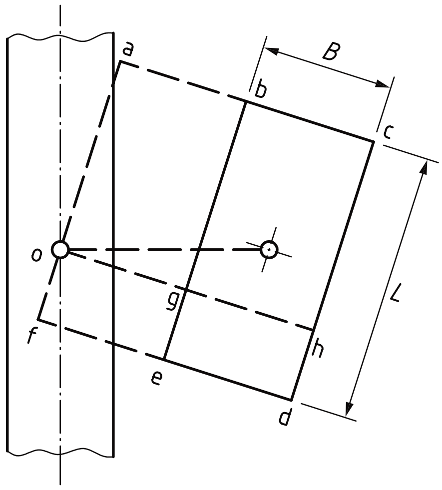
Figure A.1 **Soil loads and stresses produced by surface loads** (after Fadum [11]) (Reproduced from Young and O'Reilly [7] with permission from HMSO.)



The soil stress at the pipe crown produced by such a surcharge can be calculated in the manner illustrated in Figure A.2.

Heavy vehicles with broad caterpillar tracks may be treated in a similar manner.

Figure A.2 **Uniform surcharge U_s/unit area of limited extent in fixed position**



The vertical soil stress, σ, at O is:

$$\sigma = U_s I_\sigma$$

where I_σ is found from Figure A.1 by summation of separate influence values:

$$I_{oach} + I_{ohdf} - I_{oabg} - I_{ogef}$$

[see also Figure A.1(b)]

A.4 Surcharge pressure due to vehicle loads

The surcharge pressures (P_s) given in the BS EN 1295-1:2007, National Annex A are in graphical form and have been reproduced from the TRRL report *A guide to design loadings for buried rigid pipes* [7]. Axes on these charts are to logarithmic scales, which has to be taken into account when scaling. In a subsequent TRRL report *Simplified tables of external loads on buried pipelines* [8] the data for main roads and fields is presented in tabular form in Appendix II. This data has been reproduced in Table A.1 with addition of that for light roads and the fields value at 0.5 m depth of cover, based on the configuration of wheel loadings given in Figure 4.

Table A.1 **Surcharge pressures, P_s (kN/m^2)**

Cover depth H (m)	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**	**1.6**
Main roads	—	120	103	91	81.5	74	67.9	62.8	58.6	55	51.8	49
Light roads	—	120	100.6	85	72.8	63.2	55.3	48.6	43.2	38.5	34.6	31.2
Fields	85	69.5	57.5	48.6	41.6	36.1	31.6	27.8	24.7	22	19.8	17.8

Cover depth H (m)	**1.7**	**1.8**	**1.9**	**2**	**2.2**	**2.4**	**2.6**	**2.8**	**3**	**3.2**	**3.4**	**3.6**
Main roads	46.5	44.3	42.2	40.3	36.9	33.9	31.2	28.8	26.7	24.7	22.9	21.3
Light roads	28.2	25.7	23.4	21.5	18.2	15.6	13.5	11.8	10.3	9.2	8.2	7.3
Fields	16.1	14.7	13.4	12.3	10.4	8.89	7.69	6.72	5.91	5.24	4.67	4.19

Cover depth H (m)	**3.8**	**4**	**4.5**	**5**	**5.5**	**6**	**6.5**	**7**	**8**	**9**	**10**
Main roads	19.8	18.5	15.6	13.3	11.4	9.92	8.67	7.63	6.02	4.86	4
Light roads	6.6	6	4.8	3.9	3.2	2.7	2.3	2	1.5	1.2	1
Fields	3.78	3.43	2.73	2.23	1.85	1.56	1.3	1.15	0.88	0.69	0.57

The tabulated surcharge pressures can be determined approximately using the following:

main roads: $$P_s = \frac{54.5}{H} + \frac{42}{1.8^H} \tag{A.3}$$

light roads: $$P_s = \frac{39.5}{H^{1.5}} + \frac{59}{2.7^H} \tag{A.4}$$

fields: $$P_s = \frac{22.5}{H^{1.5}} + \frac{34}{2.7^H} \tag{A.5}$$

The error, at depths ⩽6 m, is within: ±5.4% for main roads, ±5.2% light roads and ±3.8% for fields.

The concentrated surcharge load for rigid pipes is given by:

$$W_{csu} = P_s B_c$$ (BS EN 1295-1:1997, equation 5)

A.5 Load coefficients for the incomplete projection condition

The load coefficient is determined using equation 3 in BS EN 1295-1:1997, but to solve this equation requires the height of the plane of equal settlement (H_e) as an input. The determination of this parameter is not given in BS EN 1295-1:1997 but the TRRL report *A guide to design loadings for buried rigid pipes* [7], based on original work by Spangler [12] showed that H_e can be found from:

$$\frac{e^{2K\mu H_e/B_c}-1}{2K\mu}\left(\frac{1}{2K\mu}+\frac{H-H_e}{B_c}+\frac{r_{sd}p}{3}\right)+\frac{1}{2}\left(\frac{H_e}{B_c}\right)^2+\frac{r_{sd}p}{3}\left(\frac{H-H_e}{B_c}\right)e^{2K\mu H_e/B_c}$$

$$-\frac{H_e}{2K\mu B_c}-\frac{HH_e}{B_c^2}=r_{sd}p\frac{H}{B_c} \tag{A.6}$$

BS EN 1295-1:1997 presents solutions of the above for specific values of $r_{sd}p$ in Table NA.2; an alternative is to use the following approximation:

$$C_c = \left\{0.68\left(r_{sd}p\right)^{0.41} + 1\right\}\frac{H}{B_c} - 0.1\left(r_{sd}p\right)^{0.57} \tag{A.7}$$

The error, when compared with Table NA.2, is within ±4.4% in the range: $r_{sd}p$ of 0 to 5 and $H/B_c \geqslant 0.3$. When the load is given by the incomplete projection condition then the error is reduced and is within −1.4% to +2.8%. For $H/B_c < 0.3$ the complete projection condition can be assumed.

The errors in using the approximation instead of the equations in Table NA.2 are detailed in Table A.2.

Table A.2 **Equation errors (percent)**

$r_{sd}p$	H/B_c						
	0.3	**0.5**	**0.7**	**1**	**10**	**100**	**500**
0	0	0	0	0	0	0	0
0.1	+1	+1.7	+2.1	+2.3	+2.8	+2.8	+2.8
0.3	+2	+1.9	+1.9	+1.9	+1.8	+1.8	+1.8
0.5	+1.6	+1.3	+1.1	+1	+0.8	+0.8	+0.8
0.7	+2	+1	+0.7	+0.4	−0.1	−0.2	−0.2
1	+4.4	+2.1	+1.2	+0.6	−0.5	−0.6	−0.6
2	+3.3	+1	+0.3	−0.3	−1.3	−1.4	−1.4
3	+2.1	+0.8	+0.3	0	−0.6	−0.6	−0.6
4	−1.6	−0.6	−0.2	0	+0.4	+0.5	+0.5
5	−4.2	−1.4	−0.4	+0.3	+1.4	+1.5	+1.6

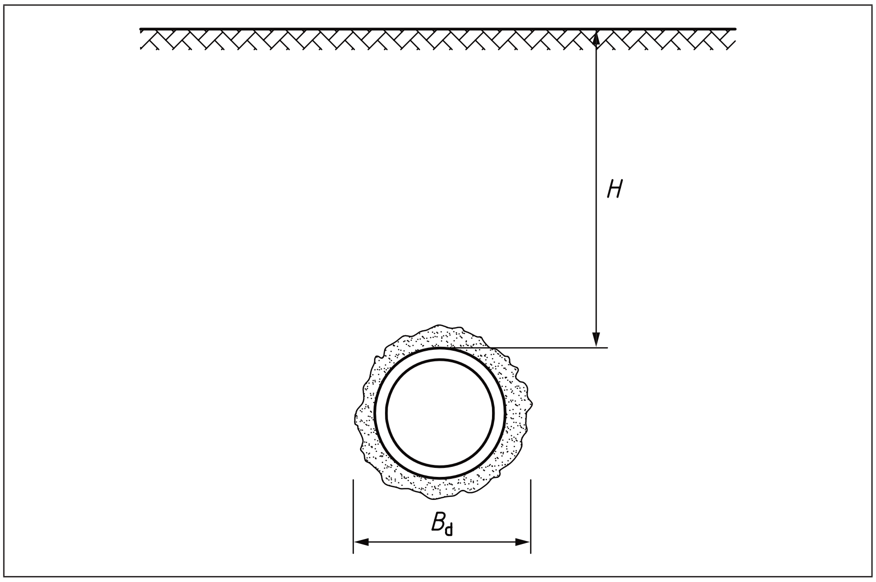
A.6 Pipes installed by jacking

When pipes are installed by jacking, the overlying soil can bridge over the pipe and relieve it of a substantial part of the load that would be imposed if it were installed in a trench. There is also the possibility of a reduction of bending moment in the pipe walls, particularly when the pipe is backgrouted after installation, as a result of the development of horizontal soil resistance. It is suggested that such pipes be designed as if laid in a trench having the same width as the hole cut through the soil (see Figure A.3) using the $K\mu$ value of the poorest soil over, or adjacent to, the pipe. This procedure is likely to produce a conservative design but, given the indeterminate nature of the problem, the uncertainty in the amount of bridging and in the development of side pressure, and the considerable difficulty of replacing damaged pipes, this is probably all to the good; in any event jacked pipes need to be sufficiently strong to resist the jacking forces applied during installation.

A.7 Pipes installed in tunnels and headings

Where the hydraulic design requires pipes less than 1 m diameter at depth, it might be appropriate to install such pipes within a tunnel or a heading or a larger jacked pipe. For conduits larger than 1 m diameter, using one of the conventional types of tunnel, or pipe jacking as considered in **A.6**, would be the normal solution when trenching is inappropriate. In most cases a tunnel or heading is a permanent structure, but on occasions it might only be needed during the construction of the pipeline.

Figure A.3 **Pipe in tunnel, heading or jacked into place**



A.8 Bedding factor for rigid pipes under an embankment

Because it is difficult to ensure good compaction of the sidefills for pipes in trenches, the effect of any lateral pressure on rigid pipes in trenches is generally neglected and this practice should be followed where pipes are laid in a trench dug into an embankment. However, for pipes placed as the embankment is being constructed and where succeeding layers of fill are then placed and compacted against and over the pipe, then the active pressure generated within the fill will act horizontally on the part of the pipe exposed above the natural ground and will produce moments in the pipe opposite to those produced by the vertical loads. This is the reason for the enhanced bedding factors given for the embankment conditions in BS EN 1295-1:1997, Table NA.7. The lateral pressure effectively reduces the effect of the vertical loads on the pipe but these are generally neglected because of uncertainty that the beneficial active pressure will be present.

A.9 Induced trench

Under high fills the induced trench method has been used as a means of reducing the load acting on the pipe. This introduces a "soft spot" over the pipe, producing a less stiff pipe/ground system which results in the loads arching across the pipe and thus being shed onto the sidefill. A similar effect may be produced in a more controlled fashion by installing a suitably designed semi-rigid or flexible pipe.

A.10 Longitudinal flexibility

The design procedure so far assumes that the support is uniformly distributed along the pipe.

Local concentration of support will:

a) cause the pipes to be loaded as beams (applies mainly to the smaller diameters);

b) result in increased ring bending at the support points;

c) produce increased shear stresses in the pipe walls; and

d) cause vertical shearing forces at joints.

Each of these can lower the supporting strength of a pipeline. Although the use of flexible joints considerably reduces the effects of a) to c) they can still act within the individual pipe length if proper care is not taken to ensure that there are no hard spots within the prepared bed or backfill.

When concrete beddings are used, unless the bedding is designed as a rigid beam spanning between supports, it is important to retain the flexibility of the joints. Gaps should be left in the in-situ concrete at each joint formed by vertical sheets of compressible material such as expanded polystyrene. It is essential that concrete is not allowed to enter the pipe joint.

At structures, e.g. buildings or manholes, the projecting piece of pipe should be kept as short as possible, just sufficient to make the joint, so as to reduce the length of the cantilever. Unless differential settlement is expected to be minimal the next adjoining pipe should also be kept short, so that the joints at each end act as a pair of hinges; if considerable settlement is expected a second short pipe should be used before commencing with full length pipes (see **A.13.3**).

A.11 Multiple pipes in trench

A.11.1 General

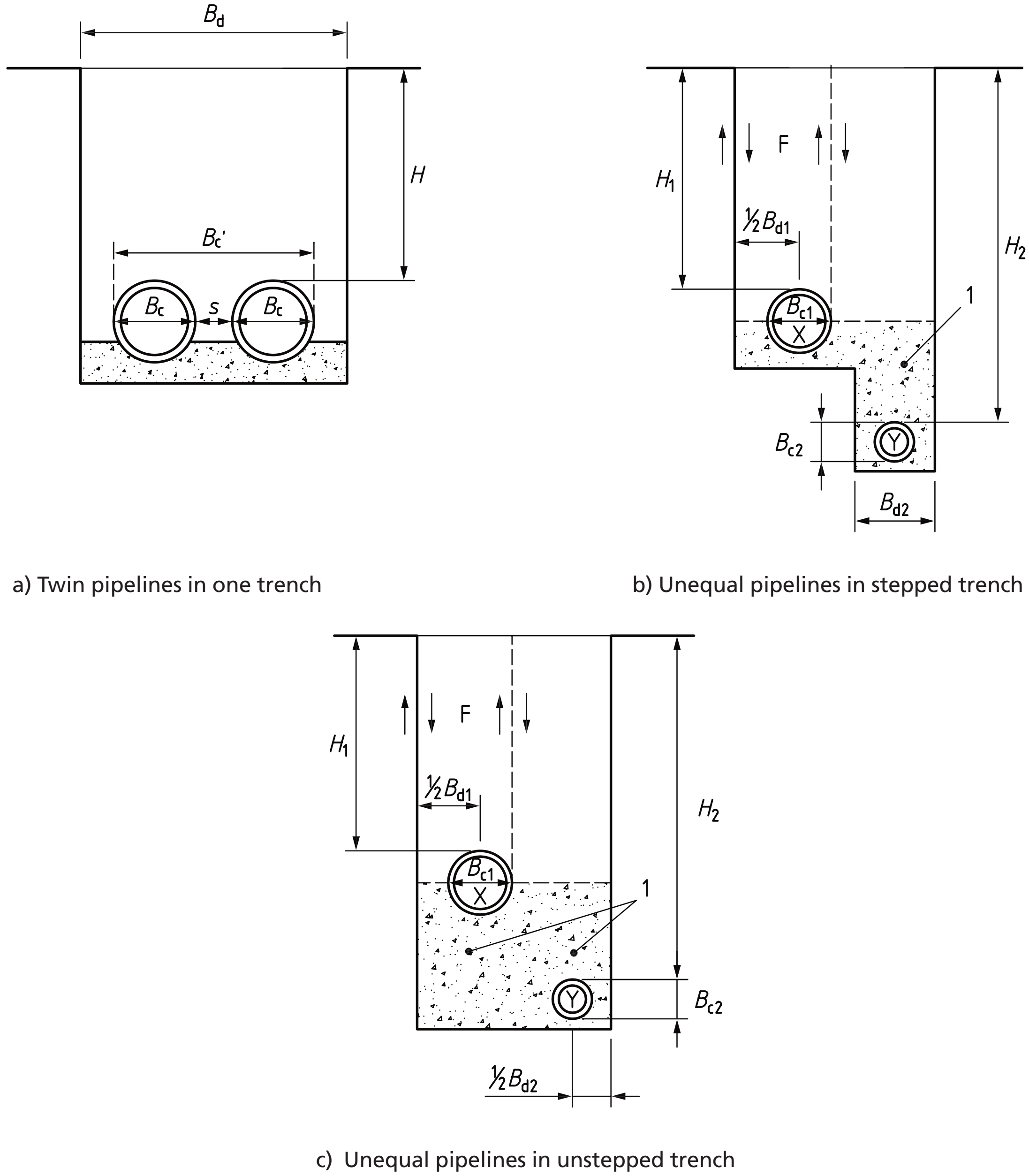
For convenience, two or more pipes are often laid in a single trench, the pipes being either at the same or at differing levels (see Figure A.4). In the latter case, the upper pipe is sometimes installed on a step in the trench [see Figure A.4b)]. There are risks attached to this practice since, even in firm ground, there is always the likelihood that the step will break or crack away intermittently so that support for the upper pipe will be non-uniform. As a result, the upper pipe might be overstressed due to inadequate arc of support from the bedding. Also, longitudinal bending stresses might be excessive, especially if the pipes are relatively long, or there might be leakage/failure at the joints due to shear. Only adequate compaction of the fill around the lower pipe and up to the springing of the upper pipe will eliminate this risk. The alternative is to omit the step, as shown in Figure A.4c); again full compaction of the bedding materials around the pipes is essential.

For calculation of the soil load:

- Rigid pipes: the soil loads can be estimated as detailed in **A.11.2** to **A.11.4**. If the pipe is $\leqslant$DN375 and is designed for wide trench loading, then no special calculation is needed.
- Semi-rigid pipes: the principles applied to rigid pipes can be used with the soil pressures determined by BS EN 1295-1:1997, equations 12 and 14.
- Flexible pipes: the geostatic pressure should be used.

The loads from surcharges are determined in the usual way.

Figure A.4 **Multiple pipe trenches**



Key

F Friction

1 Full compaction essential

A.11.2 Twin equal diameter pipelines (rigid pipes)

The pair of pipes may be considered as equivalent to a single pipe of outside width $B'_c = 2B_c + s$. The load on this equivalent pipe is the lesser of the two values $C_d \gamma B_d^2$ or $C_c \gamma B_c'^2$; the value of C_c is based on the ratio H / B'_c. The fill load on each pipe is one half the load on the equivalent pipe. If s exceeds about $B_c / 2$ the method errs on the safe side. The method may be adapted to multiple pipes in trench.

A.11.3 Unequal diameter pipelines in stepped trench (rigid pipes)

The load on the left-hand half of pipe X is given by $\frac{1}{2}C_{d1}\gamma B_{d1}^2$ or by $\frac{1}{2}C_{c1}\gamma B_{c1}^2$, whichever is the lesser. The load on the right-hand half of pipe X is given by $\frac{1}{2}C_{c1}\gamma B_{c1}^2$. The values of C_{d1} and C_{c1} are those appropriate to depth H_1. Provided the top of pipe Y is appreciably below the step it may be treated as being laid in a trench of width B_{d2} and the total weight on it will be the lesser of either $C_{d2}\gamma B_{d2}^2$ or $C_{c2}\gamma B_{c2}^2$. The values of C_{d2} and C_{c2} are those appropriate to depth H_2. If, however, the top of pipe Y is not below the level of the step it should be treated in two halves as for pipe X.

In calculating the load on the right-hand half of pipe X the value of $r_{sd}p$ used to determine C_{c1} needs consideration. Should the fill below the step be poorly compacted this will have the effect of increasing the effective value of $r_{sd}p$, and due allowances should be made for this. However, because of the risk already mentioned of the step breaking away, particular care should be exercised to obtain a high degree of compaction and ensure that settlement of this lower fill is reduced to an absolute minimum, by employing aggregate that is easy to compact and working it thoroughly into position.

A.11.4 Unequal diameter pipelines in unstepped trench (rigid pipes)

The halves of both pipes are treated separately as for pipe "X" in **A.11.3**.

Because of the greater thickness of bedding for the upper pipe, particularly if it is considerably higher than the lower one, care needs to be taken in the compaction of the bedding prior to laying the upper pipe and of the bedding up to the springing so as to minimize settlement and especially to ensure that such settlement is substantially uniform along the length of the pipe.

The method of treating each pipe in separate halves is also applicable to multiple pipes in trench.

A.12 Submerged pipeline

The effect of submergence is to reduce the "effective" vertical pressure exerted on the pipe by the backfill, owing to the buoyancy of the solid particles, and at the same time to exert a hydrostatic pressure on the pipe periphery of a magnitude dependent on the depth of submergence. Such hydrostatic pressure produces negligible bending moments in the walls of a circular pipe apart from the effect of the differing pressures at top and bottom of the pipe and this effect will be largely cancelled when the pipe runs full. The net effect on a circular pipe of submergence is therefore to reduce the bending moment. This is not the case for a non-circular conduit where the effect of the hydrostatic pressure has to be taken into account.

In practice most pipelines, owing to dewatering during construction and possibly during repair, will be subjected to the full overburden loads for some period during their life. Therefore no reduction should be taken for the effects of submergence.

Buoyant uplift forces will be present on buried pipelines located below the groundwater table equal to the weight of water displaced. Usually these forces are eliminated by the pressure of the backfill above the pipeline, but care needs to be exercised when designing large diameter pipelines at shallow depths of cover, and pipelines which will stand empty for long periods of time.

A.13 Pipelines in poor ground

A.13.1 Bedding construction in poor ground

Where the trench formation has little bearing strength and will not support pipe bedding material effectively, it might be necessary to provide a stable formation before pipelaying, particularly for gravity drainage or sewerage systems. Such conditions most commonly occur in peat, silty ground, soft to very soft alluvial clays, running sand, or in artificially filled ground.

Although soft trench formations are sometimes simply stabilized 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.

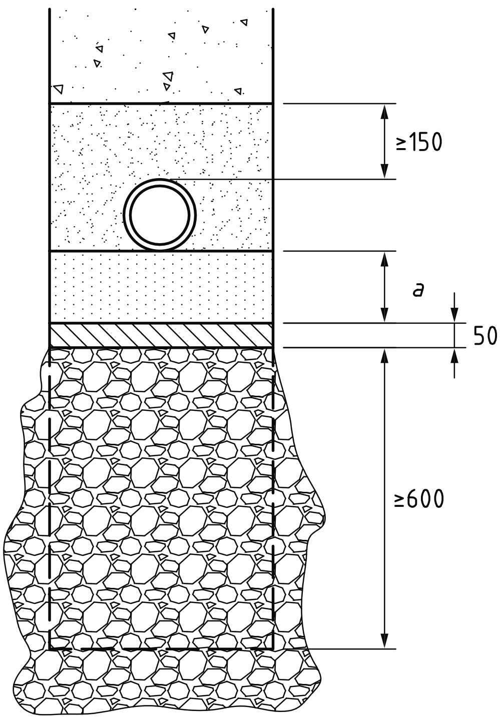
For example, the trench formation can be over-excavated to allow for the placing and compaction of hardcore or aggregate in layers to form a firm trench bottom and achieve some local ground compaction. In some cases this will need to be blinded before the pipes are laid on their specified bedding.

The pipe bedding construction requirements are calculated in the normal way but it is important that "wide trench" design criteria are used because "narrow trench" conditions cannot be guaranteed in this situation.

See Figure A.5.

Figure A.5 **Pipelines in poor ground**

Dimensions in millimetres



Key

a Depth of bedding material below pipe

50 mm Possible blinding thickness

Main backfill

Selected backfill

Granular bedding

Concrete blinding

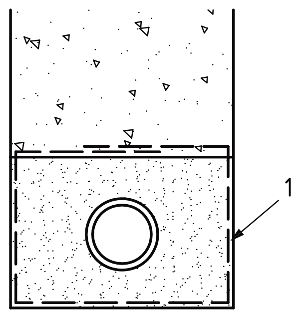
Compacted gravel rejects or small hardcore

Where groundwater is present at a level above trench formation in fine grained soils the strength of pipe beddings can be reduced. Granular bedding material encourages water movement, washing fines out of the surrounding ground, causing a loss of support to the bedding and pipeline.

The traditional method of dealing with this problem was to include a proportion of coarse sand in granular 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 in a geotextile as shown in Figure A.6, including any additional compacted material in the trench bottom as detailed for soft ground conditions.

Figure A.6 **Use of geotextile around pipe embedment**



Key

Main backfill

Pipe bedding/surround material

1 Geotextile wrapped over pipe bedding/surround

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. The specification for the geotextile, particularly the pore size, should be related to the nature of the fines in the ground, and specialist advice might need to be sought.

Prior to commencing pipelaying it is essential to satisfactorily dewater the trench formation. Any well point dewatering should 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.

Care should be exercised when using “drag-box” or similar trench support systems 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. It is important that backfilling should proceed progressively as the support system is removed.

Where pipes enter a rigid structure (manhole or building) care will be needed to provide adequate flexibility to deal with the differential settlement (see **A.13.3**).

A.13.2 Pipelines supported on piles

Where pipelines have to be laid in very poor ground such as bogs, the weak soils in low-lying coastal areas, or poorly compacted fill, the practice is sometimes adopted of supporting the pipeline on piles driven down into firmer ground, as shown in Figure A.7. In such cases the pipes can be subjected to a much enhanced loading when, as is almost inevitable, the adjoining ground settles relative to the pipeline.

Rigid pipes are usually laid with concrete haunching on a reinforced concrete beam of sufficient strength to span between the piles. Flexibility at joints is generally unnecessary although the effect of deflection of the beam on the pipes will need to be considered.

Semi-rigid pipes usually have sufficient beam strength to span piles and are located in concrete saddles to minimize the local support stresses; a competent structural pipelines engineer or the pipe manufacturer should be consulted for design details.

A study of soil loads for piled installations [13] showed that the load coefficient can be taken as:

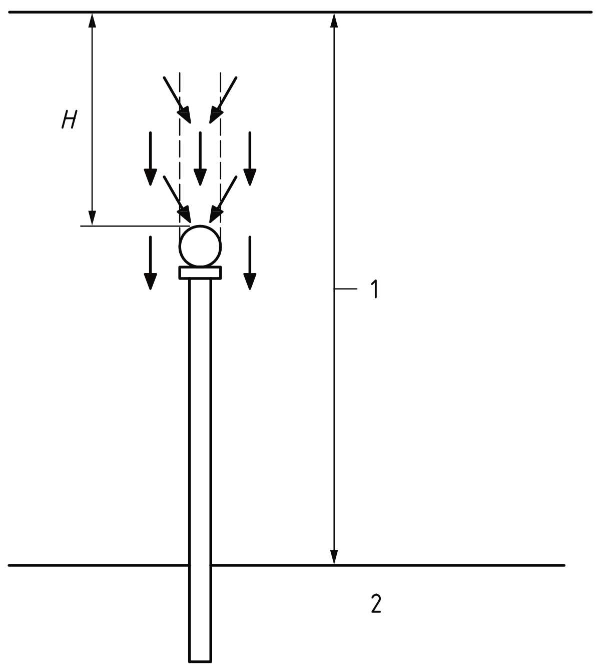
$$C_c = \frac{H}{B_c}\left[0.433\frac{H}{B_c}+1\right] \qquad \text{(A.8)}$$

The soil load is given by:

$$W_c' = C_c \gamma B_c^2 \qquad \text{(BS EN 1295-1:1997, equation1)}$$

For rigid pipes laid on beams on piles, the load should be calculated using the greater of the width of the beam or the outside diameter of the pipe or its concrete bedding and surround.

Figure A.7 **Pipeline on piles**



Key

1 Weak ground or poorly compacted fill

2 Original ground or firm statum

A.13.3 Rocker pipes

Where a pipeline is built into any manhole or inspection chamber, or other structure such as a groundbeam or concrete surround, some differential settlement between the pipeline and structure is to be expected.

To avoid the consequent high shear loads on the pipe built into the structure, the first flexible joint on the pipeline should be provided as close to the face of the structure as practicable. This should be within 150 mm for pipe diameters less than 300 mm.

A short length "rocker" pipe should be laid next before any full length pipes are used, to isolate the pipeline from small relative movements caused by differential settlement. The maximum length of the rocker pipe should be as shown in Table A.3. Short length pipes with pre-formed joints are available from manufacturers or plain-ended pipes may be cut to size.

Table A.3 **Recommended maximum length of rocker pipes**

Nominal pipe diameter mm	Maximum length m
<300	0.6
301 – 450	0.75
451 – 750	1.00
>750	1.25

NOTE For ductile iron pipes ⩾DN1100 the maximum length is given by DN + 100 mm.

Consideration should be given to the angular performance of the joints of short rocker pipes subject to significant settlement.

Where large differential settlements are anticipated, for example in waterlogged soils, peat, silt or made ground, the number of short length pipes may be increased, but it is essential that care is taken to ensure that allowable angular deflections at individual pipe joints are not exceeded. Shallow gradients should be avoided in soils where large settlements are likely, in order to minimize the possibility of deposition of solids.

Pipe materials with a high degree of longitudinal continuity and flexibility, such as welded polyethylene and welded steel, do not typically require rocker pipes at structures but other engineering solutions might be required where settlements are large.

A.13.4 Non-circular conduits

Examples of non-circular concrete pipes available are "eggs" and ellipses. They are available with flexible joints and may be designed in the same way as a circular pipe of the same plan width. Such non-circular sections are particularly useful for drainage where enhanced flow is needed.

Rectangular section culverts are also available in concrete. Their design is the same as for other structures in reinforced concrete, with the dimensions and reinforcement determined by analysis. For example, culverts under highways and railways have to carry the loads set out in BS 5400-2 and the structural members are designed to sustain the bending moments produced by the most adverse combination of loads and pressure. They are particularly useful for service ducts and subways under road and railways where headroom is restricted, and they can be installed much more rapidly than in-situ reinforced concrete structures.

A.14 Trench backfilled with concrete

A.14.1 Lean concrete

In some cases it may be considered that the best solution in the circumstances is to backfill a trench with lean concrete. Such a decision should not be taken lightly and any use of lean concrete backfill as a ploy to compensate for poor workmanship and lack of supervision will only lead to later difficulties. Where lean concrete is used its compressive strength should not exceed 5 MN/m^2 at 28 days. Apart from expense there are a number of drawbacks to the use of lean concrete backfill over pipes. Alternating stiff and weak, or hard and soft, conditions in nature often present difficulties and it is not generally good engineering to create them by putting a rigid backfill in pipe trenches. Just as hard spots cause problems below a pipe they can be a problem above. It is difficult to ensure, particularly if supervision is lacking, that some of the lean concrete backfill has not pierced, or displaced, the cushioning layer over the pipe and so is resting in places on the pipe; similarly, piped services straddling the trench could be encased in the rigid backfill. Excavation through lean concrete backfill for repairs or future connections to the pipe will be difficult and the likelihood is that the excavation will be made by attacking the backfill from the sides thus enlarging the opening in the road and increasing the danger of damage to nearby services.

With a vertical sided trench it seems reasonable to expect there will be occasions when, because of shrinkage of either the concrete or the soil, contact between the backfill and surrounding ground is lost, or the soil/concrete interface becomes lubricated, which is likely to diminish seriously any relieving friction at the interfaces. As in the case of delayed removal of trench sheeting, it is advisable to assume that the whole weight of the backfill will be carried by a rigid pipe and so equation A.1 applies; for semi-rigid pipe equation 14 should be used with $C_d = H/B_d$, and for flexible pipes equation 20 should be used. For a V-shaped or stepped trench the argument would not apply provided there was a cushion of at least 150 mm, but preferably 300 mm, of soil between the top of the pipe and the bottom of the concrete filling. In such a case, much of the weight can be borne directly by the soil at the sides provided that the shear strength of the soil in the steps or V-slopes is adequate to carry it.

As regards traffic loading, while it has been shown in experiments that the stresses induced in pipes by traffic are reduced when concrete backfill is used, it is not considered appropriate to make allowance for this.

Lean concrete is of course a very useful material for reinstating the layers of the road itself and nothing in the foregoing should be construed as implying the contrary.

A.14.2 Foamed concrete

Foamed concrete is often used for reinstating trenches, particularly in highways, but there is no reason why it should not be used in new construction as an alternative to lean concrete.

Advantages of foamed concrete include the following:

a) very easy to place;

b) self-levelling and self-compacting;

c) similar density and strength to original soil;

d) lighter than lean or structural concretes;

e) can be excavated;

f) can form part of the pavement construction (but not the surface course).

As it is self-compacting, there should be good contact between the concrete and the wall of the trench, providing some reduction in loading. However, for small pipes (e.g. DN600) it is prudent to ignore this effect and to assume that the full weight of the backfill will be carried by a rigid pipe and so equation A.1 applies; for a semi-rigid pipe equation 14 should be used with $C_d = H/B_d$, and for flexible pipes equation 20 should be used.

Foamed concrete should conform to TRL Application Guide AG39 [14]. Within highways, the material should be approved by the Highway Authority. A C2 mix (a compressive strength of 2 N/mm^2 to 10 N/mm^2 at 90 days) may be used for all layers up to sub-base in all road types and for sub-base in Road Types 3 and 4[2)]. A C4 mix (4 N/mm^2 to 10 N/mm^2 at 90 days) should be used for road base and for sub-base in Road Types 1 and 2[2)].

Because of its fluidity, foamed concrete presents a drowning hazard for the first three to six hours after pouring.

A.14.3 Concrete surround to flexible pipes

In general concrete surround is not normally needed for flexible pipes.

Where plastics pipes under internal pressure are to be surrounded in concrete some, if not all, of the hoop stress will be transferred to the concrete, which is typically much stiffer than the pipe. The designer will need to check specific cases but, except for small pipe sizes, will need to include steel reinforcement to carry the hoop load. Additionally the pipe might need some soft wrapping material at entry and exit from the concrete surround to provide a transition from the rigid surround. For GRP pipe fittings surrounded in concrete it might be more cost and structurally effective to reinforce the concrete rather than to attempt to allow expansion and wrap the full length of the pipe or fitting in soft material. This is because compression of the wrap will induce hoop load on the concrete and because the fittings themselves might need reinforcement to withstand the distortion caused by internal pressure.

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2) As defined in the Highway Authorities and Utilities Committee [HAUC (UK)] document *New Roads and Street Works Act 1991. Specification for the reinstatement of openings in highways* [15].

A.15 Thrust blocks

Thrust is generated in pressure pipelines where there are changes in direction, changes in diameter, closed valves etc. Generally these thrusts are resisted either by concrete thrust blocks cast against undisturbed soil, or some form of continuity in the pipeline which enables the soil friction to be mobilized. This continuity can be generally gained by welded joints in the case of steel or polyethylene, or anchored joints in the case of ductile iron. It is essential that the anchorage length is checked to ensure its sufficiency, and the effect of any joints which will not transmit longitudinal tension has to be taken into account. These joints might need to be tied or anchored via an in-line thrust block. Where anchored joints are used, for example using toothed gaskets for ductile iron pipe, allowance has to be made for the movement which is required for the anchorage to take effect.

A.16 Pipes at shallow depths

A.16.1 General

Where pipes have to be laid at shallow depths special precautions are required to reduce the risk of damage.

A.16.2 Protection to shallow pipelines

Shallow pipelines might 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 as follows:

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.

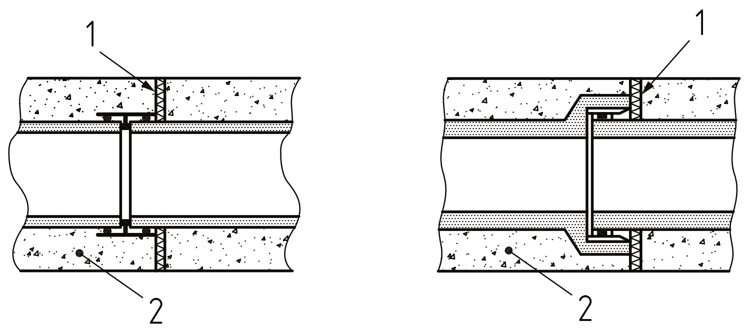
Where pipelines are likely to be exposed to construction activity and cannot be isolated by directing site traffic away from them they may be temporarily bridged, or protected by choosing a stronger bedding combination.

In general, 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.

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 either bitumen impregnated insulating board conforming to BS EN 622-4:1997, 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.

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 A.8, particularly in building drainage applications.

Figure A.8 **Protection of a shallow pipeline using concrete surround**



a) Sleeve jointed pipes

b) O-ring jointed pipes

Key

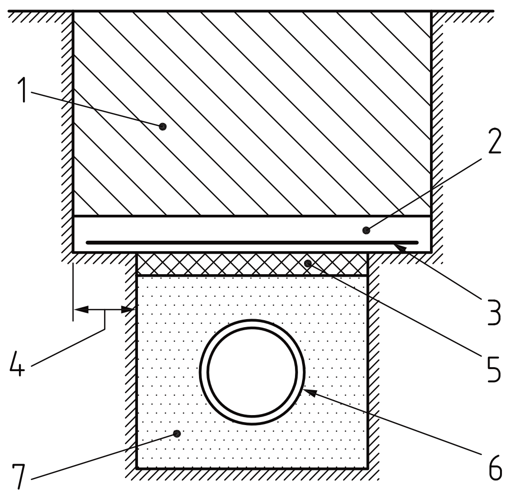
1 Compressible material at one end of sleeve

2 Concrete surround

Where more uniform support of the pipeline is found, the construction joints at pipe joints may be less frequent. However, it is recommended that they are not more than 5 m apart.

An alternative method of protection is to use concrete slabs of sufficient strength to span the trench, as shown in Figure A.9.

Figure A.9 **Protection of shallow pipeline with a slab**



Key

1 Backfill

2 Concrete slab

3 Reinforcement

4 Minimum 300 mm bearing on original ground

5 Compressible material

6 Pipe

7 Granular surround

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 and its bearing have to be structurally capable of carrying the imposed load. In roads with a reinforced concrete slab construction, this can be easily accomplished by continuing the slab over the trench. Separate slabs might 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 material in the normal way as shown in Figure A.9.

In all cases, backfilling should be carefully carried out as recommended in BS EN 1610:1998, Clause **11**.

Where concrete backfill to trenches is demanded for early permanent reinstatement, either using lean mix or foamed 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.

A.17 Laying rigid pipes with concrete beds or surrounds

Where bedding or surrounding a pipe in concrete is required it is important to ensure that the trench formation will provide a firm foundation for the concrete bed, for example by using a blinding layer of weak concrete or granular material, or its value in strengthening the pipeline will be lost. It might 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 dimensions for concrete bedding or surround are sufficient 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 is the greater.

All concrete for pipe bedding should be of structural quality, minimum C20/25, and should be thoroughly compacted into place. Care should be taken in placing concrete so as not to move pipes or construction joints.

Plain and reinforced concrete beddings and surrounds are illustrated in Figure A.10. The use of concrete arches is not recommended because it is difficult to ensure adequate support of the base of the arch at the sides of the pipes. Additionally, since 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 counter or even overtake the higher bedding strength of an arch or surround.

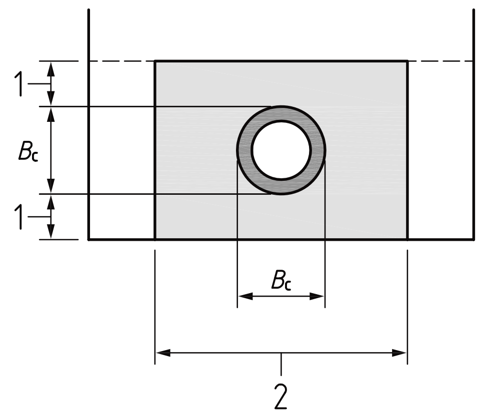
For reinforced concrete beds, the minimum transverse steel area should not be less than 0.4% of the area of the concrete in longitudinal section.

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.

The area of vertical steel within the reinforced surround and longitudinal steel in bedding or surround is nominal for construction purposes, where flexibility at joints is maintained.

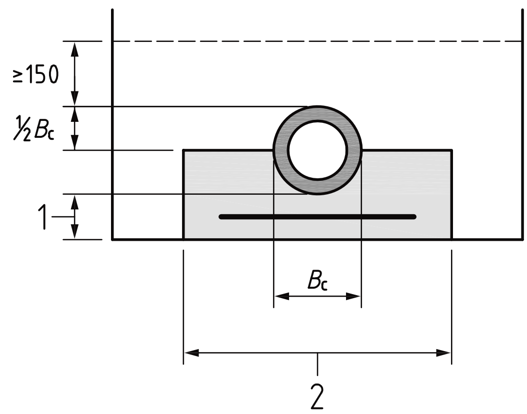
Figure A.10 **Plain and reinforced beddings and surrounds**

Dimensions in millimetres

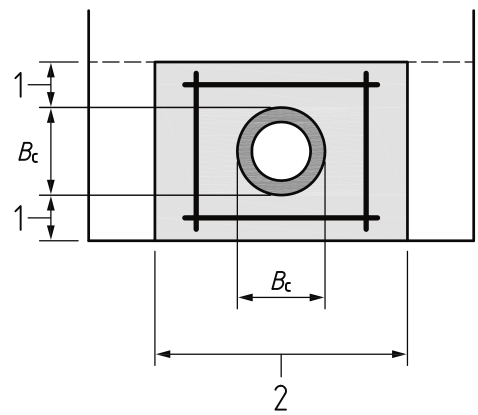


a) Unreinforced concrete surround. Bedding factor 4.5 (maximum diameter 600 mm)

Reference: ASCE *Gravity sanitary sewer design and construction* [16]

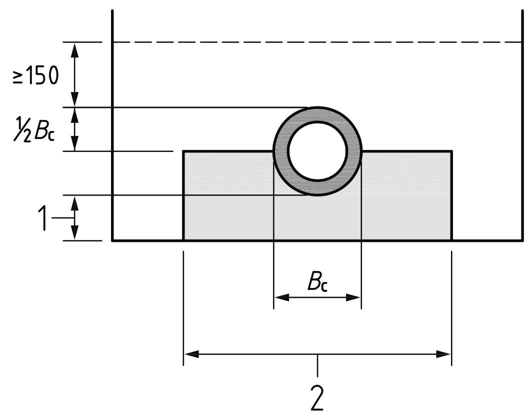


b) Reinforced concrete bed. Bedding factor 3.4 (0.4% steel)



c) Reinforced concrete surround. Bedding factor 4.8 (4 × 1% steel)

Reference: TRRL *Simplified tables* [8]



d) Unreinforced concrete bed. Bedding factor 2.6

Key

1 The larger of ¼B_c or 150 mm

2 The larger of 1½B_c or B_c + 300 mm

NOTE The two right-hand diagrams [b) and d)] are versions of Bedding Class A shown in BS EN 1295-1:1997, Table NA.7. The level of the concrete is shown horizontally at springing level since that is what is required to achieve the stated bedding factor, and concrete is often placed to that level in practice. The dimensions shown are also slightly larger here than those shown in BS EN 1295-1:1997, National Annex A, for practical reasons.

Annex B (informative) Simplified tables

B.1 Simplified bedding table for vitrified clay pipes

B.1.1 General

Table B.1 has been simplified from the information given in the bedding construction tables [17] available from the Clay Pipe Development Association (CPDA) and is compatible with the method of calculation described in this British Standard.

The parameters given in **B.1.2** to **B.1.6** have been used.

B.1.2 Pipes and pipe strengths

Table B.1 covers vitrified clay pipes as specified in BS EN 295-1 of classes and crushing strengths normally available in the UK. Other classes and crushing strengths may be found in BS EN 295-1.

B.1.3 Pipe embedments and bedding factors

Table B.1 shows rigid pipe embedments of classes D, N, F, B and S as specified in BS EN 1295-1:1997, Table NA.7, using the bedding factors specified in BS EN 1295-1:1997, **B.1.12**, reference 4) (IGN 4-11-02 [18]).

B.1.4 Loading conditions

Loads have been calculated for pipes laid in trenches either in main roads or in fields and gardens to cover the range of normal applications. Calculations for special circumstances can be made using the information in this British Standard.

B.1.5 Trench widths

Table B.1 assumes the existence of wide trench conditions. Full calculations for narrow trenches could result in more economic use of bedding materials or greater depth of application for the same pipe strength.

B.1.6 Depths of cover

Table B.1 sets out the applicable ranges of depths of cover for each pipe size, pipe strength, loading condition and type of embedment, with a maximum depth shown limited to a practicable value of 6.0 m. Where this depth can be exceeded the value 6.0+ is shown and further values can be found in the CPDA tables [17]. However, both at greater depths and at shallow depths, particularly less than 1.0 m, there might be additional considerations to be taken into account as set out in this British Standard.

Table B.1 **Simplified table for the embedment of vitrified clay pipes**

Nominal diameter mm	**Bedding construction class**	**Bedding factor**	**Pipe strength class**	**Crushing strength** kN/m	**Main roads** m	**Fields and gardens** m
100	D or N	1.1	—	28 40	0.4 – 5.7 0.4 – 6.0+	0.4 – 6.0+ 0.4 – 6.0+
	F	1.9	—	28 40	0.4 – 6.0+ 0.4 – 6.0+	0.4 – 6.0+ 0.4 – 6.0+
	B or S	2.5	—	28 40	0.4 – 6.0+ 0.4 – 6.0+	0.4 – 6.0+ 0.4 – 6.0+
150	D or N	1.1	—	28 40	0.7 – 3.4 0.6 – 5.6	0.6 – 4.0 0.6 – 5.9
	F	1.9	—	28 40	0.6 – 6.0+ 0.6 – 6.0+	0.6 – 6.0+ 0.6 – 6.0+
	B or S	2.5	—	28 40	0.6 – 6.0+ 0.6 – 6.0+	0.6 – 6.0+ 0.6 – 6.0+
200	D or N	1.1	160 200 240	32 40 48	0.8 – 2.7 0.6 – 4.0 0.6 – 5.1	0.6 – 3.5 0.6 – 4.5 0.6 – 6.0+
	F	1.9	160 200 240	32 40 48	0.6 – 6.0+ 0.6 – 6.0+ 0.6 – 6.0+	0.6 – 6.0+ 0.6 – 6.0+ 0.6 – 6.0+
	B or S	2.5	160 200 240	32 40 48	0.6 – 6.0+ 0.6 – 6.0+ 0.6 - 6.0+	0.6 – 6.0+ 0.6 – 6.0+ 0.6 – 6.0+
225	D or N	1.1	160 200	36 45	0.9 – 2.7 0.6 – 3.9	0.6 – 3.5 0.6 – 4.4
	F	1.9	160 200	36 45	0.6 – 5.9 0.6 – 6.0+	0.6 – 6.0+ 0.6 – 6.0+
	B or S	2.5	160 200	36 45	0.6 – 6.0+ 0.6 – 6.0+	0.6 – 6.0+ 0.6 – 6.0+
300	D or N	1.1	120 160 240	36 48 72	— 0.8 – 2.7 0.6 – 5.1	0.6 – 2.5 0.6 – 3.5 0.6 – 5.4
	F	1.9	120 160 240	36 48 72	0.6 – 4.2 0.6 – 6.0 0.6 – 6.0+	0.6 – 4.6 0.6 – 6.0+ 0.6 – 6.0+
	B or S	2.5	120 160 240	36 48 72	0.6 – 5.9 0.6 – 6.0+ 0.6 – 6.0+	0.6 – 6.0+ 0.6 – 6.0+ 0.6 – 6.0+
375	D or N	1.1	95 120 160	36 45 64	— — 0.7 – 3.4	0.9 – 1.9 0.6 – 2.7 0.6 – 4.0
	F	1.9	95 120 160	36 45 64	0.7 – 3.2 0.6 – 4.5 0.6 – 6.0+	0.6 – 3.9 0.6 – 5.0 0.6 – 6.0+
	B or S	2.5	95 120 160	36 45 64	0.6 – 4.8 0.6 – 6.0+ 0.6 – 6.0+	0.6 – 5.2 0.6 – 6.0+ 0.6 – 6.0+

Table B.1 **Simplified table for the embedment of vitrified clay pipes** *(continued)*

Nominal diameter mm	Bedding construction class	Bedding factor	Pipe strength class	Crushing strength kN/m	Main roads m	Fields and gardens m
400	D or N	1.1	95	38	—	0.9 – 1.8
			120	48	—	0.6 – 2.6
			160	64	0.8 – 2.9	0.6 – 3.7
	F	1.9	95	38	0.8 – 3.0	0.6 – 3.8
			120	48	0.6 – 4.4	0.6 – 4.9
			160	64	0.6 – 6.0+	0.6 – 6.0+
	B or S	2.5	95	38	0.6 – 4.6	0.6 – 5.1
			120	48	0.6 – 6.0+	0.6 – 6.0+
			160	64	0.6 – 6.0+	0.6 – 6.0+
450	D or N	1.1	95	43	—	0.8 – 1.9
			120	54	—	0.6 – 2.7
			160	72	0.8 – 3.0	0.6 – 3.8
	F	1.9	96	43	0.7 – 3.2	0.6 – 3.9
			120	54	0.6 – 4.5	0.6 – 5.0
			160	72	0.6 – 6.0+	0.6 – 6.0+
	B or S	2.5	96	43	0.6 – 4.8	0.6 – 5.2
			120	54	0.6 – 6.0+	0.6 – 6.0+
			160	72	0.6 – 6.0+	0.6 – 6.0+
500	D or N	1.1	96	48	—	0.8 – 1.9
			120	60	—	0.6 – 2.7
			160	80	0.8 – 3.0	0.6 – 3.8
	F	1.9	96	48	0.7 – 3.2	0.6 – 3.9
			120	60	0.6 – 4.5	0.6 – 5.0
			160	80	0.6 – 6.0+	0.6 – 6.0+
	B or S	2.5	96	48	0.6 – 4.8	0.6 – 5.2
			120	60	0.6 – 6.0+	0.6 – 6.0+
			160	80	0.6 – 6.0+	0.6 – 6.0+
600	D or N	1.1	80	48	—	—
			95	57	—	0.8 – 1.9
			160	96	0.7 – 3.1	0.6 – 3.8
	F	1.9	80	48	1.0 – 2.1	0.6 – 3.2
			95	57	0.7 – 3.2	0.6 – 3.9
			160	96	0.6 – 6.0+	0.6 – 6.0+
	B or S	2.5	80	48	0.6 – 3.8	0.6 – 4.4
			95	57	0.6 – 4.8	0.6 – 5.2
			160	96	0.6 – 6.0+	0.6 – 6.0+

B.2 Simplified bedding table for concrete pipes

Table B.2 sets out the applicable ranges of depths of cover for each pipe size, pipe strength, loading condition and type of embedment, with a maximum depth shown limited to a practicable value of 6.0 m. Where this depth can be exceeded the value 6.0+ is shown.

Advice on depths greater than 6.0 m should be sought from the pipe manufacturer and an experienced structural pipeline design engineer.

Pipes up to and including DN600 are assumed to be unreinforced, DN675 and above are assumed to be reinforced. The user should check with the manufacturer to confirm whether pipes are reinforced or unreinforced.

Bedding factors are as given in BS EN 1295-1.

Table B.2 **Simplified bedding table for concrete pipes**

DN	**Bedding class**	**Bedding factor**	**Pipe strength class**	**Crushing strength** kN/m	**Main roads** m	**Fields** m
225	D	1.1	120	27	—	0.6 – 2.4
	F	1.5	120		0.9 – 3.2	0.6 – 6.0+
	B	1.9	120		0.9 – 6.0+	0.6 – 6.0+
	S	2.2	120		—	—
300	D	1.1	120	36	—	0.6 – 3.2
	F	1.5	120		1.0 – 6.0+	0.6 – 6.0+
	B	1.9	120		0.9 – 1.0	—
	S	2.2	120		0.9 – 6.0+	—
375	D	1.1	120	45	—	0.6 – 2.2
	F	1.5	120		1.0 – 2.4	0.6 – 3.8
	B	1.9	120		0.9 – 5.2	0.6 – 6.0+
	S	2.2	120		0.9 – 6.0+	6.0+
450	D	1.1	120	54	—	0.6 – 2.6
	F	1.5	120		0.9 – 2.8	0.6 – 4.4
	B	1.9	120		0.9 – 6.0+	0.6 – 6.0+
	S	2.2	120		6.0+	6.0+
525	D	1.1	120	63	—	0.6 – 2.8
	F	1.5	120		0.9 – 3.6	0.6 – 5.0
	B	1.9	120		0.9 – 6.0+	5.0 – 6.0+
	S	2.2	120		6.0+	—
600	D	1.1	120	72	—	0.6 – 2.4
	F	1.5	120		1.0 – 3.0	0.6 – 4.6
	B	1.9	120		0.9 – 6.0+	0.6 – 6.0+
	S	2.2	120		6.0+	6.0+
675	D	1.1	120	81	—	0.9 – 1.8
	F	1.5	120		—	0.6 – 3.4
	B	1.9	120		0.9 – 4.2	0.6 – 5.4
	S	2.2	120		0.9 – 6.0+	0.6 – 6.0+
750	D	1.1	120	90	—	0.9 – 2.0
	F	1.5	120		—	0.6 – 3.6
	B	1.9	120		0.9 – 4.6	0.6 – 5.6
	S	2.2	120		0.9 – 6.0+	0.6 – 6.0+
825	D	1.1	120	99	—	0.9 – 2.0
	F	1.5	120		—	0.6 – 3.8
	B	1.9	120		0.9 – 5.0	0.6 – 5.8
	S	2.2	120		0.9 – 6.0+	0.6 – 6.0+

Table B.2 **Simplified bedding table for concrete pipes** *(continued)*

DN	Bedding class	Bedding factor	Pipe strength class	Crushing strength kN/m	Main roads m	Fields m
900	D	1.1	120	108	—	0.9 – 1.8
	F	1.5	120		—	0.6 – 3.2
	B	1.9	120		0.9 – 3.6	0.6 – 4.6
	S	2.2	120		0.9 – 5.2	0.6 – 5.8
1050	D	1.1	120	126	—	0.9 – 2.0
	F	1.5	120		1.4 – 1.6	0.6 – 3.4
	B	1.9	120		0.9 – 4.0	0.6 – 5.0
	S	2.2	120		0.9 – 5.6	0.6 – 6.0+
1200	D	1.1	120	144	—	0.6 – 2.0
	F	1.5	120		1.4 – 1.6	0.6 – 3.4
	B	1.9	120		0.9 – 4.0	0.6 – 5.0
	S	2.2	120		0.9 – 5.6	0.6 – 6.0+

B.3 Simplified bedding table for ductile iron pipes

B.3.1 Pipe details

Water pipes with flexible joints should be in accordance with prEN 545:2009. DN80 to DN300 pipes should be class 40 and DN350 to DN600 pipes should be class 30. Pressure sewer pipe with flexible joints should be in accordance with BS EN 598:2007+A1.

B.3.2 Embedment classes

Embedment classes are defined in BS EN 1295-1:1997, Table NA.8, and those relevant to the embedment tables for ductile iron pipe are reproduced in Table B.3.

Table B.3 **Embedment classes**

Class	Component	Materials
S1	Bed and sidefill	Gravel (single size)
S2		Gravel (graded)
S3		Sand and coarse grained soil with <12% fines
S4		Coarse grained soil with >12% fines OR Fine grained soil, liquid limit <50%, medium to no plasticity and >25% coarse grained material
S5		Fine grained soil, liquid limit <50%, medium to no plasticity and <25% coarse grained material
D	Bed	Trench bottom with joint holes to ensure that the barrel is fully supported
	Sidefill	S3 to S5

B.3.3 Native soil embedments

The embedment tables (Tables B.4 and B.5) have been derived using class D with S3, S4 and S5 but they can also be used for classes S3, S4 and S5. An additional embedment, "Poor soils", has been included as these not covered in BS EN 1295-1:1997, Table NA.8. When installing pipes in poor soils, consideration should be given to the comments in **A.11**. For native gravels, embedment class D/S3 should be used.

B.3.4 Imported embedments

The imported embedments (S1 and S2) have not been evaluated individually in the embedment tables but have been combined by using a modulus of soil reaction (E'_2) that is the lower of S1 and S2 at a particular value of compaction.

B.3.5 Native modulus of soil reaction

The modulus of soil reaction for native soils (E'_3) is given in BS EN 1295-1:1997, Table NA.1. For native embedments the modulus was taken as that for the embedment class at 85% modified Proctor density. For "Poor soils" the overall modulus for the embedment (E') was taken as zero, i.e. the pipe can withstand the soil and vehicle loads without any lateral support from the embedment. For imported embedments it was assumed that E'_3 = 1 MN/m^2. This value compares with, for example, the range 0 to 1.5 MN/m^2 for very soft clay.

B.3.6 Trench installations

The trench widths are given in the tables in terms of "*x*" where the width is the external diameter of the pipe plus "*x*". In selecting a trench width, consideration should be given to the type of compaction equipment, any trench sheeting and site practice. Compaction should be carried out in layers and any trench sheeting should be pulled progressively to enable the specified modified Proctor density to be achieved.

B.3.7 Embankment installations

The embankment installation is indicated in the trench width column (Embank.) and the minimum width assumed for any compaction each side of the pipe was 1.65 times the external pipe diameter.

B.3.8 Safe depths of cover

The safe depths of cover in the tables have been calculated in accordance with BS EN 1295-1:1997, National Annex A. In the determination of the safe depths the beneficial influence of internal pressure has been omitted and the maximum was terminated at 6.0 m. For larger sizes of pipe, greater depths or parameters outside those used in the tables, the pipe manufacturer and an experienced structural pipeline design engineer should be consulted.

Table B.4A **Safe depths of cover (m) for ductile iron water pipe with field surcharge**

<table>
<tr><th colspan="3">DN</th><th>80</th><th>100</th><th>150</th><th>200</th><th>250</th><th>300</th><th>350</th><th>400</th><th>450</th><th>500</th><th>600</th></tr>
<tr><th>Class</th><th>M_p (%)</th><th>x (m)</th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th></tr>
<tr><td rowspan="8">D/S3</td><td rowspan="4">85</td><td>0.3</td><td colspan="11" rowspan="3">0.5 – 6.0+</td></tr>
<tr><td>0.6</td></tr>
<tr><td>0.9</td></tr>
<tr><td>Embank.</td><td colspan="6">0.5 – 6.0+</td><td>0.5 – 5.6</td><td>0.5 – 4.9</td><td>0.5 – 4.6</td><td>0.5 – 4.7</td><td>0.5 – 4.9</td></tr>
<tr><td rowspan="4">90</td><td>0.3</td><td colspan="11" rowspan="4">0.5 – 6.0+</td></tr>
<tr><td>0.6</td></tr>
<tr><td>0.9</td></tr>
<tr><td>Embank.</td></tr>
<tr><td rowspan="12">D/S4</td><td rowspan="4">85</td><td>0.3</td><td colspan="11" rowspan="2">0.5 – 6.0+</td></tr>
<tr><td>0.6</td></tr>
<tr><td>0.9</td><td colspan="7">0.5 – 6.0+</td><td>0.5 – 5.5</td><td>0.5 – 5.1</td><td>0.5 – 5.3</td><td>0.5 – 5.8</td></tr>
<tr><td>Embank.</td><td colspan="5">0.5 – 6.0+</td><td>0.5 – 5.9</td><td>0.5 – 4.7</td><td>0.5 – 3.9</td><td>0.5 – 3.5</td><td>0.5 – 3.5</td><td>0.5 – 3.7</td></tr>
<tr><td rowspan="4">90</td><td>0.3</td><td colspan="11" rowspan="3">0.5 – 6.0+</td></tr>
<tr><td>0.6</td></tr>
<tr><td>0.9</td></tr>
<tr><td>Embank.</td><td colspan="7">0.5 – 6.0+</td><td>0.5 – 5.4</td><td>0.5 – 5.1</td><td>0.5 – 5.2</td><td>0.5 – 5.5</td></tr>
<tr><td rowspan="4">95</td><td>0.3</td><td colspan="11" rowspan="4">0.5 – 6.0+</td></tr>
<tr><td>0.6</td></tr>
<tr><td>0.9</td></tr>
<tr><td>Embank.</td></tr>
<tr><td rowspan="12">D/S5</td><td rowspan="4">85</td><td>0.3</td><td colspan="7">0.5 – 6.0+</td><td>0.6 – 6.0+</td><td>0.6 – 4.7</td><td>0.6 - 4.6</td><td>0.6 - 4.8</td></tr>
<tr><td>0.6</td><td colspan="3" rowspan="3">0.5 – 6.0+</td><td>0.5 – 5.0</td><td>0.5 – 5.1</td><td>0.5 – 5.1</td><td>0.5 – 3.5</td><td>0.6 – 2.6</td><td>0.6 – 2.1</td><td>0.6 - 2.1</td><td>0.6 - 2.5</td></tr>
<tr><td>0.9</td><td>0.5 – 5.0</td><td>0.5 – 4.9</td><td>0.5 – 4.8</td><td>0.5 – 3.4</td><td>0.6 – 2.6</td><td>0.6 – 2.1</td><td>0.6 – 2.1</td><td>0.6 – 2.2</td></tr>
<tr><td>Embank.</td><td>0.5 – 5.0</td><td>0.5 – 4.9</td><td>0.5 – 4.8</td><td>0.5 – 3.4</td><td>0.6 – 2.6</td><td>0.6 – 2.1</td><td>0.6 – 2.1</td><td>0.6 – 2.2</td></tr>
<tr><td rowspan="4">90</td><td>0.3</td><td colspan="8">0.5 – 6.0+</td><td>0.6 – 6.0+</td><td>0.6 – 6.0+</td><td>0.6 – 6.0+</td></tr>
<tr><td>0.6</td><td colspan="6">0.5 – 6.0+</td><td>0.5 – 5.5</td><td>0.5 – 3.8</td><td>0.6 – 3.2</td><td>0.6 – 3.2</td><td>0.6 – 3.5</td></tr>
<tr><td>0.9</td><td colspan="3" rowspan="2">0.5 – 6.0+</td><td>0.5 – 5.7</td><td>0.5 – 5.7</td><td>0.5 – 5.4</td><td>0.5 – 4.1</td><td>0.5 – 3.2</td><td>0.5 – 2.7</td><td>0.5 – 2.7</td><td>0.5 – 2.8</td></tr>
<tr><td>Embank.</td><td>0.5 – 5.7</td><td>0.5 – 5.7</td><td>0.5 – 5.6</td><td>0.5 – 4.3</td><td>0.5 – 3.5</td><td>0.5 – 3.1</td><td>0.5 – 3.2</td><td>0.5 – 3.3</td></tr>
<tr><td rowspan="4">95</td><td>0.3</td><td colspan="8" rowspan="3">0.5 – 6.0+</td><td>0.6 – 6.0+</td><td>0.6 – 6.0+</td><td>0.6 – 6.0+</td></tr>
<tr><td>0.6</td><td>0.5 – 5.7</td><td>0.5 – 5.5</td><td>0.5 – 5.4</td></tr>
<tr><td>0.9</td><td>0.5 – 5.6</td><td>0.5 – 5.2</td><td>0.5 – 4.9</td></tr>
<tr><td>Embank.</td><td colspan="11">0.5 – 6.0+</td></tr>
</table>

Table B.4A **Safe depths of cover (m) for ductile iron water pipe with field surcharge** *(continued)*

DN			**80**	**100**	**150**	**200**	**250**	**300**	**350**	**400**	**450**	**500**	**600**
Class	M_p (%)	x (m)											
Poor soils		0.3	0.5 – 6.0+							0.7 – 4.8	0.9 – 3.0	0.9 – 3.1	0.8 – 3.3
		0.6	0.5 – 6.0+			0.5 – 4.7	0.5 – 4.7	0.5 – 4.5	0.5 – 3.1	0.7 – 2.2	0.9 – 1.6	0.9 – 1.5	0.8 – 1.7
		0.9				0.5 – 4.7	0.5 – 4.7	0.5 – 4.5	0.5 – 3.1	0.7 – 2.2	0.9 – 1.6	0.9 – 1.5	0.8 – 1.7
		Embank.				0.5 – 4.7	0.5 – 4.7	0.5 – 4.5	0.5 – 3.1	0.7 – 2.2	0.9 – 1.6	0.9 – 1.5	0.8 – 1.7
S1 or S2	Uncompacted	0.3	0.5 – 6.0+										
		0.6											
		0.9	0.5 – 6.0+								0.5 – 5.4	0.5 – 5.4	0.5 – 5.5
		Embank.	0.5 – 6.0+							0.5 – 5.2	0.5 – 4.8	0.5 – 4.8	0.5 – 5.0
	80	0.3	0.5 – 6.0+										
		0.6											
		0.9											
		Embank.											

Table B.4B **Safe depths of cover (m) for ductile iron water pipe with main road surcharge**

<table>
<tr><th colspan="3">DN</th><th>80</th><th>100</th><th>150</th><th>200</th><th>250</th><th>300</th><th>350</th><th>400</th><th>450</th><th>500</th><th>600</th></tr>
<tr><th>Class</th><th>M_p (%)</th><th>x (m)</th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th></tr>
<tr><td rowspan="8">D/S3</td><td rowspan="4">85</td><td>0.3</td><td rowspan="3" colspan="11">0.6 – 6.0+</td></tr>
<tr><td>0.6</td></tr>
<tr><td>0.9</td></tr>
<tr><td>Embank.</td><td colspan="6">0.6 – 6.0+</td><td>0.6 – 5.3</td><td>0.6 – 4.5</td><td>0.6 – 4.2</td><td>0.6 – 4.3</td><td>0.6 – 4.5</td></tr>
<tr><td rowspan="4">90</td><td>0.3</td><td rowspan="4" colspan="11">0.6 – 6.0+</td></tr>
<tr><td>0.6</td></tr>
<tr><td>0.9</td></tr>
<tr><td>Embank.</td></tr>
<tr><td rowspan="12">D/S4</td><td rowspan="4">85</td><td>0.3</td><td rowspan="2" colspan="7">0.6 – 6.0+</td><td>0.7 – 6.0+</td><td>0.8 – 6.0+</td><td>0.8 – 6.0+</td><td>0.7 – 6.0+</td></tr>
<tr><td>0.6</td><td>0.7 – 6.0+</td><td>0.8 – 6.0+</td><td>0.8 – 6.0+</td><td>0.7 – 6.0+</td></tr>
<tr><td>0.9</td><td rowspan="2" colspan="3">0.6 – 6.0+</td><td>0.6 – 5.7</td><td>0.6 – 6.0+</td><td>0.6 – 6.0+</td><td>0.6 – 5.6</td><td>0.7 – 4.6</td><td>0.8 – 4.2</td><td>0.8 – 4.4</td><td>0.7 – 5.0</td></tr>
<tr><td>Embank.</td><td>0.6 – 5.7</td><td>0.6 – 5.7</td><td>0.6 – 5.6</td><td>0.6 – 4.3</td><td>0.7 – 3.3</td><td>0.8 – 2.8</td><td>0.8 – 2.9</td><td>0.7 – 3.1</td></tr>
<tr><td rowspan="4">90</td><td>0.3</td><td colspan="8">0.6 – 6.0+</td><td>0.7 – 6.0+</td><td>0.7 – 6.0+</td><td>0.6 – 6.0+</td></tr>
<tr><td>0.6</td><td rowspan="2" colspan="11">0.6 – 6.0+</td></tr>
<tr><td>0.9</td></tr>
<tr><td>Embank.</td><td colspan="6">0.6 – 6.0+</td><td>0.6 – 5.8</td><td>0.6 – 5.0</td><td>0.6 – 4.8</td><td>0.6 – 4.9</td><td>0.6 – 5.1</td></tr>
<tr><td rowspan="4">95</td><td>0.3</td><td rowspan="4" colspan="11">0.6 – 6.0+</td></tr>
<tr><td>0.6</td></tr>
<tr><td>0.9</td></tr>
<tr><td>Embank.</td></tr>
<tr><td rowspan="12">D/S5</td><td rowspan="4">85</td><td>0.3</td><td colspan="6">0.6 – 6.0+</td><td>0.8 – 6.0+</td><td>1.4 – 5.1</td><td>—</td><td>—</td><td>—</td></tr>
<tr><td>0.6</td><td rowspan="3" colspan="3">0.6 – 6.0+</td><td>0.6 – 4.6</td><td>0.6 – 4.5</td><td>0.6 – 4.8</td><td>0.8 – 2.8</td><td>—</td><td>—</td><td>—</td><td>—</td></tr>
<tr><td>0.9</td><td>0.6 – 4.6</td><td>0.6 – 4.5</td><td>0.6 – 4.4</td><td>0.8 – 2.8</td><td>—</td><td>—</td><td>—</td><td>—</td></tr>
<tr><td>Embank.</td><td>0.6 – 4.6</td><td>0.6 – 4.5</td><td>0.6 – 4.4</td><td>0.8 – 2.8</td><td>—</td><td>—</td><td>—</td><td>—</td></tr>
<tr><td rowspan="4">90</td><td>0.3</td><td rowspan="2" colspan="6">0.6 – 6.0+</td><td>0.8 – 6.0+</td><td>1.1 – 6.0+</td><td>1.7 – 4.2</td><td>1.7 – 4.0</td><td>1.5 – 4.2</td></tr>
<tr><td>0.6</td><td>0.7 – 4.4</td><td>1.1 – 2.3</td><td>—</td><td>—</td><td>—</td></tr>
<tr><td>0.9</td><td rowspan="2" colspan="3">0.6 – 6.0+</td><td>0.6 – 5.4</td><td>0.6 – 5.4</td><td>0.6 – 5.1</td><td>0.6 – 3.6</td><td>0.9 – 2.4</td><td>—</td><td>—</td><td>—</td></tr>
<tr><td>Embank.</td><td>0.6 – 5.4</td><td>0.6 – 5.4</td><td>0.6 – 5.3</td><td>0.6 – 3.9</td><td>0.7 – 2.9</td><td>0.9 – 2.4</td><td>0.8 – 2.5</td><td>0.7 – 2.6</td></tr>
<tr><td rowspan="4">95</td><td>0.3</td><td colspan="6">0.6 – 6.0+</td><td>0.7 – 6.0+</td><td>1.0 – 6.0+</td><td>1.3 – 6.0+</td><td>1.3 – 6.0+</td><td>1.2 – 6.0+</td></tr>
<tr><td>0.6</td><td rowspan="2" colspan="7">0.6 – 6.0+</td><td>0.9 – 6.0+</td><td>1.2 – 4.3</td><td>1.2 – 4.0</td><td>1.2 – 4.0</td></tr>
<tr><td>0.9</td><td>0.7 – 6.0+</td><td>0.9 – 4.6</td><td>0.9 – 4.2</td><td>1.0 – 3.8</td></tr>
<tr><td>Embank.</td><td colspan="11">0.6 – 6.0+</td></tr>
</table>

Table B.4B **Safe depths of cover (m) for ductile iron water pipe with main road surcharge** *(continued)*

DN			**80**	**100**	**150**	**200**	**250**	**300**	**350**	**400**	**450**	**500**	**600**
Class	M_p **(%)**	x **(m)**											
Poor soils		0.3	0.6 – 6.0+						1.1 – 6.0+	—	—	—	—
		0.6	0.6 – 6.0+			0.6 – 4.3	0.6 – 4.2	0.6 – 4.0	1.2 – 2.1	—	—	—	—
		0.9				0.6 – 4.3	0.6 – 4.2	0.6 – 4.0	1.2 – 2.1	—	—	—	—
		Embank.				0.6 – 4.3	0.6 – 4.2	0.6 – 4.0	1.2 – 2.1	—	—	—	—
S1 or S2	Uncompacted	0.3	0.6 – 6.0+							0.7 – 6.0+	0.8 – 6.0+	0.8 – 6.0+	0.8 – 6.0+
		0.6	0.6 – 6.0+								0.7 – 6.0+	0.7 – 6.0+	0.7 – 6.0+
		0.9	0.6 – 6.0+							0.6 – 5.6	0.7 – 4.6	0.7 – 4.6	0.7 – 4.7
		Embank.								0.6 – 4.9	0.6 – 4.4	0.6 – 4.4	0.6 – 4.6
	80	0.3	0.6 – 6.0+								0.8 – 6.0+	0.8 – 6.0+	0.7 – 6.0+
		0.6									0.7 – 6.0+	0.7 – 6.0+	0.7 – 6.0+
		0.9	0.6 – 6.0+										
		Embank.											
	85	0.3	0.6 – 6.0+								0.7 – 6.0+	0.7 – 6.0+	0.7 – 6.0+
		0.6	0.6 – 6.0+									0.7 – 6.0+	0.7 – 6.0+
		0.9	0.6 – 6.0+										
		Embank.											
	90	0.3	0.6 – 6.0+								0.7 – 6.0+	0.7 – 6.0+	0.7 – 6.0+
		0.6	0.6 – 6.0+										
		0.9											
		Embank.											
	95	0.3	0.6 – 6.0+								0.7 – 6.0+	0.7 – 6.0+	0.7 – 6.0+
		0.6	0.6 – 6.0+										
		0.9											
		Embank.											

Table B.5A **Safe depths of cover (m) for ductile iron pressure sewer pipe with field surcharge**

DN			80	100	150	200	250	300	350	400	450	500	600
Class	M_p (%)	x (m)											
D/S3	85	0.3	0.5 – 6.0+										
		0.6											
		0.9											
		Embank.	0.5 – 6.0+					0.5 – 5.5	0.5 – 5.0	0.5 – 4.7	0.5 – 4.4	0.5 – 4.3	0.5 – 4.3
	90	0.3	0.5 – 6.0+										
		0.6											
		0.9											
		Embank.											
D/S4	85	0.3	0.5 – 6.0+										
		0.6											
		0.9	0.5 – 6.0+					0.5 – 5.8	0.5 – 5.4	0.5 – 5.1	0.5 – 4.9	0.5 – 4.7	0.5 – 4.7
		Embank.	0.5 – 6.0+				0.5 – 5.6	0.5 – 4.6	0.5 – 4.1	0.5 – 3.6	0.5 – 3.3	0.5 – 3.1	0.5 – 3.0
	90	0.3	0.5 – 6.0+										
		0.6											
		0.9											
		Embank.	0.5 – 6.0+					0.5 – 5.9	0.5 – 5.5	0.5 – 5.2	0.5 – 5.0	0.5 – 4.9	0.5 – 5.0
	95	0.3	0.5 – 6.0+										
		0.6											
		0.9											
		Embank.											
D/S5	85	0.3	0.5 – 6.0+							0.6 – 5.8	0.7 – 3.9	0.8 – 3.0	0.9 – 2.3
		0.6	0.5 – 6.0+				0.5 – 4.5	0.5 – 3.4	0.5 – 2.8	0.6 – 2.3	0.7 – 1.9	0.8 – 1.5	—
		0.9					0.5 – 4.5	0.5 – 3.4	0.5 – 2.8	0.6 – 2.3	0.7 – 1.9	0.8 – 1.5	—
		Embank.					0.5 – 4.5	0.5 – 3.4	0.5 – 2.8	0.6 – 2.3	0.7 – 1.9	0.8 – 1.5	—
	90	0.3	0.5 – 6.0+							0.6 – 6.0+	0.6 – 5.7	0.7 – 4.1	0.8 – 3.2
		0.6	0.5 – 6.0+					0.5 – 5.2	0.5 – 4.1	0.5 – 3.4	0.6 – 2.9	0.7 – 2.5	0.8 – 2.2
		0.9	0.5 – 6.0+				0.5 – 5.2	0.5 – 4.1	0.5 – 3.4	0.5 – 2.9	0.6 – 2.5	0.6 – 2.2	0.7 – 1.9
		Embank.					0.5 – 5.3	0.5 – 4.3	0.5 – 3.7	0.5 – 3.3	0.5 – 3.0	0.5 – 2.7	0.5 – 2.5
	95	0.3	0.5 – 6.0+								0.6 – 6.0+	0.7 – 6.0+	0.7 – 4.9
		0.6									0.5 – 5.3	0.6 – 4.4	0.7 – 3.8
		0.9									0.5 – 5.4	0.5 – 4.6	0.6 – 3.8
		Embank.	0.5 – 6.0+										

Table B.5A **Safe depths of cover (m) for ductile iron pressure sewer pipe with field surcharge** *(continued)*

DN			**80**	**100**	**150**	**200**	**250**	**300**	**350**	**400**	**450**	**500**	**600**
Class	M_p (%)	x (m)											
Poor soils		0.3	0.5 – 6.0+						0.6 – 6.0+	0.8 – 3.6	1.0 – 2.4	—	—
		0.6	0.5 – 6.0+				0.5 – 4.2	0.5 – 3.1	0.6 – 2.5	0.8 – 1.9	—	—	—
		0.9					0.5 – 4.2	0.5 – 3.1	0.6 – 2.5	0.8 – 1.9	—	—	—
		Embank.					0.5 – 4.2	0.5 – 3.1	0.6 – 2.5	0.8 – 1.9	—	—	—
S1 or S2	Uncompacted	0.3	0.5 – 6.0+										0.6 – 6.0+
		0.6	0.5 – 6.0+									0.5 – 5.6	0.5 – 4.8
		0.9	0.5 – 6.0+							0.5 – 5.8	0.5 – 5.1	0.5 – 4.5	0.5 – 4.1
		Embank.	0.5 – 6.0+						0.5 – 5.5	0.5 – 4.9	0.5 – 4.5	0.5 – 4.3	0.5 – 4.1
	80	0.3	0.5 – 6.0+										0.6 – 6.0+
		0.6	0.5 – 6.0+										
		0.9	0.5 – 6.0+										0.5 – 5.8
		Embank.	0.5 – 6.0+										
	85	0.3	0.5 – 6.0+										
		0.6											
		0.9											
		Embank.											

Table B.5B **Safe depths of cover (m) for ductile iron pressure sewer pipe with main road surcharge**

<table>
<tr><th colspan="3">DN</th><th>80</th><th>100</th><th>150</th><th>200</th><th>250</th><th>300</th><th>350</th><th>400</th><th>450</th><th>500</th><th>600</th></tr>
<tr><th>Class</th><th>M_p (%)</th><th>x (m)</th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th></tr>
<tr><td rowspan="8">D/S3</td><td rowspan="4">85</td><td>0.3</td><td colspan="11" rowspan="3">0.6 – 6.0+</td></tr>
<tr><td>0.6</td></tr>
<tr><td>0.9</td></tr>
<tr><td>Embank.</td><td colspan="5"></td><td>0.6 – 5.2</td><td>0.6 – 4.7</td><td>0.6 – 4.3</td><td>0.6 – 4.0</td><td>0.6 – 3.8</td><td>0.6 – 3.8</td></tr>
<tr><td rowspan="4">90</td><td>0.3</td><td colspan="11" rowspan="4">0.6 – 6.0+</td></tr>
<tr><td>0.6</td></tr>
<tr><td>0.9</td></tr>
<tr><td>Embank.</td></tr>
<tr><td rowspan="12">D/S4</td><td rowspan="4">85</td><td>0.3</td><td colspan="7">0.6 – 6.0+</td><td>0.7 – 6.0+</td><td>0.8 – 6.0+</td><td>0.9 – 6.0+</td><td>1.0 – 6.0+</td></tr>
<tr><td>0.6</td><td colspan="6">0.6 – 6.0+</td><td>0.7 – 6.0+</td><td>0.8 – 6.0+</td><td>0.9 – 6.0+</td><td>1.0 – 5.4</td><td>1.0 – 4.9</td></tr>
<tr><td>0.9</td><td colspan="4" rowspan="2">0.6 – 6.0+</td><td>0.6 – 5.8</td><td>0.6 – 5.0</td><td>0.7 – 4.6</td><td>0.8 – 4.2</td><td>0.9 – 3.9</td><td>1.0 – 3.6</td><td>1.1 – 3.6</td></tr>
<tr><td>Embank.</td><td>0.6 – 5.3</td><td>0.6 – 4.2</td><td>0.7 – 3.5</td><td>0.8 – 3.0</td><td>0.9 – 2.6</td><td>1.0 – 2.2</td><td>1.2 – 2.0</td></tr>
<tr><td rowspan="4">90</td><td>0.3</td><td colspan="7">0.6 – 6.0+</td><td>0.7 – 6.0+</td><td>0.7 – 6.0+</td><td>0.8 – 6.0+</td><td>0.8 – 6.0+</td></tr>
<tr><td>0.6</td><td colspan="8">0.6 – 6.0+</td><td>0.7 – 6.0+</td><td>0.8 – 6.0+</td><td>0.8 – 6.0+</td></tr>
<tr><td>0.9</td><td colspan="9">0.6 – 6.0+</td><td>0.7 – 6.0+</td><td>0.7 – 6.0+</td></tr>
<tr><td>Embank.</td><td colspan="5">0.6 – 6.0+</td><td>0.6 – 5.6</td><td>0.6 – 5.2</td><td>0.6 – 4.8</td><td>0.6 – 4.6</td><td>0.6 – 4.5</td><td>0.6 – 4.6</td></tr>
<tr><td rowspan="4">95</td><td>0.3</td><td colspan="9">0.6 – 6.0+</td><td>0.7 – 6.0+</td><td>0.7 – 6.0+</td></tr>
<tr><td>0.6</td><td colspan="11" rowspan="3">0.6 – 6.0+</td></tr>
<tr><td>0.9</td></tr>
<tr><td>Embank.</td></tr>
<tr><td rowspan="12">D/S5</td><td rowspan="4">85</td><td>0.3</td><td colspan="5">0.6 – 6.0+</td><td>0.9 – 6.0+</td><td>1.2 – 6.0+</td><td>—</td><td>—</td><td>—</td><td>—</td></tr>
<tr><td>0.6</td><td colspan="4" rowspan="3">0.6 – 6.0+</td><td>0.6 – 4.0</td><td>0.9 – 2.7</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td></tr>
<tr><td>0.9</td><td>0.6 – 4.0</td><td>0.9 – 2.7</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td></tr>
<tr><td>Embank.</td><td>0.6 – 4.0</td><td>0.9 – 2.7</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td></tr>
<tr><td rowspan="4">90</td><td>0.3</td><td colspan="5" rowspan="2">0.6 – 6.0+</td><td>0.8 – 6.0+</td><td>1.0 – 6.0+</td><td>1.4 – 6.0+</td><td>—</td><td>—</td><td>—</td></tr>
<tr><td>0.6</td><td>0.7 – 4.1</td><td>0.9 – 2.8</td><td>—</td><td>—</td><td>—</td><td>—</td></tr>
<tr><td>0.9</td><td colspan="4" rowspan="2">0.6 – 6.0+</td><td>0.6 – 4.9</td><td>0.6 – 3.6</td><td>0.8 – 2.8</td><td>1.1 – 1.9</td><td>—</td><td>—</td><td>—</td></tr>
<tr><td>Embank.</td><td>0.6 – 4.9</td><td>0.6 – 3.8</td><td>0.7 – 3.2</td><td>0.8 – 2.6</td><td>1.0 – 2.1</td><td>1.2 – 1.6</td><td>—</td></tr>
<tr><td rowspan="4">95</td><td>0.3</td><td colspan="5">0.6 – 6.0+</td><td>0.7 – 6.0+</td><td>0.9 – 6.0+</td><td>1.2 – 6.0+</td><td>1.5 – 6.0+</td><td>2.2 – 3.8</td><td>—</td></tr>
<tr><td>0.6</td><td colspan="6">0.6 – 6.0+</td><td>0.8 – 6.0+</td><td>1.0 – 5.2</td><td>1.3 – 3.7</td><td>—</td><td>—</td></tr>
<tr><td>0.9</td><td colspan="7">0.6 – 6.0+</td><td>0.8 – 5.7</td><td>1.0 – 4.3</td><td>1.2 – 3.3</td><td>—</td></tr>
<tr><td>Embank.</td><td colspan="11">0.6 – 6.0+</td></tr>
</table>

Table B.5B **Safe depths of cover (m) for ductile iron pressure sewer pipe with main road surcharge** *(continued)*

DN			**80**	**100**	**150**	**200**	**250**	**300**	**350**	**400**	**450**	**500**	**600**
Class	M_p (%)	x (m)											
Poor soils		0.3	0.6 – 6.0+				0.7 – 6.0+	1.2 – 6.0+	—	—	—	—	—
		0.6	0.6 – 6.0+			0.6 – 5.8	0.7 – 3.7	1.3 – 2.0	—	—	—	—	—
		0.9				0.6 – 5.8	0.7 – 3.7	1.3 – 2.0	—	—	—	—	—
		Embank.				0.6 – 5.8	0.7 – 3.7	1.3 – 2.0	—	—	—	—	—
S1 or S2	Uncompacted	0.3	0.6 – 6.0+							0.7 – 6.0+	0.9 – 6.0+	1.0 – 6.0+	1.3 – 6.0+
		0.6								0.7 – 6.0+	0.8 – 5.5	1.0 – 4.3	1.2 – 3.4
		0.9								0.6 – 5.0	0.7 – 4.2	0.9 – 3.6	1.1 – 2.9
		Embank.	0.6 – 6.0+					0.6 – 5.9	0.6 – 5.1	0.6 – 4.5	0.6 – 4.1	0.6 – 3.8	0.6 – 3.6
	80	0.3	0.6 – 6.0+							0.7 – 6.0+	0.8 – 6.0+	1.0 – 6.0+	1.2 – 6.0+
		0.6	0.6 – 6.0+								0.7 – 6.0+	0.9 – 6.0+	1.0 – 5.0
		0.9	0.6 – 6.0+									0.7 – 6.0+	0.9 – 4.8
		Embank.	0.6 – 6.0+										
	85	0.3	0.6 – 6.0+							0.7 – 6.0+	0.8 – 6.0+	0.9 – 6.0+	1.1 – 6.0+
		0.6	0.6 – 6.0+								0.7 – 6.0+	0.8 – 6.0+	1.0 – 6.0+
		0.9	0.6 – 6.0+									0.7 – 6.0+	0.8 – 6.0+
		Embank.	0.6 – 6.0+										
	90	0.3	0.6 – 6.0+							0.7 – 6.0+	0.8 – 6.0+	0.9 – 6.0+	1.1 – 6.0+
		0.6	0.6 – 6.0+								0.7 – 6.0+	0.8 – 6.0+	0.9 – 6.0+
		0.9	0.6 – 6.0+										0.8 – 6.0+
		Embank.	0.6 – 6.0+										
	95	0.3	0.6 – 6.0+							0.7 – 6.0+	0.8 – 6.0+	0.9 – 6.0+	1.1 – 6.0+
		0.6	0.6 – 6.0+								0.7 – 6.0+	0.8 – 6.0+	0.9 – 6.0+
		0.9	0.6 – 6.0+										0.7 – 6.0+
		Embank.	0.6 – 6.0+										

Bibliography

Standards publications

For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 5400-2, *Steel, concrete and composite bridges – Part 2: Specification for loads*

BS EN 295-1, *Vitrified clay pipes and fittings and pipe joints for drains and sewers – Part 1: Requirements*

prEN 545:2009, *Ductile iron pipes, fittings, accessories and their joints for water pipelines – Requirements and test methods*

PD CEN/TR 1295-2:2005, *Structural design of buried pipelines under various conditions of loading – Part 2: Summary of nationally established methods of design*

Other publications

[1] CLARKE, N.W.B. *Simplified tables of external loads on buried pipelines*. National Building Studies Special Report 32, Department of Scientific and Industrial Research, Building Research Station. London: HMSO, 1962.

[2] CLARKE, N.W.B. *Loading charts for the design of buried rigid pipes*. National Building Studies Special Report 37, Ministry of Technology, Building Research Station. London: HMSO, 1966.

[3] YOUNG, O.C. *High-strength beddings for unreinforced concrete and clayware pipes*. National Building Studies Special Report 38, Ministry of Technology, Building Research Station. London: HMSO, 1967.

[4] YOUNG, O.C. *Simplified tables of external loads on buried pipelines*. Building Research Station, Department of the Environment. London: HMSO, 1970, Third Impression 1972.

[5] WALTON, J.H. *The structural design of the cross-section of buried vitrified clay pipelines*. Clay Pipe Development Association Ltd. London: CPDA, 1970.

[6] WORKING PARTY ON SEWERS AND WATER MAINS. First Report. Department of the Environment. London: HMSO, 1975.

[7] YOUNG, O.C. and M.P. O'REILLY. *A guide to design loadings for buried rigid pipes*. Transport and Road Research Laboratory, Department of Transport. London: HMSO, 1983, Second Impression 1987.

[8] YOUNG, O.C., BRENNAN, G. and M.P. O'REILLY. *Simplified tables of external loads on buried pipelines*. Transport and Road Research Laboratory, Department of Transport. London: HMSO, 1986.

[9] LEONHARDT, G. *Belastungsannahmen bei erdverlegten GFK-Rohen*, AVK, Freudenstadt, 4th October 1978.

[10] SPANGLER, M.G. *Soil engineering*. Second edition. Scranton, Pennysylvania: International Textbook Company, 1960.

[11] FADUM, R.E. *Influence values for vertical stresses in a semi-infinite soil due to surface loads.* Graduate School of Engineering, Harvard University, USA, 1941.

[12] SPANGLER, M.G. *Field measurements of the settlement ratios of various highway culverts*, Bulletin 170, The Iowa State College Bulletin AMES, IOWA, Vol. XLIX, 16th August 1950, No.11.

[13] MATYAS, E.L. and J.B. DAVIS. Prediction of vertical earth loads on rigid pipes. *Journal of Geotechnical Engineering*. 1983, **109** (2).

[14] BRADY, K.C., WATTS, G.R.A. and M.R. JONES. *Specification for foamed concrete*, Application Guide AG39. Wokingham: Transport Research Laboratory, 2001, ISSN 1365-6929.

[15] HIGHWAY AUTHORITIES AND UTILITIES COMMITTEE. *New Roads and Street Works Act 1991. Specification for the reinstatement of openings in highways.* HAUC (UK), 2002.

[16] AMERICAN SOCIETY OF CIVIL ENGINEERS and WATER POLLUTION CONTROL FEDERATION. *Gravity sanitary sewer design and construction*, Reston, Virginia: ASCE Publications, 1982.

[17] CLAY PIPE DEVELOPMENT ASSOCIATION. *Bedding construction and flow capacity of vitrified clay pipelines*. London: Clay Pipe Development Association Limited, 1995.

[18] WATER INDUSTRY. *Revised bedding factors for vitrified clay pipes*. IGN 4-11-02. Swindon: Water Research Centre, 1992.

Further reading

TREW, J.E., TARBET, N.K., DE ROSA, P.J., MORRIS, J.D., CANT, J. and J.L. OLLIFF. *Pipe materials selection manual.* 2nd Edition. Swindon: Water Research Centre, 1995.

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