

AS/NZS 3725 Supplement 1:2007

Design for installation of buried concrete pipes—Commentary (Supplement to AS/NZS 3725:2007)



AS/NZS 3725 Supp 1:2007

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AS/NZS 3725 Supplement 1:2007

Design for installation of buried concrete pipes—Commentary (Supplement to AS/NZS 3725:2007)

Originated as AS 3725 Supp 1—1989.
Jointly revised and redesignated AS/NZS 3725 Supp 1:2007.

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PREFACE

This Commentary was prepared by the Joint Standards Australia/Standards New Zealand Committee WS-006, Concrete Pipes. It is intended that it be read in conjunction with AS/NZS 3725, *Design for installation of buried concrete pipes*, but does not form part of that Standard.

In preparing AS 3725—1989, the then committee considered it desirable that only necessary requirements be detailed in the Standard and that any additional explanations, advice or comments (based on experience gained over the years) be brought to the attention of the design engineer and other users of the Standard by the production of a Commentary. The current committee supports this view and has produced this updated commentary to support the 2006 revision.

It is not intended that the Standard be interpreted as preventing the use of methods of load assessment other than those specified, as indeed such alternative methods will possibly be required for circumstances not covered by the Standard. However, the committee considers that in the more usually encountered situations, the methods outlined in the Standard are those most acceptable to all concerned, due to their relative simplicity and the length of satisfactory experience so far obtained in their application.

For ease of cross-reference, clause numbers and titles used in the Commentary are the same as those used in the body of the Standard, but are prefixed with the letter C. However, figures (designated C1, C2, etc.) and appendices (designated CA, CB, etc.) provide additional information and do not correspond to those in the Standard. Not all Clauses in the Standard require comment and thus the numbering of this document is not comprehensive.

References given in the Commentary text are listed in Appendix CA.

Appendix CC of the Commentary contains a number of examples illustrating the application of the Standard to the selection of an appropriate pipe from AS 4058, *Precast concrete pipes—Pressure and non-pressure* or AS 4139, *Fibre-reinforced concrete pipes and fittings*. The examples are in the form of typical selection problems each followed by a worked solution.

The term ‘Paragraph’ followed by ‘C’ refers to the text of the Commentary.

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STANDARDS AUSTRALIA/STANDARDS NEW ZEALAND

Australian/New Zealand Standard**Design for installation of buried concrete pipes—Commentary
(Supplement to AS/NZS 3725:2007)****C1 SCOPE**

The main purpose of the Standard is to provide an agreed basis for determining the vertical working loads on installed steel-reinforced, fibre-reinforced and unreinforced concrete pipes and a range of installation conditions. The Standard relates these loads to the loads applied to sample pipes in the standard load tests, so that an appropriate 'strength class' of pipe can be selected from AS 4058 or AS 4139, as applicable, which will be suitable for the particular field application.

Designers should consider the possibility of the application of non-vertical permanent loads on installed pipes such as steeply sloping soil surface or adjacent structures (but not transient loads) for a particular application. Where non-vertical loads are present and are assessed as significant, the designer should specify that the pipe be supplied with circular grid reinforcements.

A secondary purpose of the Standard is to reduce the large variety of likely installation conditions and bedding choices to a small number of representative types.

The earlier work of Spangler at the Iowa Engineering Experimental Station and that of the Californian Department of Transport with high embankment fills form the background for determining loads and for adopting standard installations. Previous editions of this Standard and ASTM C 1479-01 (Ref. 16) are also considered. The standard installations of ASTM C 1479-01 are the result of work by Heger (Ref. 17) and of Simpson, Gumpertz and Heger for the American Concrete Pipe Association. Heger carried out extensive finite element analysis modelling using a computerized direct design method SPIDA (Ref. 18) which used the soil parameters determined experimentally by Selig (Ref. 19). Research work at Adelaide University by Costin for the Concrete Pipe Association of Australasia has also been referenced. The choice of bedding factors for the range of standard installations is based on these works. The general acceptance of AS 5100.2, *Bridge design*, Part 2: *Design loads* (Ref. 2) and the Transit New Zealand *Bridge Manual* (Ref. 3) have allowed fuller treatment of railway and highway live loads to be presented here.

Methods of pipe laying and bedding preparation are not stipulated in the Standard because the continuing and rapid development of specialized earthmoving equipment and procedures would soon render such requirements obsolete. However, in Paragraph C8, detailed procedures for haunch compaction are outlined, as experience has indicated this to be one of the most difficult aspects of circular pipe bedding. Attention is also drawn to Ref. 4 which contains much useful information on the subject.

Compaction percentages are included to be more specific with regard to bedding and backfill compaction requirements. For side fill, the compaction percentages are given for both cohesive and cohesionless soils to emphasize that some measure of cohesiveness is acceptable in the select fill.

Documents referred to in this Commentary are listed in Appendix CA.

NOTE: See Preface to this Commentary for a description of the Clause numbering within.

C4 DEFINITIONS

C4.2 Bedding

See Paragraph C9 covering pipe support and bedding factors.

C4.3 Bedding factor (*F*)

See Paragraph C9 for derivation and Paragraph C10 for application.

C4.4 Fill

The term 'fill' is used throughout with a qualifier indicating particular requirements as follows:

- (a) *Backfill or embankment fill* The Standard deals with the backfill and embankment fill from the aspect of pipe performance only. In installations involving road and railway embankments, or trenches through urban areas, the stability criteria for the finished surface above the pipes may impose more restrictive requirements on the fill specification than required for pipe performance.
- (b) *Ordinary fill* The restrictions on size and percentage of stones in ordinary fill are to facilitate compaction in restricted areas and to limit damage to the pipes during placement and compaction.
- (c) *Select fill* The relevant classification information from Appendix A of AS 1726 has been reproduced as Appendix CB of this Supplement. Select fill covers material classed as 'coarse-grained soils' in the 'unified soil classification' with the exclusion of the silty-soil classes GM (silty gravels) and SM (silty sands).

C4.5 Foundation

Pipelines are installed for many purposes and in a variety of naturally occurring conditions. The foundation material should be able to support the loads placed on it and should be carefully graded or excavated to provide an even bed and maintain alignment of the pipes. The trench width should be the minimum necessary to permit the pipes to be properly laid and the fill compacted.

Very soft or expansive clays, irregular or fragmented rock and saturated soils, particularly those containing aggressive groundwater, are all unsuitable foundations and should be avoided. Where these types of foundation materials cannot be avoided, the use of one or more of the following techniques may ensure that a uniform bedding support is obtained:

- (a) Adequate drainage of groundwater.
- (b) Use of geotextile fabrics.
- (c) Removal of all unsuitable material and its replacement with compacted select material.
- (d) Use of cement-treated soils.

Since foundation conditions may vary considerably along a pipeline, specifications for pipelaying should provide for over-excavation of unsuitable foundation material and specify the replacement material required to form an acceptable foundation. This replacement material should preferably be cohesionless material that resists washing (not more than 15% less than 0.075 mm) and be free from perishable material and material aggressive to concrete.

Figures 11 to 13 of the Standard give appropriate depths to foundation level from the bottom of the pipe.

C4.7 Installation condition

The various equations given in the Standard for calculating dead loads due to fill materials, were derived from load conditions associated with particular configurations of an installation. These configurations have been traditionally classified on the basis of the relative levels of the top of the finished formation and the top of the pipe with respect to the level of the adjacent ground surface, which can be most clearly seen in a cross-section of an installation (see Figures 2 to 5 of the Standard). Thus, embankment or trench installation conditions are distinguished by cross-sections where the finished surface is respectively above or at the level of the adjacent ground surface, and positive or negative projection conditions are distinguished by cross-sections where the top of the pipe is respectively above or below the level of the adjacent ground surface.

The installation profiles given in Figures 2, 3 and 4 of the Standard have been adopted from the previous edition with a change from 300 mm to 150 mm to height of overfill zone above the pipe and minimum distance between multiple pipes added. The height of overfill zone and the minimum distance between multiple pipes are selected to be in agreement with other rigid and flexible pipe Standards requirements. For all installation types it is imperative that the haunch material be placed and compacted without voids in the embankment or trench profile. Where this degree of compaction is required, the minimum distance between pipes should be increased to allow access for the work to be done.

C4.8 Overlay zone

The purpose of the overlay zone is to protect the exposed portion of the pipe from direct physical damage due to construction activities following the laying and bedding of the pipe and compaction of the support material around the lower part of the pipe. Ordinary fill is quite satisfactory for this purpose but more finely graded material may be used, if convenient.

C4.10 Settlement ratio (r_s)

See Paragraph C6.3.6.

C5 NOTATION

- | | |
|-------------|---|
| w | The actual unit weight of the fill material should be known or measured prior to commencing calculations (see Clause 6.2) and a design value assessed. In the absence of site-specific data, use a compacted fill value of 20 kN/m ³ |
| C'_e, C_n | The prime superscript has been used with these symbols in the Standard to indicate that the coefficients are different from corresponding coefficients attributed to Spangler (see also Paragraph C6.3.3) |

C6 VERTICAL LOADS ON PIPES

C6.3 Working dead loads due to fill or in situ materials

C6.3.2 Trench condition

The values of the coefficient C_t obtained from Figure 6 are calculated from Equation C1 (Ref. 1):

$$C_t = \frac{1 - e^{-2K\mu'(H/B)}}{2K\mu'} \quad \dots C1$$

where

$K = (1 - \sin \phi) / (1 + \sin \phi)$ and is the Rankine earth pressure coefficient

ϕ = angle of internal friction of the fill material in the trench

$\mu' = \tan \phi'$

= the coefficient of friction between the fill material and the sides of the trench

e = the base of natural logarithms

The values contained in Figure 6 have been calculated using the values of $K\mu'$ in Table C1.

TABLE C1
 $K\mu'$ VALUES

Soil type	Soil parameter $K\mu'$	Angle of internal friction ϕ
Silts and clays (ML, CL) (LL, 50%)	0.11	25
Clayey sands (SC) or clayey gravels (GC)	0.15	30
Sand and gravel (SW, SP, GW, GP)	0.19	33

Where loads are determined from Equation 1, it should be noted that the values of C_t obtained from Figure 6 allow for the development and maintenance of a beneficial friction between the trench wall and the fill material in the trench. If, for some reason, this friction is decreased or not developed, the load on the pipe will be greater than that given by Equation 1.

Decreased development or non-development may occur if, during construction, withdrawal of a trench wall support system (shoring and/or sheeting) is allowed to destroy the contact between the wall and the fill or if the area is subjected to prolonged heavy traffic vibrations. Designers should therefore take into consideration the construction techniques and regulatory requirements likely to apply in the particular project and/or location and adopt appropriate bedding factors accordingly. The design of a pipeline assumes a particular trench width. If anything occurs to increase this width, then referral should be made to the designer.

The Clause specifies that the load in the trench condition has to be taken as the lower value derived from either the trench or the embankment formula. Generally speaking, as a trench becomes wider, the frictional forces noted above become a decreasing proportion of the total vertical forces acting on the pipe until a width is reached where embankment considerations begin to dominate. The theoretical transition point between trench and embankment loading conditions may be obtained from Figure C1. Where sloping trench sides are used, the working load due to fill in a trench condition is calculated using the trench width at the top of the pipe. It is preferable to keep the sides of the trench vertical up to the top of the pipe and then batter the slopes above this point.

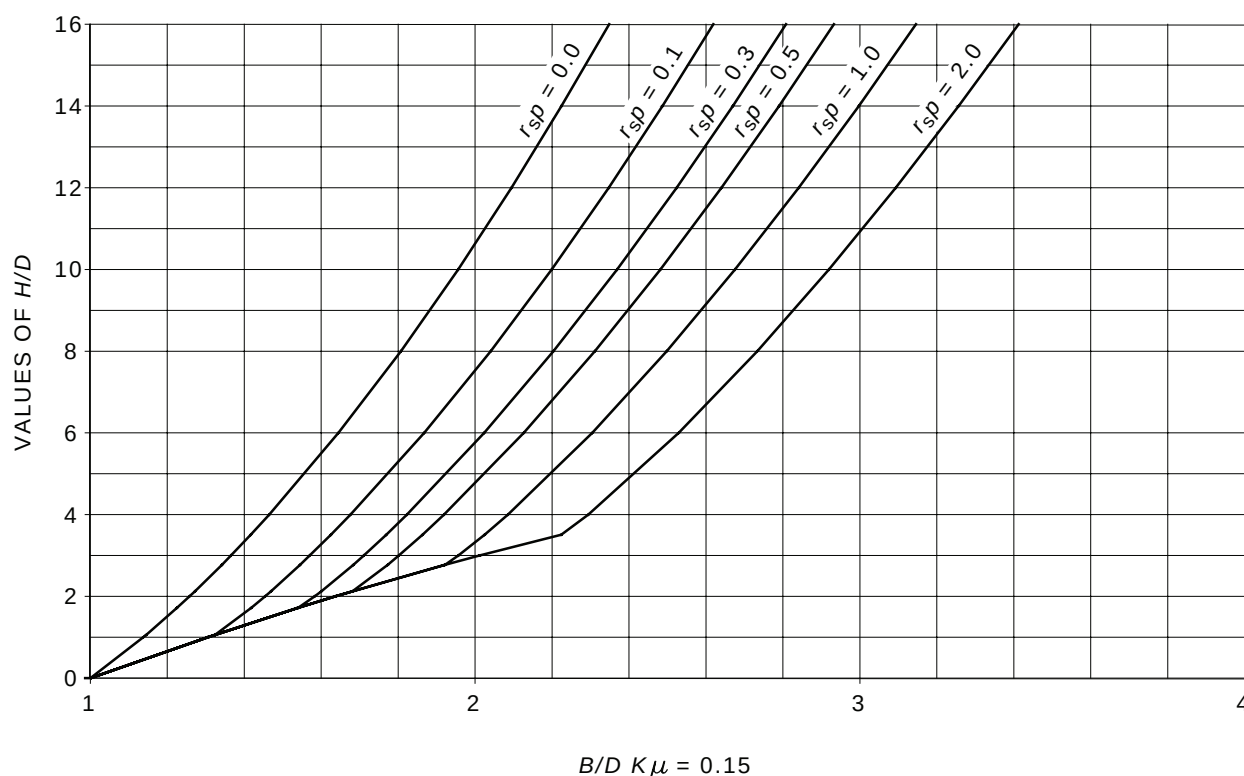


FIGURE C1 TRANSITION POINT BETWEEN TRENCH AND EMBANKMENT LOADING CONDITIONS

Since both the load on the pipe and the cost of excavation increase with trench width, economy of design dictates a trench width as narrow as practicable.

The practical considerations governing minimum trench width are—

- (a) the dimensions of the excavator bucket;
- (b) the maximum external pipe diameter;
- (c) the thickness of the trench wall supporting system, where required; and
- (d) the clearance between the outside of the pipe and the trench wall or wall support system, which should be sufficient to accommodate the operator and equipment necessary to—
 - (i) place and compact the bedding and haunch materials to ensure complete filling with material to the specified density;
 - (ii) make and inspect the joints; and
 - (iii) install any fittings.

The minimum clearance between pipe and trench wall, and between multiple pipes, given in the Standard is generally considered satisfactory provided the methods of installation can ensure that the specified embedment requirements for placement and compaction of haunch and side zone materials can be achieved. Careful consideration is recommended for large diameter pipe (greater than DN 1500), multiple pipe and Type HS3 bedding installations. It is important that no voids exist within these zones as they have the potential to allow migration of material and consequently reduce the compaction in the embedment profile.

The design for concrete pipe embedment profile and the resultant recommended bedding factors for the standard range of installations is based on work carried out both in Australia and America by the respective Concrete Pipe Associations. The most recent work by Simpson, Gumertz & Heger for the American Concrete Pipe Association involved the development of standard installations based on investigations using finite element techniques. The recommendations for embedment profile and requirements for natural material each side of the pipe have been adopted from these investigations.

In all instances, the choice of trench width should be a compromise between the demand for minimum excavation/backfilling and adequate work-space where side fill compaction is important for the performance of the installation as a whole.

The determination of vertical load on a pipe, from the earth fill above the pipe, is based on calculations for both trench and embankment (wide trench) conditions and the minimum value adopted. Where the minimum value is from the trench condition calculation, a maximum trench width should be specified on the drawings. Any increase in trench width will increase the load on the pipe and may cause an overload for the specified pipe load class.

Similarly, where the minimum value is from the embankment condition calculation, it is not necessary to specify the trench width on the drawings as it has no effect on the specified pipe load class.

C6.3.3 Embankment conditions

C6.3.3.1 Positive projection

The coefficients (C'_e) in this Paragraph and (C'_n) in Paragraph C6.3.3.2, are the Marston and Spangler coefficients presented in a more convenient form. The prime superscript has been used to emphasize the difference between these coefficients and the original coefficients (C_e) and (C_n) (Ref. 1).

The value of C'_e obtained from Figure 7 is calculated from a series of formulae (Equations C2 to C4). To use these equations it is necessary to introduce and explain the concept of the plane of equal settlement (H_e). In a positive projecting concrete pipe, the fill either side of the pipe will settle more than the fill directly above the pipe, which will result in shearing forces being developed within the fill. The plane of equal settlement is at a height above the concrete pipe where the shearing forces induced by settlements are zero (see Figure C2). The position of the plane of equal settlement will vary with the height of fill above the pipe. For lower values of fill, the shear forces may extend to the top of the fill. Marston referred to this condition as the 'complete projection condition' (Ref. 1). Where the shear forces only extend part way up the fill as shown in Figure C2, Marston referred to this as the 'incomplete projection condition'.

The value of H_e can be calculated from the following equation (Ref. 1):

$$\left[\frac{1}{2K\mu} + \left(\frac{H}{D} - \frac{H_e}{D} \right) + \frac{r_s p}{3} \right] \cdot \frac{e^{2K\mu(H_e/D)} - 1}{2K\mu} + \frac{1}{2} \left(\frac{H_e}{D} \right)^2 + \frac{r_s p}{3} \left(\frac{H}{D} - \frac{H_e}{D} \right) \cdot e^{2K\mu(H_e/D)} \dots C2$$

$$- \frac{1}{2K\mu} \cdot \frac{H_e}{D} - \frac{H}{D} \cdot \frac{H_e}{D} = r_s p \frac{H}{D}$$

The solution to the equation may be such that $H_e > H$, that is, the plane of equal settlement is above the ground surface and is said to be imaginary. If such a solution is obtained the shear forces extend to the top of the fill and the complete projection condition exists. If $H_e < H$, then the incomplete projection exists.

For the complete projection condition (i.e., $H_e > H$), C'_e is calculated from the following equation:

$$C'_e = \left[\frac{e^{2K\mu(H/D)} - 1}{2K\mu} \right] \cdot \frac{D}{H} \quad \dots C3$$

For the incomplete projection condition (i.e., $H_e < H$), C'_e is calculated from the following equation:

$$C'_e = \left[\frac{e^{2K\mu(H/D)} - 1}{2K\mu} + \left(\frac{H}{D} - \frac{H_e}{D} \right) \cdot e^{2K\mu(H/D)} \right] \cdot \frac{D}{H} \quad \dots C4$$

where

$K = (1 - \sin \phi) / (1 + \sin \phi)$ and is the Rankine earth pressure coefficient

ϕ = angle of internal friction of the fill material

$\mu = \tan \phi$

= the coefficient of internal friction between the fill material

e = base of natural logarithms

The values of C'_e in Figure 7 have been calculated using the values of $K\mu$ in Table C2.

TABLE C2
 $K\mu$ VALUES

Soil type	Soil parameter $K\mu$	Angle of internal friction ϕ
Silts and clays (ML, CL) (LL, 50%)	0.11	25
Clayey sands (SC) or clayey gravels (GC)	0.15	30
Sand and gravel (SW, SP, GW, GP)	0.19	33

In Figure 3 'natural surface' can be the level of either undisturbed ground or equivalent built-up and compacted fill. To be considered equivalent, the built-up compacted fill would have to be select fill compacted to a minimum of 95% (R_D) for a minimum distance from each side of the pipe trench as specified in Clause 9.2.3.1.

Induced trench

Where pipes are laid in an embankment with tops above the adjacent natural or equivalent surface in accordance with Figure C2, the working load due to the fill (W_g) is calculated from Equation 3.

This installation condition can be used for pipes under high embankment fills. As it is less commonly used, it has not been referred to in the Standard.

To obtain this condition, the embankment is constructed in the normal manner to a level some distance above the top of the pipe. A trench is then excavated part-way through the fill above the pipe, filled with straw bales and the construction of the embankment continued normally to its full height. Alternatively, the straw bales may be placed over the pipe and the embankment constructed around them.

As the height of fill above the trench increases, the straw bales are compressed, thereby inducing frictional forces between the soil column above the trench and the adjacent compacted fill. This results in a reduction of the effective load on the pipe in a manner entirely analogous to that in the trench condition.

Although the benefits of this method are well proven elsewhere (notably in California), induced trench construction has not been used to any great extent in Australia and New Zealand. This is probably due to some subsidence failures, caused by inadequate construction procedures, experienced in the early history of the method. It has been subsequently demonstrated that delayed subsidence will not occur if the embankment is properly compacted throughout and is of sufficient height to compress the bales. To ensure this, some authorities set a minimum embankment height of 15 m for the use of the induced trench method and since embankment fill below 15 m can be readily handled without resort to this approach, the limitation seems reasonable. However, successfully induced trench installations have been made with embankment heights lower than 15 m.

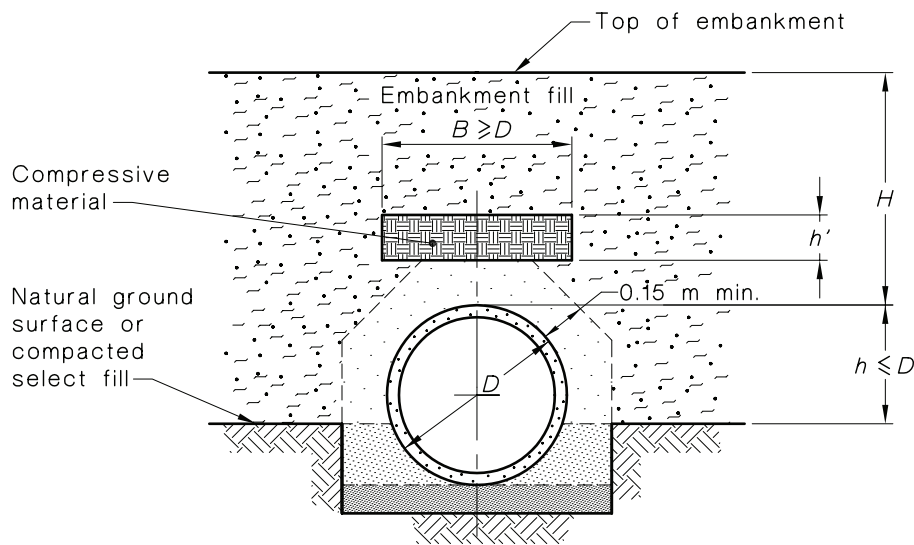


FIGURE C2 INDUCED TRENCH CONDITION

C6.3.3.2 Negative projection

This installation condition, which is shown in Figure 3(b), often occurs where pipelines requiring flat gradients pass through undulating terrain, resulting in the pipes being laid in a shallow trench and subsequently covered by an embankment.

There are a number of benefits inherent in this condition and depending on the extent to which advantage is to be taken of them, the trench may be filled with compressible material or compacted fill.

Having regard to the commentary on the induced trench condition below, it is clear that a negative projection embankment condition can be made to operate in an identical manner. Indeed, if full advantage is to be taken of the load reduction offered by Equation 3, then straw bales should be specified for the compressible material.

Loose fill may be specified for the compressible material if some load reduction is desirable. No allowance should be made for a reduction in the load calculations, as the compressibility of this material is indeterminate (in load calculations an assumption of $C'_e = 1.0$ would be reasonable). However, for large values of H/B (say 3 and above), if it is desired to take the trench effect into account, then a suitable procedure is described in Ref. 6.

Where low embankments are required and localized subsidence would be unacceptable, compacted fill should be specified for the trench.

The concept of the plane of equal settlement is also applicable to negative projecting conduits. For certain values of H/B , the plane of equal settlement will be at or above the surface level. For this 'complete negative projection condition' the value of C'_n obtained from Figure 8 is calculated from the following equation (Ref. 8):

$$C'_n = \frac{e^{-2K\mu(H/B)} - 1}{-2K\mu} \cdot \frac{B}{H} \quad \dots \text{C5}$$

Equation C5 is similar to the formula for the coefficient for the trench condition except that coefficient of internal friction of the fill material μ is used in lieu of μ' and it is multiplied by a ratio B/H .

Where the plane of equal settlement is below the surface level (i.e., $H_e < H$), the incomplete negative projection condition exists and the above formula is not applicable. Spangler provided a range of solutions for different settlement ratios (Ref. 1), which have been used along with the formula for the complete negative projection condition, to generate the values of C'_n obtained from Figure 8, which are given in Table C3. It should be noted that the values plotted in Figure 8 are based on a value of $K\mu = 0.13$. The values of C'_n obtained using this value may be conservative for other soil conditions. Ref. 7 contains additional information which would enable different values of C'_n to be calculated for different soil conditions.

TABLE C3
VALUES OF C'_n FOR $K\mu = 0.13$ and $H/B > 16$

r_s	C'_n			
	$p' = 0.5$	$p' = 1.0$	$p' = 1.5$	$p' = 2.0$
0.0	$(0.88H/B + 0.03) \times (B/H)$	$(0.77H/B + 0.11) \times (B/H)$	$(0.68H/B + 0.23) \times (B/H)$	$(0.59H/B + 0.37) \times (B/H)$
-0.1	$(0.77H/B + 0.09) \times (B/H)$	$(0.65H/B + 0.25) \times (B/H)$	$(0.55H/B + 0.44) \times (B/H)$	$(0.47H/B + 0.65) \times (B/H)$
-0.3	$(0.71H/B + 0.14) \times (B/H)$	$(0.58H/B + 0.34) \times (B/H)$	$(0.48H/B + 0.57) \times (B/H)$	$(0.40H/B + 0.81) \times (B/H)$
-0.5	$(0.67H/B + 0.17) \times (B/H)$	$(0.53H/B + 0.40) \times (B/H)$	$(0.44H/B + 0.65) \times (B/H)$	$(0.36H/B + 0.91) \times (B/H)$
-1.0	$(0.61H/B + 0.23) \times (B/H)$	$(0.47H/B + 0.50) \times (B/H)$	$(0.38H/B + 0.79) \times (B/H)$	$(0.31H/B + 1.07) \times (B/H)$
-2.0	$(0.53H/B + 0.31) \times (B/H)$	$(0.40H/B + 0.64) \times (B/H)$	$(0.31H/B + 0.96) \times (B/H)$	$(0.25H/B + 1.26) \times (B/H)$

C6.3.3.4 Jacked (thrust) or bored pipes condition

When establishing the strength requirements for jacking pipes, the jacking force as well as the vertical external load should be considered.

The effect of this on the pipe specification is dealt with in Ref. 8. As a general rule the cross-sectional area of the pipe joint should be large enough to limit the compression stress to between 12 MPa and 15 MPa for packed joints, assuming concentric compression. This value allows for some measure of eccentricity in the transfer of the jacking force through the joint. However, a higher stress may be used in specially controlled circumstances, or where a detailed stress analysis of the joint is carried out.

The addition of a minimum design load (W_g) for jacking pipe based on a soil parameter (c) of zero (effectively ignoring soil arching effects), and a value $C_t = 1.5$, ensures that the resultant load class for jacking pipes is necessarily conservative in its estimate of pipe design, in particular, the required wall thickness. This requirement adds robustness to the pipe and reduces the possibility of failure during pipe jacking due to excessive loads or deflections that occasionally occur during this high-risk operation.

C6.3.3.5 Settlement ratio

Settlement ratio refers to embankment conditions and is defined by the following equations:

$$r_s = [(S_m + S_g) - (S_f + d_c)]/S_m \quad \text{for positive projection; or} \quad \dots \text{C6}$$

$$r_s = [(S_g - (S_d + S_f + d_c)]/S_d \quad \text{for negative projection} \quad \dots \text{C7}$$

where

S_m = compression of the side column of soil of height D

S_g = settlement of the natural ground surface adjacent to pipes

S_f = settlement of the pipes into their foundation

S_d = compression of the fill material in the trench within the height— $p'B$

d_c = deflection of the vertical diameter of the pipes (see Figure C3)

Depending on whether r_s is positive or negative, the shear stresses between the soil prism above the pipes and the adjacent soil columns will be acting downwards or upwards on the prism. The implication of this difference is discussed in greater detail in Ref. 1.

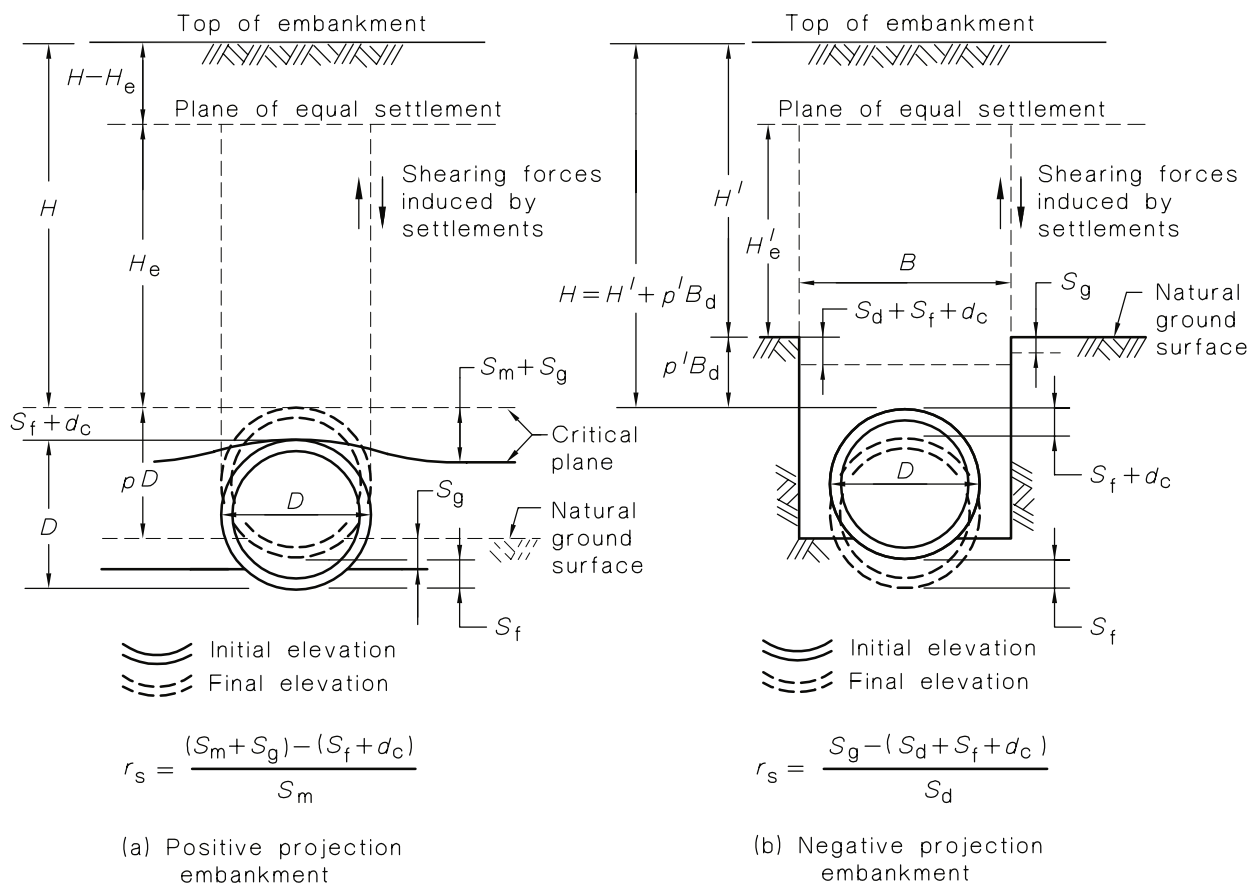


FIGURE C3 SETTLEMENT RATIO TERMS

C6.4 Working loads due to superimposed dead loads

Concentrated dead loads applied to the surface close to pipes should be avoided wherever possible; however, if it is necessary that a pipe pass close under or closely adjacent to such a load, a load-relieving structure, which transfers the load directly to a level at or near the pipe invert, should always be used. If this is not feasible, concentrated surface loads will be transmitted to pipes through a reasonable depth of fill or natural ground. The designer should use accepted methods of soil mechanics and structural analysis to determine the effect of the load on the pipes, taking account of any proposed future additional loads.

The designer is cautioned in the use of Equation 5 without first considering the actual application being designed for. In trench or embankment installations, the working load on the pipe due to earth load is calculated using various values of C_t , C'_e or C'_n which are all indirectly a measure of the frictional forces acting in the fill above a pipe. Before using an equivalent height of fill in Equations 1, 2 or 3, the designer should ensure that the relative settlements that are required to induce these frictional forces can in fact occur. Ref. 7 contains a more complete treatment of surcharge loading.

C6.5 Working loads due to superimposed live loads

C6.5.1 General

The live loads of principal concern in pipe design are the concentrated surface loads resulting from roadway, railway and construction vehicles. Live loads resulting from the passage of heavy service or emergency vehicles over the pipes will also need to be considered in off-road or off-rail areas.

Impact loadings, particularly those caused by construction equipment, may increase considerably in the transition from smooth to rough surface conditions. Designers should take into account the controls on heavy equipment movement and on the surface profiling that will be in place during and subsequent to construction.

Live loads from cars and pedestrians in car parks and pedestrian thoroughfares, etc., are usually negligible in relation to the loads due to the fill materials over the pipes and have therefore not been considered in the Standard.

Where it is necessary to consider uniformly distributed live loads of this nature, appropriate values of the loads may be obtained from AS/NZS 1170.1. These may then be treated as an equivalent height of fill as for uniformly distributed dead loads and the working load on the pipe calculated in accordance with the relevant installation condition. The portion of the test load from these causes would be obtained by dividing the working load thus calculated by 1.5, this being the bedding factor for live loads.

C6.5.2 Construction and other equipment loads

Live loads from construction equipment are an essential consideration in the design or selection of pipes, as they may constitute the maximum design loading. Some authorities have determined minimum cover requirements for passage of construction equipment, and designers may be able to use such information for guidance; however, it is the designer's responsibility to ascertain the type of equipment likely to be used and to determine the loads this equipment would transmit to the pipes at various depths of cover. For the selected pipes, minimum depths of cover at which various items of equipment or maximum loads are permitted to travel over the pipes can then be set. Adequate provisions, in the form of instructions, supervision or contractual requirements, should then be made to ensure that these design conditions are met during installation.

C6.5.3 Road vehicle loads

C6.5.3.2 Distribution of road traffic loads through fill

For covers ≥ 0.4 m, the assumptions on which pressure distributions resulting from road vehicle wheel loads are based on elastic theory and the appropriate Boussinesq equations. The equations in the Standard are based on the load distributions and tyre print sizes recommended in the review paper (R 'Distribution of Road Traffic Loads Through Fill—Review of AS 5100.2—2004, Clause 6.12', V. Nechvoglod/G. Forster, 16/3/2005, Ref. 20). The values adopted are those specifically recommended for buried structures including concrete culverts and pipes.