ELEMENTS OF PIPE DESIGN

Concrete Pipe
Association
of Australasia

ACN 007 067 656

1997/1998 CONSULTING ENGINEERS WORKSHOPS

CONSULTING ENGINEERS WORKSHOPS

1997/1998

CONCRETE PIPE ASSOCIATION
OF AUSTRALASIA

CONTENTS

1 INTRODUCTION

The Concrete Pipe Association of Australia was incorporated in 1971 to represent the concrete pipe industry and its related and ancillary manufacturers.

In 1990, the Articles and Memorandum of Association were amended to broaden its sphere of influence to include the region of Australasia and in 1993 the Association welcomed its first New Zealand member.

The Memorandum of Association sets out the Objects of the Association. These are set out in shortened form in **Figure 1.1**.

Objects of the Association

- *Represent concrete pipe industry*
- *Promote the industry*
- *Foster research and development*
- *Promote and improve standards*
- *Provide education and training*
- *Standardise and rationalise products*
- *Create public interest*
- *Disseminate technical information*
  - *– technical advice*
  - *– seminars*
  - *– library/database*
  - *– publications*

Figure 1.1 *Objects of the Association*

The various membership categories together with a list of Full Members of the Association are shown in **Figures 1.2** and **1.3** respectively.

Membership Categories

- *Full Members (Manufacturers)*
- *Associate Members (Suppliers)*
- *Affiliate Members (Related Products)*
- *Honorary Members*
- *Overseas Members*

Figure 1.2 *Membership Categories*

Full Members

Australia

- *Athlone Concrete Pipes*
- *BCP Precast*
- *CSR Humes*
- *Midland Concrete Pipes*
- *Rocla Pipeline Products*

New Zealand

- *Humes Industries*
- *Hynds Pipe Systems*

Figure 1.3 *Membership Categories*

The Association supports an industry which, when installation of its various products is taken into account, together with appropriate economic multipliers, makes a contribution in excess of one billion dollars annually to the economy of the Australasian region.

Products supported by the Association are:

- reinforced concrete pipes
- large and small reinforced concrete box culverts
- access chambers and pits
- related drainage products.

The Association has its offices in North Sydney where its national secretariat is based and from where its technical advisory service operates.

However, the organisation is heavily decentralised, operating under the guidance of a National Council but with regional committees in all Australian mainland states and New Zealand. Task forces are established to deal with specific issues.

Typical activities undertaken by CPAA include:

- membership of Standards Australia committees relating to this industry;
- formation of working groups with major government departments to address industry issues;
- advertising and promotion of the industry;
- training those involved in the industry in the following areas:
  – manufacturers
  – specifiers and designers
  – installers
  – owners;
- undertaking relevant research;
- preparation and distribution of design aids both as publications and computer software;
- provision of a technical advisory service to the industry.

The range of publications produced is shown in **Figure 1.4** and an updated order form is always available by contacting the Association.

Publications

- *Design Manuals*
  - *– Pipe Selection*
  - *– Hydraulics*
- *Technical Bulletins*
- *Seminar Papers and Reports*
- *Videos*
  - *– Pipe Selection*
  - *– Access Chambers*
- *Software*

Figure 1.4 *Concrete Pipe Association of Australasia – Publications*

Information on any aspect not covered by the seminar is readily available by contacting the Association at:

Level 6, 504 Pacific highway
ST LEONARDS NSW 2065
(Locked Bag 2011, St Leonards 2060

Tel: 02 9903 7780
Fax: 02 9437 9478

OR

26–30 Prosford Street
Ponsonby Auckland

Tel: 09 378 8083
Fax: 09 378 6231

2 ELEMENTS OF PIPELINE DESIGN

This section was to be a summary of factors to be considered in pipeline design. However there is such a multiplicity of factors to consider in selection and specification of pipes and pipe materials that it should more properly be called an overview.

Civil engineering structures inevitably depend on the characteristics of earth materials as well as of the manufactured components. To quote from Spangler(1) *All structures, regardless of the material of which they are constructed, rest ultimately upon soil or rock … In the case of sewers, culverts, tunnels, and other types of underground structures, … soil is important not only as the material upon which the structures are founded, but also as the major source of the loads to which they are subjected in service and which they must be designed to carry.*

The aim of structural design of pipelines is to create a stable interaction between the pipes and the surrounding soil, in which the pipe shape remains at least approximately circular. Australian Standards dealing with pipeline installation contain a wealth of detail, but in each case the design calculation is clearly targeted at avoiding a specific unacceptable condition:

AS 3725–1989 *Loads on Buried Pipes* – the LOAD on the pipe is limited to its proof load multiplied by a factor corresponding to the type of bedding, ie the design procedure guards against overloading the pipe.

AS 2042–1984 *Corrugated Steel Pipes, Pipe-arches, and Arches – Design and Installation* – the design limits the COMPRESSIVE STRESS IN THE PIPE WALL to a value which the pipe is designed to carry.

AS 2566–1982 *Plastic Pipelaying Design* – the design limits the DEFLECTION of the pipe (change in diameter) to 5%.

Structural Action of Pipelines

Before we proceed it is essential to understand the difference between a rigid and a flexible pipe.

A rigid pipe relies on its inherent strength and stiffness to support an imposed load.

A flexible pipe on the other hand is typically unable to support more than a small fraction of an imposed load using only its inherent strength.

A flexible pipe requires reactive earth pressure to provide the pipe with load carrying strength. In effect the vertical static earth load and live load is transferred from the pipe wall to the surrounding soil. This is achieved by a decrease in vertical diameter and an associated increase in horizontal diameter.

These concepts are shown in **Figure 2.1**.

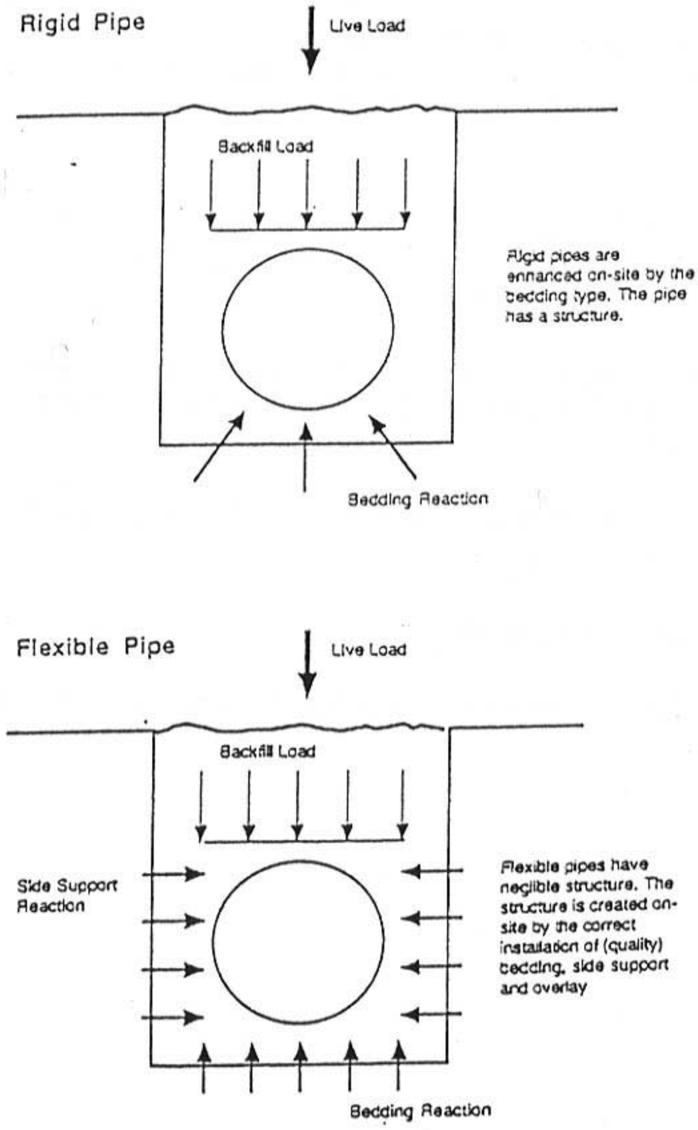


Figure 2.1 *The Structural Action of Pipelines*

Stiffness

From these concepts it follows that if a pipe is too 'flexible' the reactive haunch and side pressures may cause it to deform irregularly which concentrates the pipe wall stresses at deformation points thus leading to further material distress and buckling of the section.

To limit these deformations two properties are specified:

- pipe stiffness
- minimum short term deflection.

How is stiffness defined?

Pipe stiffness is simply the load (F) on a pipe divided by the deflection (dy) as shown in **Figure 2.2**.

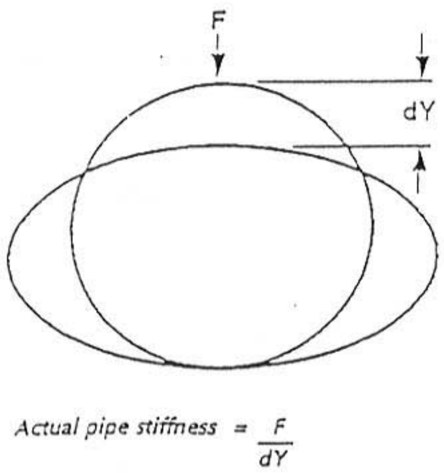


Figure 2.2 *Pipe Stiffness*

By substitution the theoretical pipe stiffness (SN) is defined as:

$$SN = \frac{EI}{Dm^3}$$

where E is the modulus of elasticity
I is the moment of inertia
Dm is the centroidal pipe diameter.

A more detailed discussion on pipe stiffness is given in Reference 2.

Design Implications of Stiffness

Having defined stiffness, how do we use it in design?

The design process is based on the Modified Iowa Formula developed by Professor Spangler[3].

In general terms:

$$\text{Conduit deformation} = \frac{\text{(lag factor) x (total load) x (bedding factor)}}{\text{(pipe stiffness factor) + (earth stiffness factor)}}$$

Once the deformation is calculated, bending strains in the pipe wall can then be determined and restricted to allowable limits.

From the Modified Iowa Formula a relationship between pipe stiffness and installation factors can be developed or implied. This is shown in **Figure 2.3**.

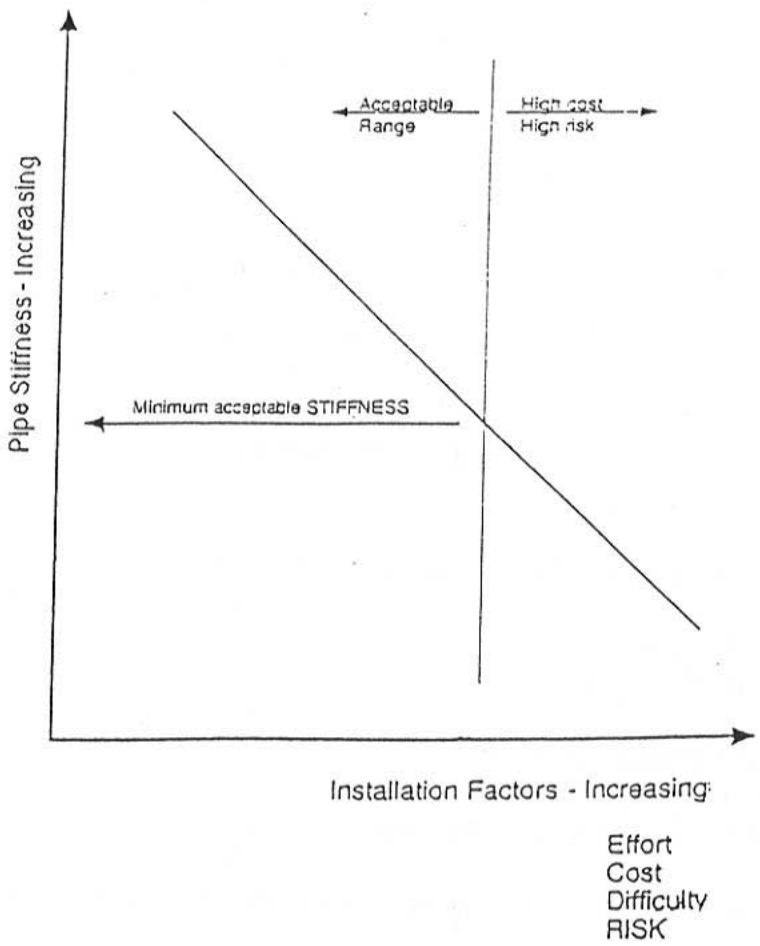


Figure 2.3 *Pipe Stiffness vs Installation*

For ease of discussion this has been shown as a linear relationship but obviously this is not the case.

Looked at from a different viewpoint, the 'decision maker' (often the designer with or without the client's input) makes a decision based on one or more of these factors and consciously or unconsciously decides on pipe stiffness.

Specifying Stiffness

Plastics creep under constant load so the modulus 'E' reduces with time. This is illustrated in **Figure 2.4**. (Source Reference 2).

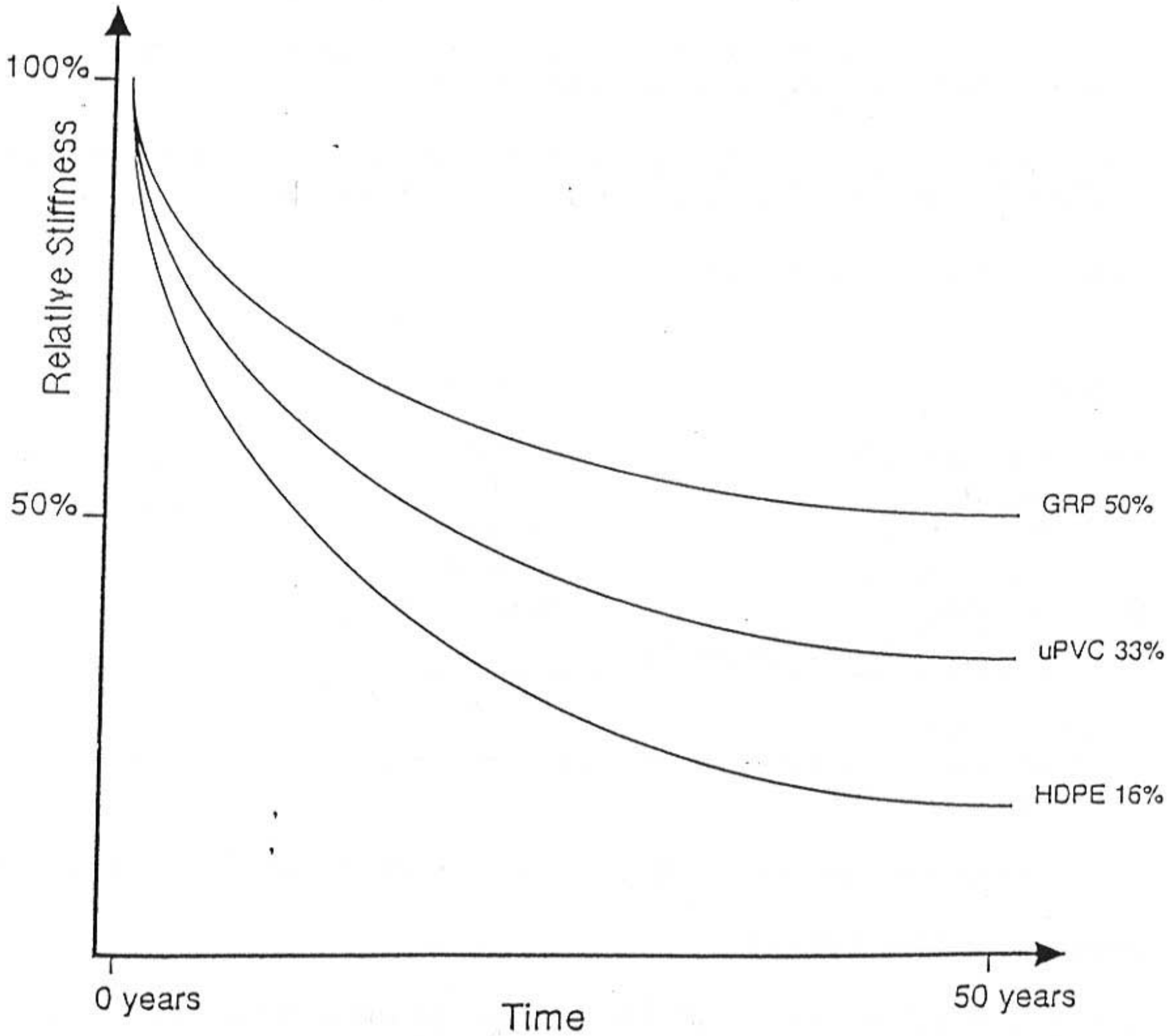


Figure 2.4 *Plastic Pipe Stiffness vs Time*

It is important to realise that in some materials such as HDPE stiffness at 50 years is only 16% of initial stiffness.

Reference 2 gives more in depth discussion on the comparison of different measures of stiffness.

The Draft Australian Standard uses the SN terminology expressed in N/m/m.

Recommended Pipe Stiffness

The Ontario Research Foundation prepared a comprehensive report in 1988 for the Ministry of Transportation, Ontario[4] which provides a very good review of the current state of the art with respect to design criteria, installation and acceptance procedures.

One of the main recommendations is a minimum SN of 5600 N/m/m. This figure has been adopted by the Concrete Pipe Association of Australasia.

Other Authorities' requirements have been converted to SN values and are summarised in **Table 2.1**. Stiffness of various types of pipes is shown in **Figure 2.5**[4].

Table 2.1 *Recommended Pipe Stiffness*

Authority	SN (N/m/m)
Ontario Research Foundation	5600
Sydney Water	
– DN375 to DN450	7000–6400
– DN600 to DN750	7500–5600
Melbourne Water	1250–2500*
Draft Australian Flexible Pipe Standard	625**

* Depending on site conditions

** Long-term stiffness. This can be converted to initial stiffness by using appropriate multiplies from Figure 4, eg for HDPE initial stiffness requirement would be 4000 N/m/m.

Clearly then the nomination of stiffness (SN) must be an essential part of any specification.

Bedding and Side Support

At the beginning of this paper the difference between rigid and flexible pipe was discussed. It was noted that a rigid pipe relied on its inherent strength and stiffness to support an imposed load. The load carrying capacity of a rigid pipe can however be significantly enhanced by its installation condition, ie its bedding factor can be increased.

In normal everyday installations however only haunch support is required.

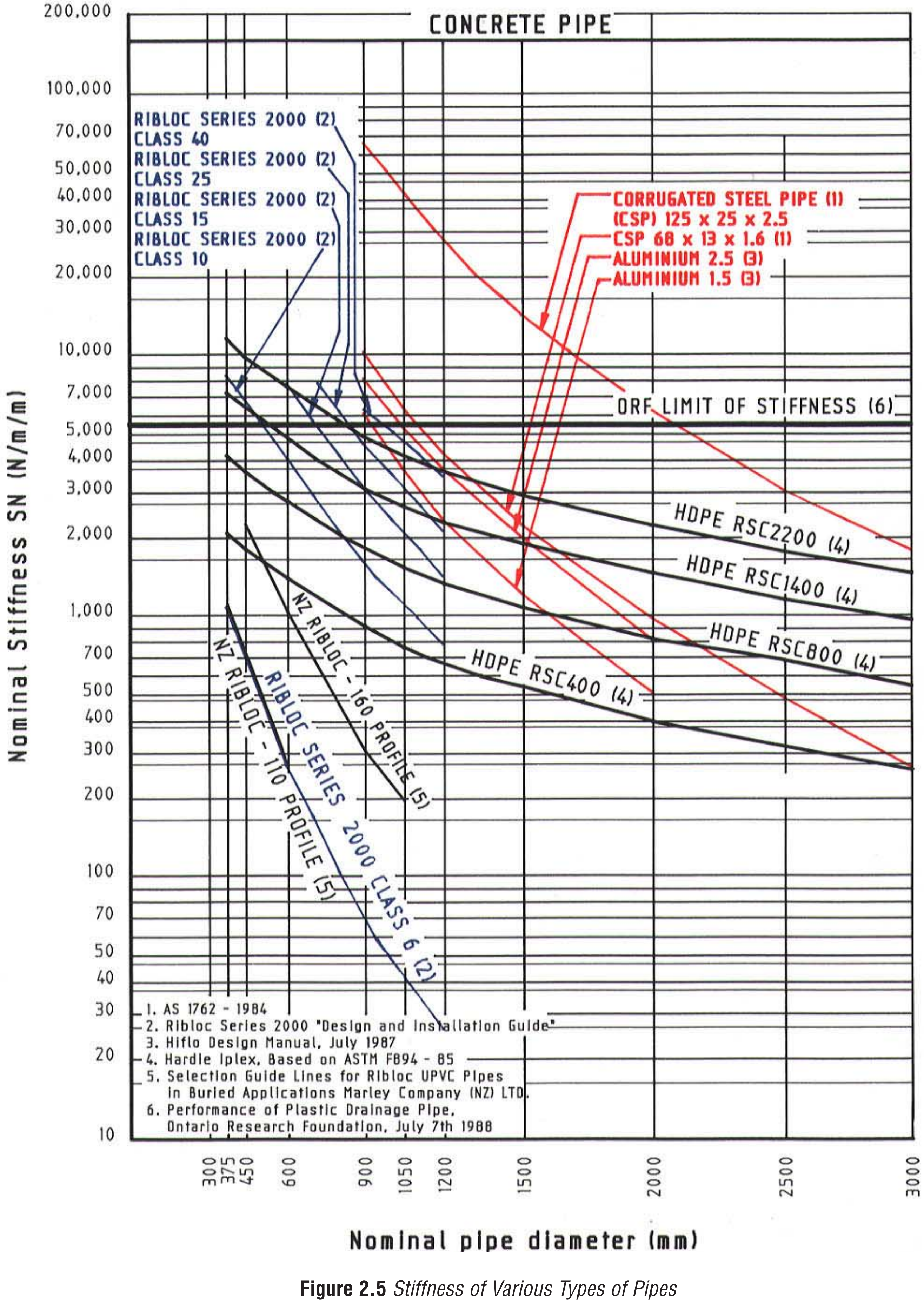


Figure 2.5 *Stiffness of Various Types of Pipes*

Grading limits for select fill in the bed and haunch zones are set out in **Table 2.2**.

Table 2.2 *Grading Limits*

Sieve size (mm)	Weight passing (%)
19	100
2.36	100 to 50
0.60	90 to 20
0.30	60 to 10
0.15	25 to 0
0.075	10 to 0

Compaction is an important part of the in ground installation and the relevant requirements are given in the applicable Standards.

For flexible pipe, as the load-carrying strength is derived by transferring loads from the pipe wall to the surrounding soil, the grading and compaction are even more critical.

Similar grading requirements to **Table 2.2** will be included in the new Australian Standard for flexible pipe.

Backfill and support are required to a minimum of 300 mm above the crown of the pipe.

Where physically possible, field tests as outlined in AS 1289 should be regularly used to measure the degree of compaction being achieved and these should be included in any specification.

In areas such as beneath the pipe in the haunch zones, where it is not possible to conduct tests due to limited headroom, where compaction is extremely critical, use of a dynamic cone penetrometer should be specified.

Compaction is probably the greatest single influence on pipe performance – and probably the least tested where it really counts.

Bearing

The long-term stability of the installation must be considered when selecting materials for bedding and support, particularly in trench conditions. The excavation of a trench on grade in impervious material may constitute a drainage channel and any material placed in the trench must resist scouring.

Sound crushed rock can be an excellent material from a stability point of view, even if gap graded.

The disadvantage of a gap graded material is that it must be surrounded by a suitable filter material, usually geotextile, if it is used in connection with foundation materials containing fines which can leach into voids.

We have only looked at three aspects in structural design. There are obviously many more but I believe these are the most significant.

Restrictions on Use

Many Authorities place restrictions on the use of flexible pipes. Some examples of these restrictions are given in Table 2.3.

Table 2.3 *Restriction on Use of Flexible Pipe*

Authority	Restriction
Sydney Water	Cover Third party interference Max deflection (short term) 3%
Melbourne Water	Cover

It is always prudent to ascertain the requirements of the Local Authority.

References

1 Spangler, M G and Handy, R L *Soil Engineering* 4th Edition 1982 (Harper & Rowe)

2 *How Do You Compare Stiffness of Different Types of Flexible Pipe?* Technical Bulletin TB2, Concrete Pipe Association of Australasia.

3 Spangler, M G *Structural Design of Flexible Pipe Culverts* Bull 153 Iowa Engineering Experiment Station, 1941.

4 *Performance of Plastic Drainage Pipe* Ontario Research Foundation, 1988. Also published as Technical Bulletin TB3/94, Concrete Pipe Association of Australasia.

5 *Standard Practice for Least Cost (Life Cycle) Analysis of Concrete Culvert, Storm Sewer, and Sanitary Sewer Systems* ASTM C1131–95, 1995.

3 SPUN CONCRETE PIPES

All of the concrete pipes used in Australasia are manufactured to AS 4058 *Precast Concrete Pipes (Pressure and Non-pressure)* or NZS 3107. These standards will be superseded by a new joint Australian/New Zealand standard in late 1998.

There are two methods for making concrete pipes commonly used in Australasia:

- roller suspension/compaction
- centrifugal wet spinning.

Less commonly, wet casting may used if the pipes being produced are larger than 2250 mm in diameter.

Roller suspension/compaction

- The empty mould with its reinforcing grid in place is suspended on a rotating roller.
- The mould is filled with a very dry concrete mix (w/c ratio barely above that required for hydration).
- The concrete is compacted between the sides of the mould and the rotating roller. This, together with the vibration, produces a strong, durable pipe.
- The mould is taken off the machine and the pipe is trowelled.
- The pipe is cured (generally in a steam chamber).
- The pipe is removed from the mould.

Centrifugal wet spinning

- The empty mould with its reinforcing grid in place is placed on a spinning machine which rotates the mould at high speed.
- About half the concrete is placed in the mould while the mould rotates at ‘filling speed’. This holds the reinforcement in place.
- The mould is vibrated while the rest of the concrete is placed into the mould.
- When the mould is full the spin speed is increased. This compacts the concrete densely into the mould and forces the excess water out of the concrete.
- The pipe is trowelled to remove excess water and slurry.
- The pipe is cured.
- The pipe is removed from the mould.

Both of these processes are illustrated in the short video presentation.

4 REINFORCEMENT

Welded steel reinforcement is used in most concrete pipes.

The reinforcing cages in concrete pipes may be circular or oval in shape.

Pipes with oval (elliptical) reinforcing have the word "TOP" stencilled on them. If these pipes have lifting holes, then the lifting holes will be at the top of the pipe.

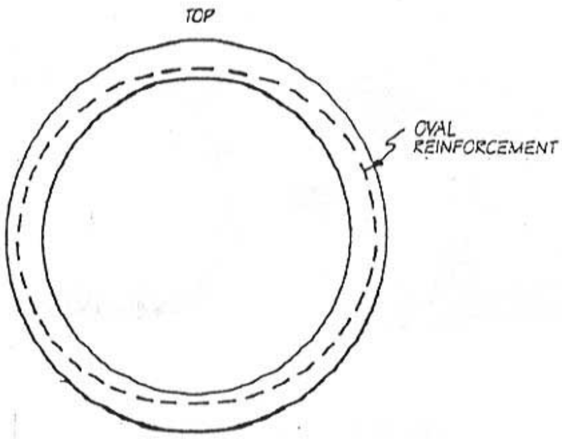


Figure 4.1 *Oval Reinforcement Cage*

Pipes with oval reinforcing are designed to place the reinforcement as close to the tension face as possible. This design maximises the steel reinforcing. It gives the pipe the required strength without needing to use as much steel as a pipe with circular reinforcing.

It is important to store, lift and lay these pipes with the 'top' up otherwise they may crack because they are not designed to take significant load on the sides of the pipe.

Pipes with circular reinforcement do not have the word "TOP" stencilled on them. Often these are pressure pipes (with two layers of reinforcement) and do not have lifting holes, so it does not matter in which orientation the pipes are laid.

5 JOINTS

Types of joints

The ends of pipes are made differently depending on how they are intended to be jointed.

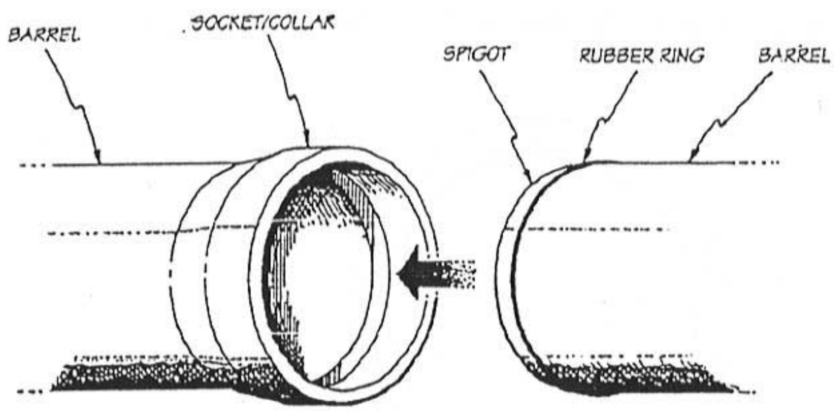


Figure 5.1 *Socketed Pipes*

Spigot and socket joints

One end of the pipe is referred to as the socket and the other end as the spigot. The spigot fits into the socket of the previously laid pipe. The joint is then sealed. To seal the joint a rubber ring is used. Rubber rings make a flexible joint and allow the pipes to move and still keep a watertight joint.

Flush jointed pipes

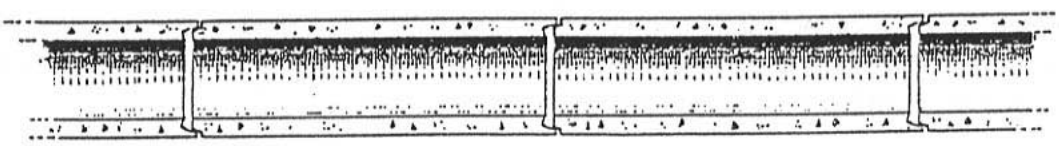


Figure 5.2 *Flush Joints*

There are three main ways to seal flush jointed pipes. The optimal solution depends on the situation. The three alternatives are:

- **open joints** – Some specifications require that you do not seal the joints. If the joints are not sealed then the pipes will not be watertight. So why leave the joints unsealed? If the water table is high ground water is attracted to the gravel bed the pipe is lying in. Leaving the joints unsealed allows this ground water to enter the pipe and drain away.

- **cement mortar** – This makes a more watertight joint and stops sand ingress.

- **external band (sand band)** – These are best if the fill over the pipe or the bedding material contains fine sand. The band stops the sand entering the pipe through the joint. If sand enters through the joint and flows along the pipeline there are two problems it can cause. Firstly, the pipe can silt up and secondly fill above and around the pipe is lost which can result in pot holes in the ground or loss of pipe support.

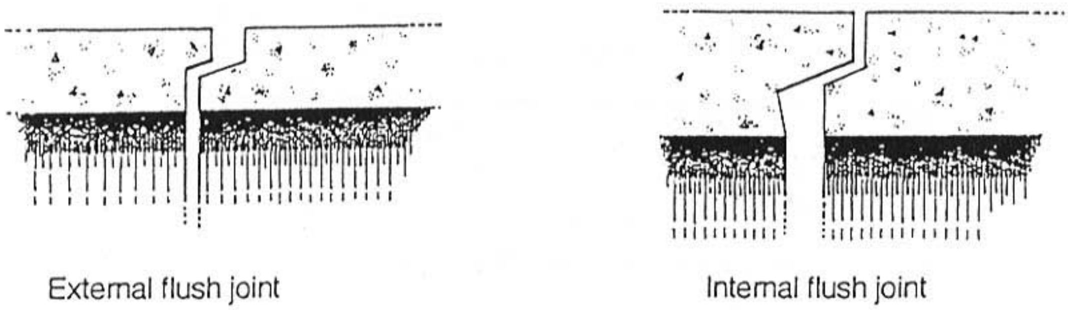


Figure 5.3 *Flush Joint Details*

Smaller pipes (up to and including 525 mm diameter) have external flush joints (these are mortared/sealed from the outside). Larger pipes (over 525 mm diameter) have internal flush joints (these are mortared/sealed from the inside).

Butt jointed pipes (jacking pipe)

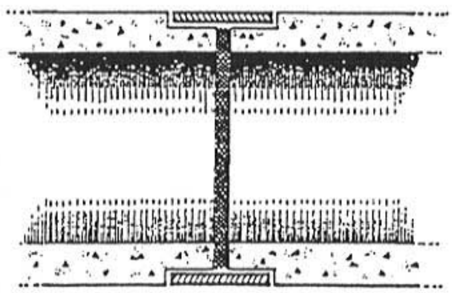


Figure 5.4 *Butt Joints*

Butt joint pipes are mainly used for jacking pipes. Jacking involves pushing pipes through sandy or silty soil and is more common in smaller diameter pipes and where the normal methods of excavating, pipelaying and backfilling are not possible or too costly eg deep sewer lines.

Butt jointed pipes are well suited to jacking because the butt joint maximises the contact area and allows maximum load transfer across the joint.

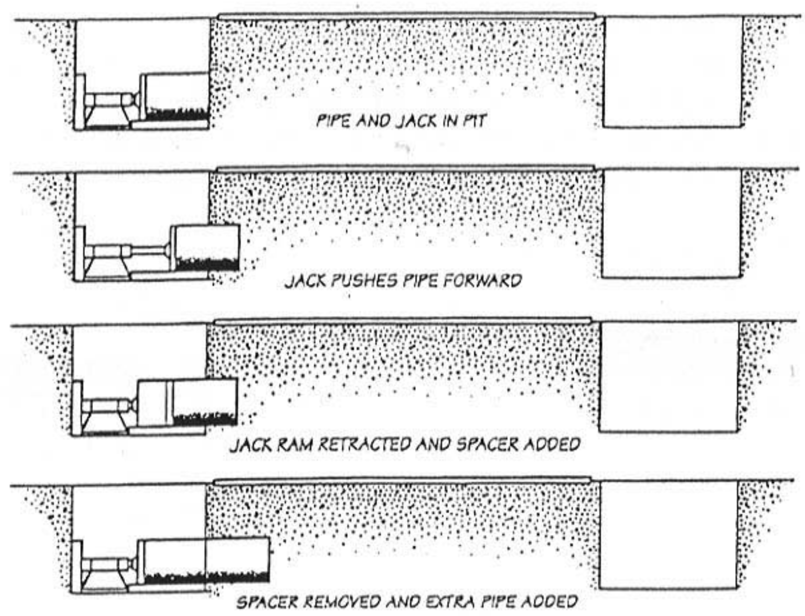


Figure 5.5 *Typical Pipe Jacking Installation*

6 TESTING

Tests by the manufacturer
To help maintain quality, pipes are tested by the manufacturer at the factory.

There are two types of testing routinely carried out by the manufacturer:

- load testing
- hydrostatic testing.

Other types of testing which may be carried out by the manufacturer include absorption testing and materials testing.

Load testing

A sample of pipes is randomly selected (in accordance with the manufacturer's QA system) from a factory's production. These pipes are load tested to make sure they can support the design loads placed on the pipeline. This is done by placing the pipe in a jig that applies a specified load to the tip of the pipe barrel and measuring the load at which a 0.1 mm crack occurs.

The importance of the load test will become apparent when standard installations are considered.

Hydrostatic testing

Most sewer and pressure pipes are tested to make sure they do not leak. this is done by blocking both ends of the pipe and filling it with either water or air to set pressure for a set time. Acceptable levels of leakage are determined by the specification.

Field testing

Testing undertaken during or after construction is known as field testing. Field test are tests that are done by the pipelayer after the pipeline has been laid.

Most sewer and pressure pipes, and selected stormwater drainage pipelines need to be pressure tested before the pipeline is used. The specification will call up field testing if required.

Field testing makes sure that the pipes have been jointed properly and laid correctly.

The Concrete Pipe Association of Australasia has a brochure available which describes appropriate methods of field testing. Remember, field testing tests the quality of construction NOT the quality of the pipes.

7 LOADS ON PIPES

The load acting on a concrete pipe is made up of the following components:

- superimposed load
- soil load
- construction loads.

Superimposed (or live) load – is generally caused by traffic and its effect decreases the deeper a pipe is buried and load effects are spread into the surrounding soil.

Soil load – increases with depth and depends on factors such as:

- soil type
- trench width
- installation type.

Soil type – usually a clay soil is more dense than a granular material so pipe installations backfilled with more dense materials will carry a greater load.

Trench width – generally the wider the trench the greater the load imposed by the backfill over the pipe up to the point where wide trenches effectively become embankments. Trench width is always measured at the top of the pipe.

Installation type – the bedding factor which is the ratio of the load carried by the designed pipeline installation to the factory test load.

$$\text{Bedding factor} = \frac{\text{Load carried by pipeline installation}}{\text{Factory test load}}$$

is a measure of the support a pipeline is given by the surrounding installation. The better the installation the greater the support and the greater the load carrying capacity of the installation. The various standard installations, given in Australian Standard AS 3725 *Loads on Buried Concrete Pipes* will be discussed in the next topic.

Construction loads

Studies carried out by Brisbane City Council have shown that excessive compaction force caused by a combination of:

- over compaction
- selection of inappropriate compaction equipment
- running construction equipment over pipes before there is adequate cover

is one of the major causes of pipe failures.

A short video will highlight some of the modes of failure.

8 STANDARD INSTALLATIONS

Supporting Concrete Pipes

The Australian Standard AS 3725 *Loads on buried concrete pipes* classifies pipe installations and specifies the requirements for soil materials around the pipes and the compaction of these materials. AS 3725 would normally be referenced in the job specification.

There are three main types of pipe support in the standard:

- type U support for uncontrolled pipe installations
- type H support for pipes installed with haunch support
- type HS support for pipes installed with haunch and side support

The different types of support (U, H and HS) are needed to give the pipeline good support in different ground and load conditions. For example in good soil conditions and with light loads type H embedment might give the same strength to the pipeline as type HS embedment in poor soil or under greater loads.

Concrete pipes have a built in strength of their own which is why type U installations where the pipe has very little support are possible. However the type and quality of installation can add greatly to the strength of a pipeline and can make the pipeline able to bear greater loads (up to four times the 'inherent' strength).

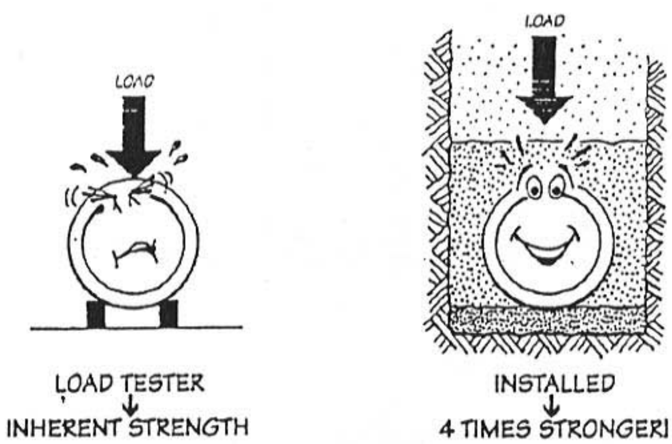


Figure 8.1 *Bedding Factors*

Pipe installations are designed for specific situations and you should always be aware of this when setting the job specification.

Type U support

Type U is an uncontrolled pipe installation. This type of support offers less support to the pipe than any of the other types.

In a type U installation:

- pipes are laid directly onto the foundation material without any bedding (except if the foundation is rock);
- if the foundation is rock 75 mm of bedding is specified;
- there is a 300 mm overlay zone of compacted ordinary fill is required to protect the pipe.

The following are examples of type U installations for a 1200 diameter pipe:

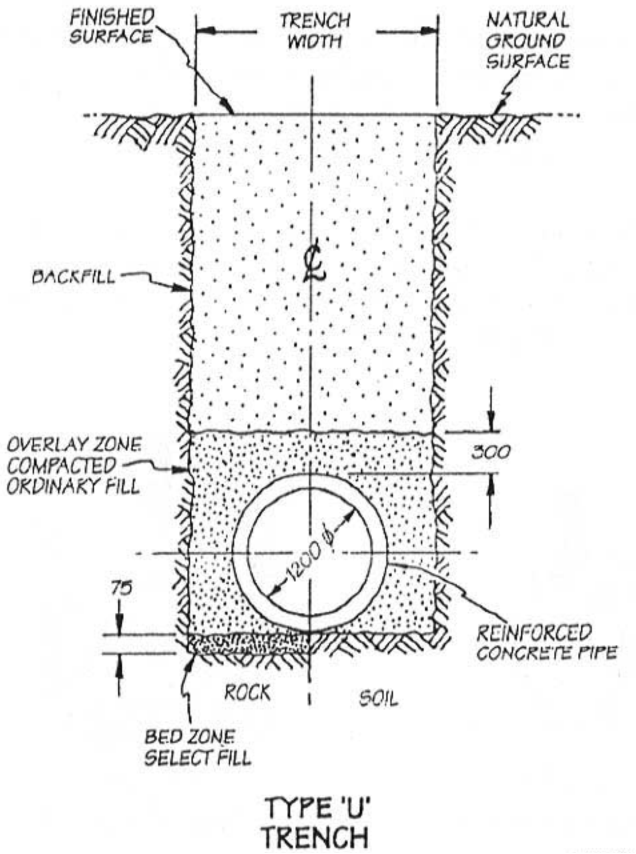


Figure 8.2(a) *Type 'U' Trench*

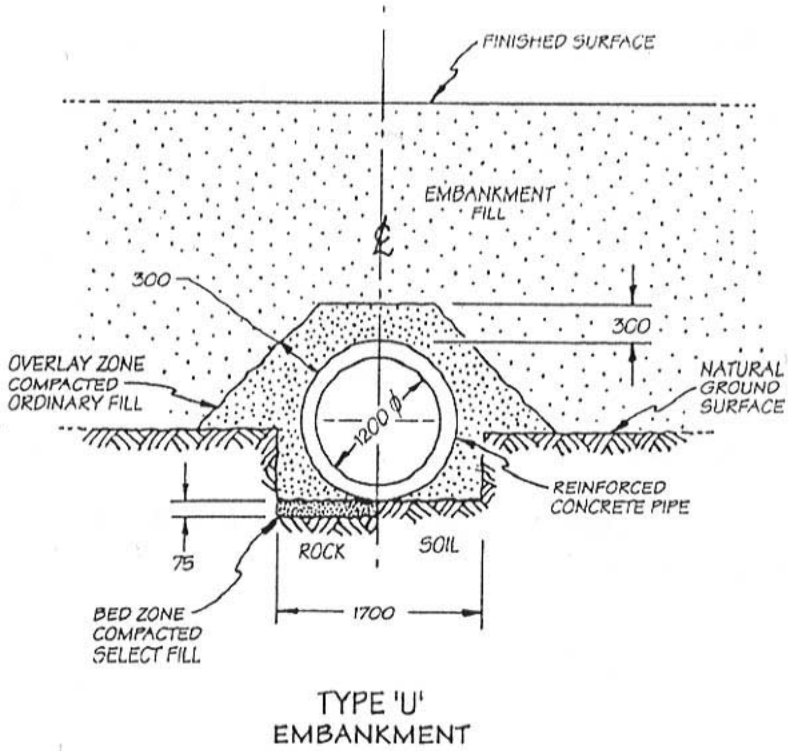


Figure 8.2(b) *Type 'U' Embankment*

The bedding factor for a type U installation is 1.

Type H support

Type H provides haunch support to the pipe by having compacted select fill in the haunch zone.

There are three types of support within type H. They are:

- H1 – haunch support to 10% of the outside diameter of the pipe;
- H2 – haunch support to 30% of the outside diameter of the pipe;
- H3 – concrete cradle.

H1 and H2 are the most commonly used. H3 is used only in special cases. CPAA does not encourage its general use.

Type H1 support

- There is a bedding of select fill.
- The haunch zone consists of compacted select fill.
- The haunch zone goes from the base of the pipe to a height of 0.1 times the diameter of the pipe (ie to $^1/_{10}$ of the diameter of the pipe).
- The haunch zone is compacted to a minimum dry density ratio of 85% (DI = 50).
- There is a 300 mm overlay zone of compacted ordinary fill.

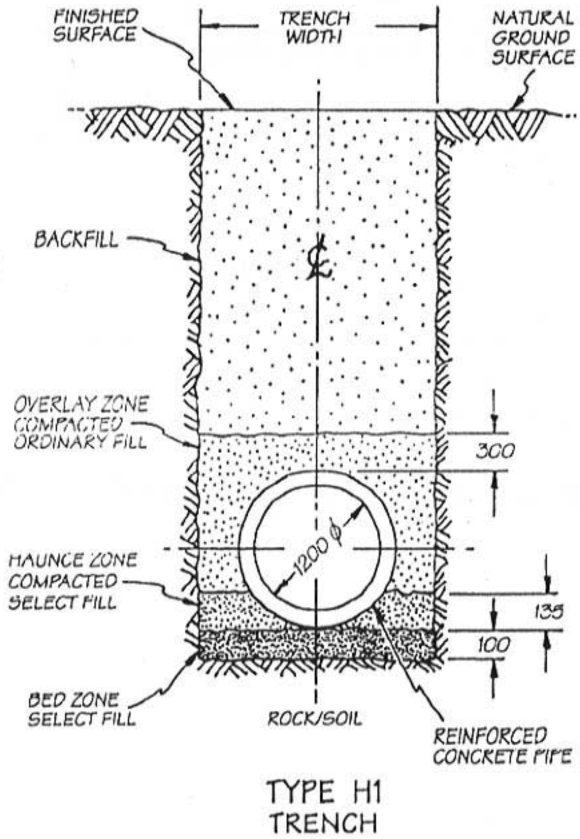


Figure 8.3(a) *Type H1 Trench*

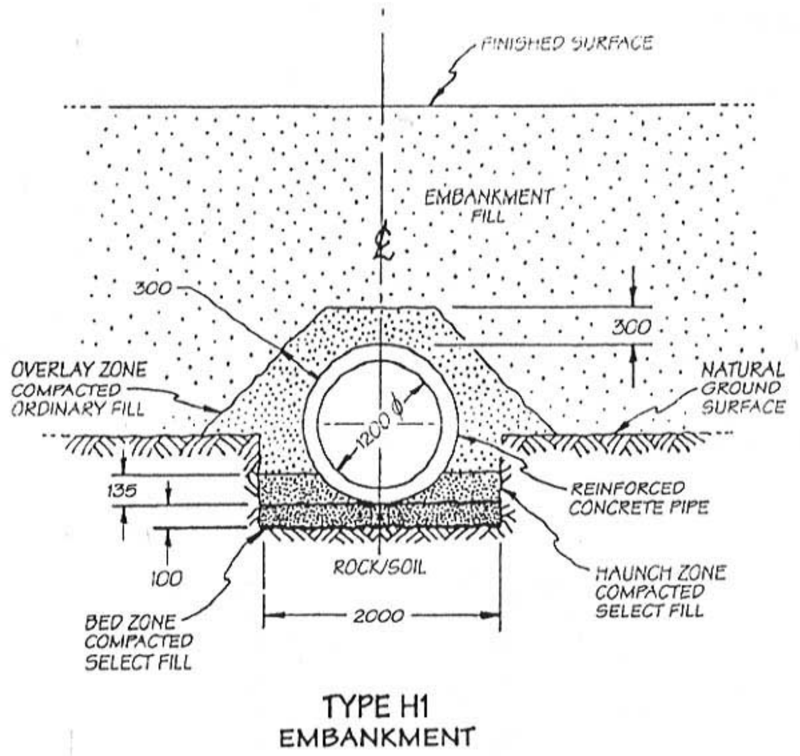


Figure 8.3(b) *Type H1 Embankment*

The bedding factor for an H1 support is 1.5.

Note the additional load can this installation can support when compared to a Type U installation.

Type H2 support

- There is a bedding of select fill.
- The haunch zone consists of compacted select fill.
- The haunch zone goes from the base of the pipe to a height of 0.3 times the diameter of the pipe (ie to 3/10 of the diameter of the pipe).
- The haunch zone is compacted to a minimum dry density ratio of 90% (DI = 60).
- There is a 300 mm overlay zone of compacted ordinary fill.

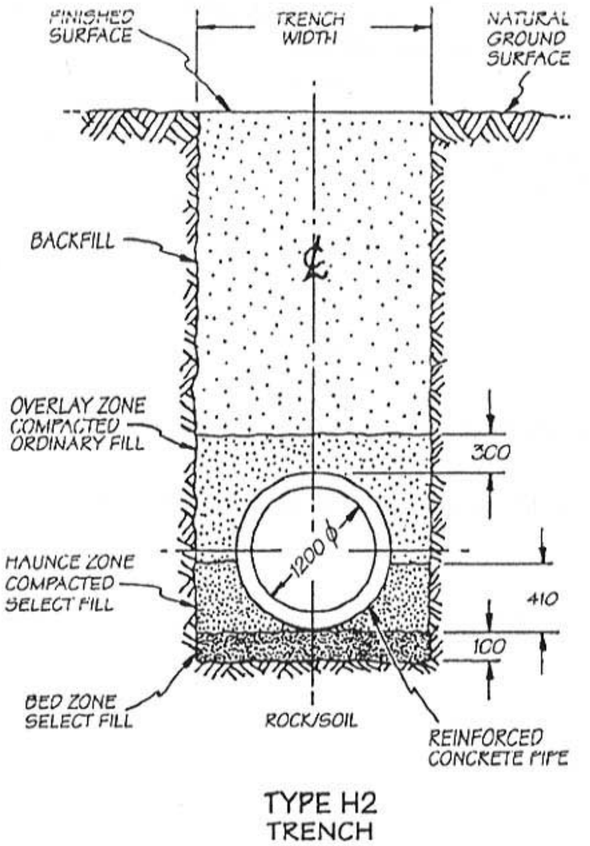


Figure 8.4(a) *Type H2 Trench*

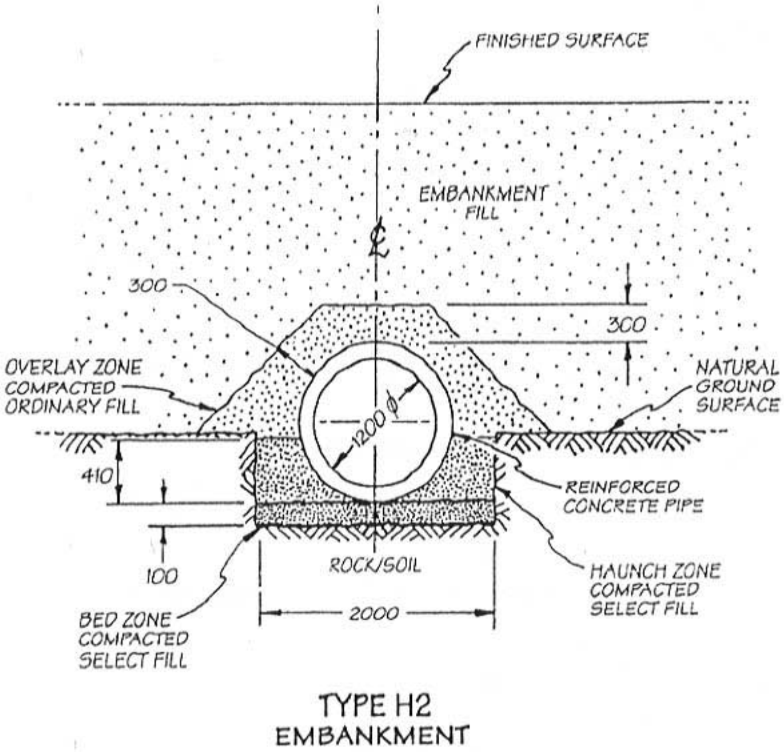


Figure 8.4(b) *Type H2 Embankment*

The bedding factor for type H2 support is 2.

Compare this with type HS1which has the same bedding factor.

Type H3 support

H3 uses concrete to support the pipe and is expensive. Because of the cost H3 is not used for general pipelaying installations and is only used in special circumstances such as installing sewer pipes on an unstable foundation.

Type HS support

Type HS provides haunch and side support to the pipe.

There are three types of support within type HS. They are:

- HS1 – haunch support to 10% of external diameter, plus side support;
- HS2 – haunch support to 30% of external diameter, plus side support;
- HS3 – haunch support to 30% of external diameter, plus side support.

The three types of HS support vary in the depth of the haunch zone and in the amount of compaction of the haunch and side zones.

The easiest way to remember about HS installations is that they are the same as H installations but with side support added.

Type HS1 support

- There is a bedding of select fill.
- The haunch and side zones consist of compacted select fill.
- The haunch zone goes from the base of the pipe to a height of 0.1 times the diameter of the pipe (ie to $^1/_{10}$ of the diameter of the pipe).
- The haunch zone is compacted to a minimum dry density ratio of 85% (DI = 50).
- The side zone goes from the top of the haunch zone to a height of 0.7 times the diameter of the pipe (ie to $^7/_{10}$ of the diameter of the pipe).
- The side zone is compacted to a minimum dry density ratio of 85% (DI = 50).
- There is a 300 mm overlay zone of compacted ordinary fill.

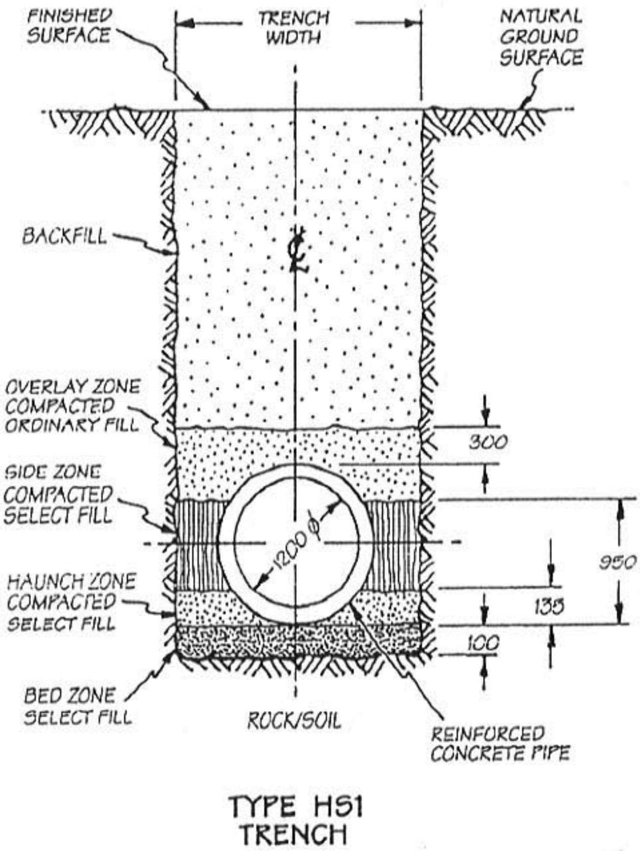


Figure 8.5(a) *Type HS1 Trench*

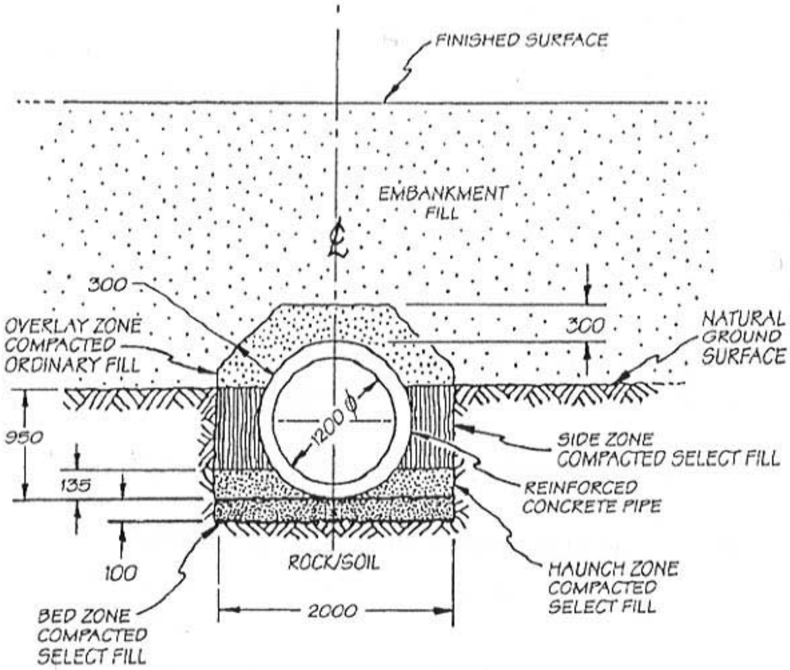


Figure 8.5(b) *Type HS1 Embankment*

The bedding factor for type HS1 support is 2 which is the same as an H2 installation.

Type HS2 support

- There is a bedding of select fill.
- The haunch and side zones consist of compacted select fill.
- The haunch zone goes from the base of the pipe to a height of 0.3 times the diameter of the pipe (ie to 3/10 of the diameter of the pipe).
- The haunch zone is compacted to a minimum dry density ratio of 90% (DI = 60).
- The side zone goes from the top of the haunch zone to a height of 0.7 times the diameter of the pipe (ie to 7/10 of the diameter of the pipe).
- The side zone is compacted to a minimum dry density ratio of 90% (DI = 60).
- There is a 300 mm overlay zone of compacted ordinary fill.

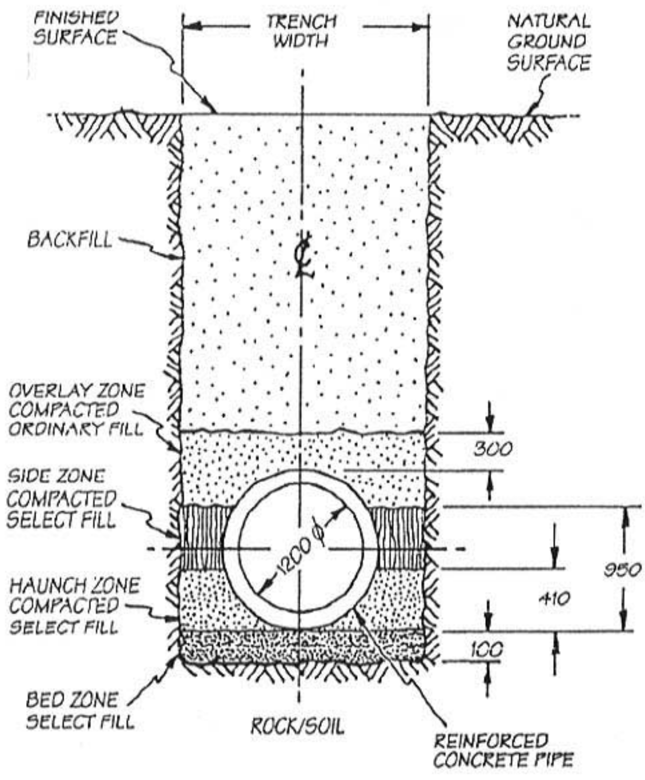


Figure 8.6(a) *Type HS2 Trench*

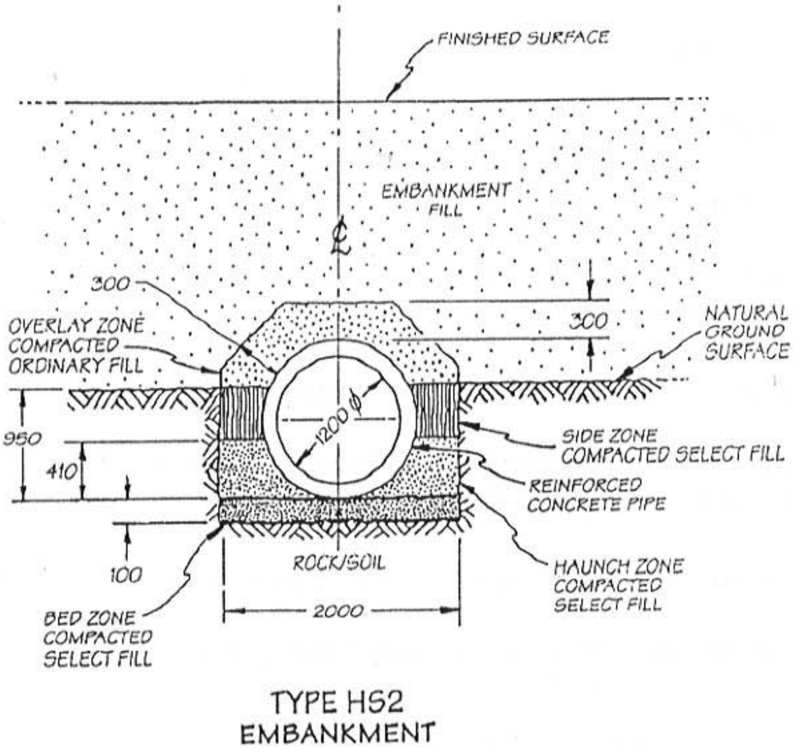


Figure 8.6(b) *Type HS2 Embankment*

The bedding factor for HS2 support is 2.5.

Type HS3 support

Most of the conditions for HS3 support are the same as for HS2 support. The difference is in the compaction. For HS3 support the haunch zone and side zones are compacted to a minimum dry density ratio of 95% (DI = 70).

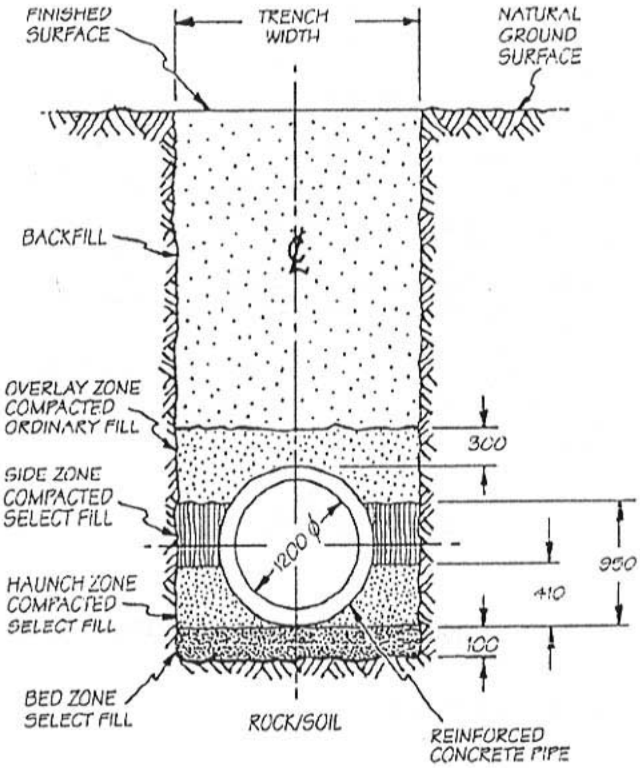


Figure 8.7(a) *Type HS3 Trench*

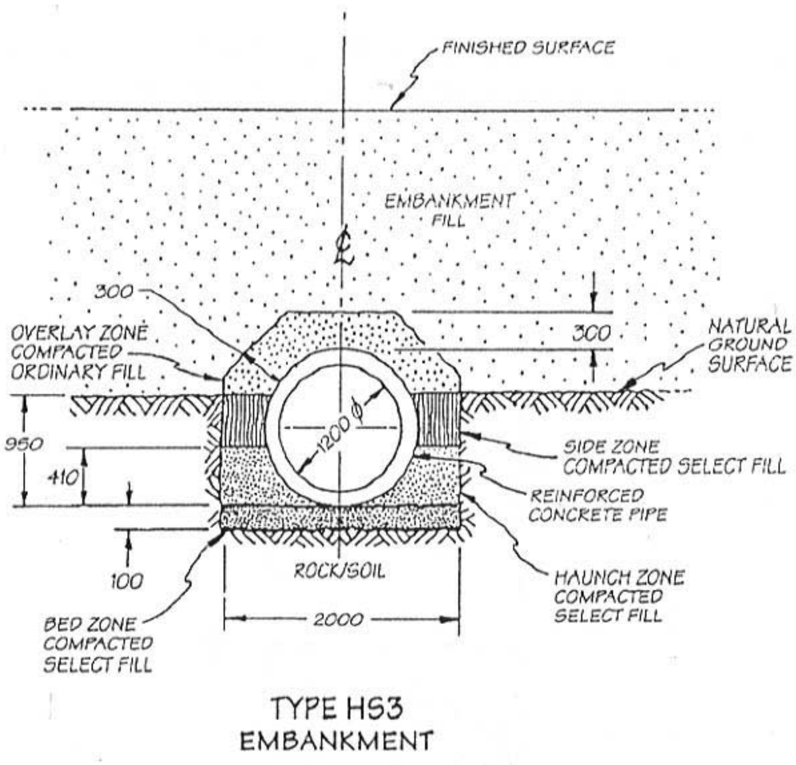


Figure 8.7(b) *Type HS3 Embankment*

The bedding factor for HS3 support is 4.

9 SPECIFICATIONS AND FAILURES

Failure

A short video of a CCTV inspection of an in-service pipeline will be viewed illustrating types of ‘failure’. This will form the basis of a group discussion on possible causes.

Specification

The firm’s standard specifications may also be critically examined in the light of previous discussion and constructive comment made for improvement.

10 DESIGN AIDS

Use of Pipe Selection and Installation Charts

The use of the three standard installation types (U, H and HS) has enabled the Concrete Pipe Association of Australasia to produce a series of simple charts to help designers select the right combination of pipe class and support type.

The charts for 600 mm diameter pipe are reproduced on the following pages.

Design example:

Use the CPAA charts to design the following pipeline which crosses parkland and is not subject to vehicle loads.

Data:

Diameter	600 mm
Depth of fill	5 m
Backfill	Clay-sand
Trench width	Minimum

1 What is the minimum trench width? ____________ metres

2 Complete the following table:

Support type	Pipe class
H1	
H2	
HS1	
HS2	

3 Why is the pipe class for H2 and HS1 the same?

4 The consultant has selected an H2/Class 3 installation and while laying the pipe some wet material is encountered and the trench walls slump, leaving a trench width of 1.8 m. Is there a problem? What are the two solutions?

5 If you choose to increase pipe class, what class would you need?

6 If you choose a better type of support, what support type would you need?

Discuss these results.

The Concrete Pipe Association of Australasia also has available software (PSS ver 3.0) which calculates pipe load class and quantities for various conditions.

This will also be used to solve the previous design example.

11 SUMMARY

We have looked at only one phase of a pipeline's life cycle, the design phase, and seen that pipeline design is not merely selecting a material with the lowest Mannings n. In fact, hydraulic roughness pales into insignificance in comparison to factors such as pit losses and assumptions made in flood estimation. Structural factors such as stiffness and the benefits of pipeline installations are equally important.

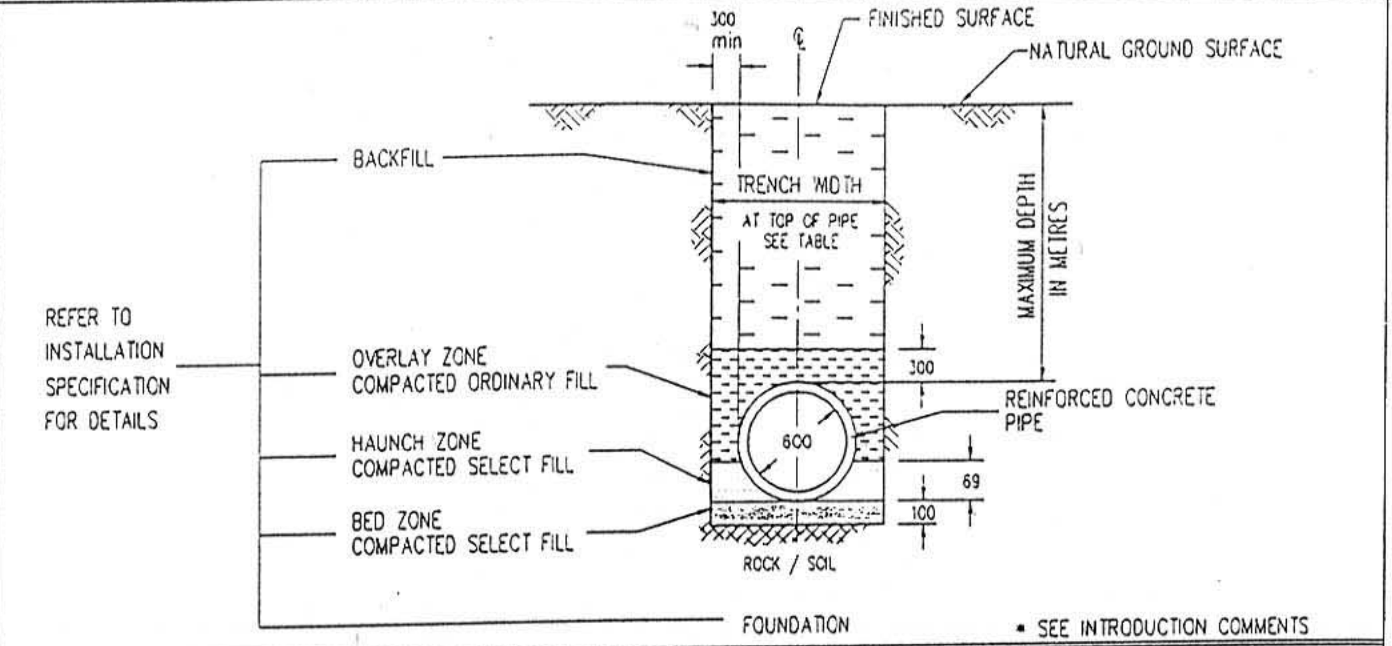
Neither should other factors, including capital cost, be the sole determinant for investment decisions.

Selection and specification of pipeline materials should be based on sound Life Cycle Costing (ie economic) and engineering principles to ensure that the end product will be fit for purpose and provide the performance required throughout the design life.

DESIGN CHARTS

PIPE SELECTION AND INSTALLATION

EARTH LOAD	TRENCH INSTALLATION	TYPE H1	DIAMETER 600mm



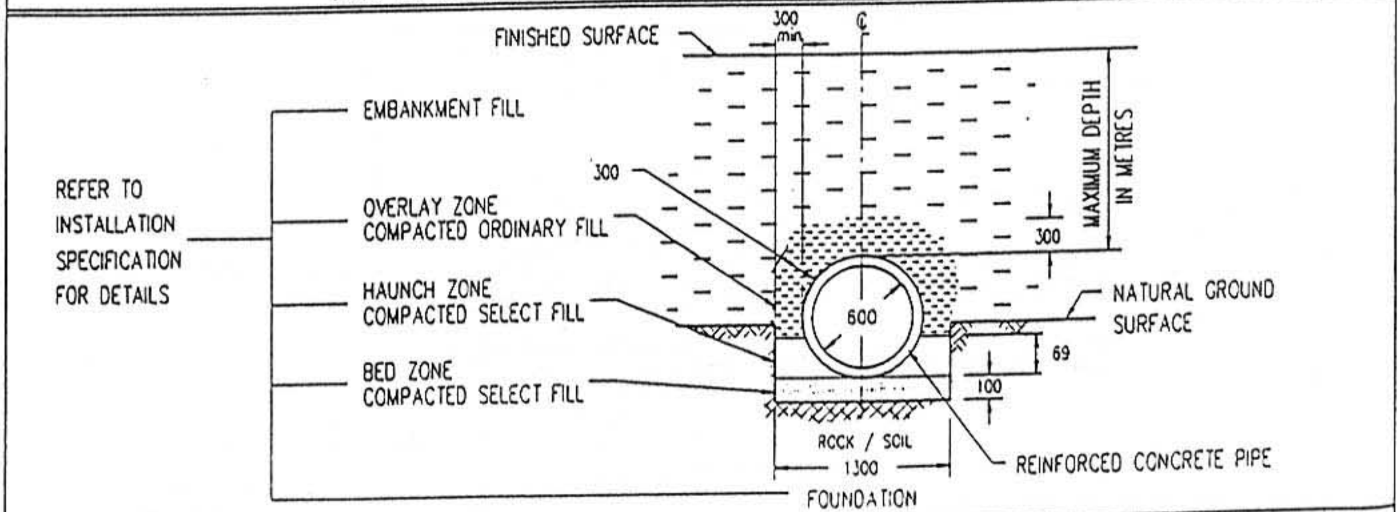
* SEE INTRODUCTION COMMENTS

MAXIMUM DEPTH IN METRES

TRENCH INSTALLATION

TRENCH WIDTH	PIPE CLASS																	
	2	3	4	6	8*	10*	2	3	4	6	8*	10*	2	3	4	6	8*	10*
1.2	3.2	11.6	>25	>25	>25	>25	2.4	4.4	9.2	>25	>25	>25	2.0	3.2	4.8	12.2	>25	>25
1.4	2.2	4.6	11.4	>25	>25	>25	-	3.2	5.0	24.9	>25	>25	-	-	-	6.8	13.2	>25
1.6	-	3.2	5.4	>25	>25	>25	-	-	-	7.6	>25	>25	-	-	-	-	8.0	13.2
1.8	-	-	-	9.4	>25	>25	-	-	-	-	9.6	>25	-	-	-	-	-	-
2.0	-	-	-	6.4	14.4	>25	-	-	-	-	-	11.0	-	-	-	-	-	-
2.2	-	-	-	-	8.8	19.8	-	-	-	-	-	-	-	-	-	-	-	-
SOIL DESCRIPTION	SAND AND GRAVEL						CLAYEY SAND						WET CLAY					
TRENCH WIDTH GREATER THAN	1.4	1.6	1.6	2.0	2.2	2.2	1.2	1.4	1.4	1.6	1.8	2.0	1.2	1.2	1.2	1.4	1.6	1.6
EMBANKMENT INSTALLATION	2.0	3.2	4.2	6.4	8.8	10.6	2.0	3.0	4.0	5.8	7.8	9.8	2.0	2.8	3.8	5.6	7.4	9.4
	X	Y	Z	1.5Z	2Z	2.5Z	X	Y	Z	1.5Z	2Z	2.5Z	X	Y	Z	1.5Z	2Z	2.5Z
	PIPE CLASS																	

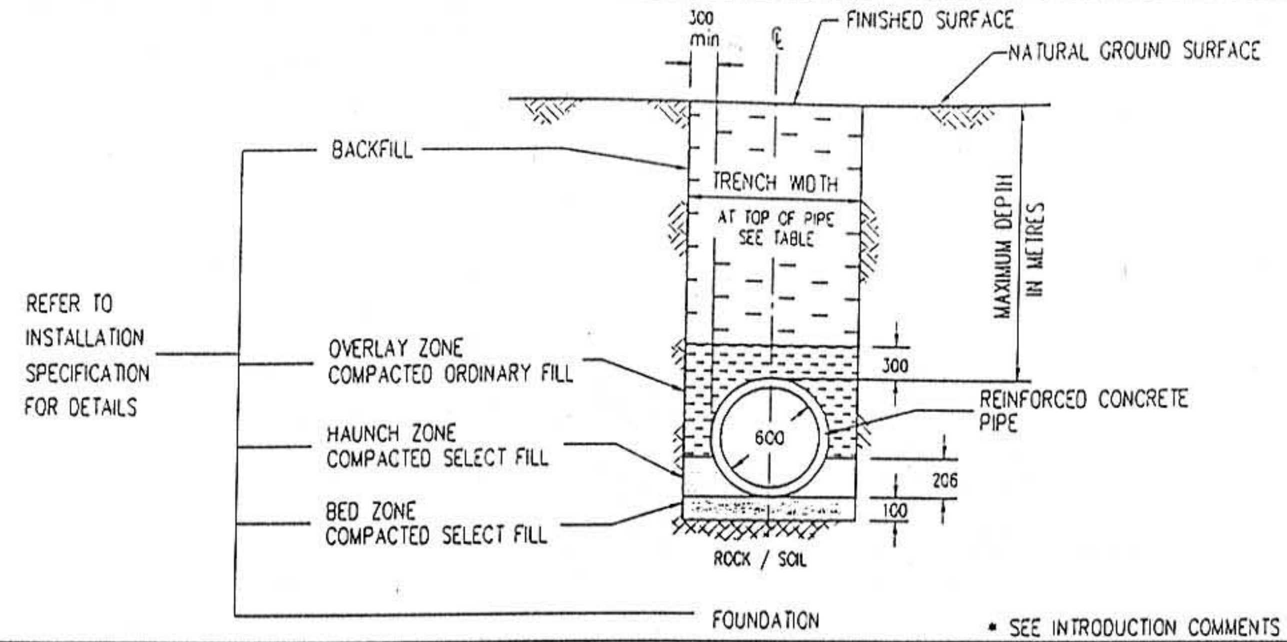
MAXIMUM DEPTH IN METRES



DATE OF ISSUE JUNE 1990	EMBANKMENT INSTALLATION	TYPE H1	600mm

PIPE SELECTION AND INSTALLATION

EARTH LOAD	TRENCH INSTALLATION	TYPE H2	DIAMETER 600mm

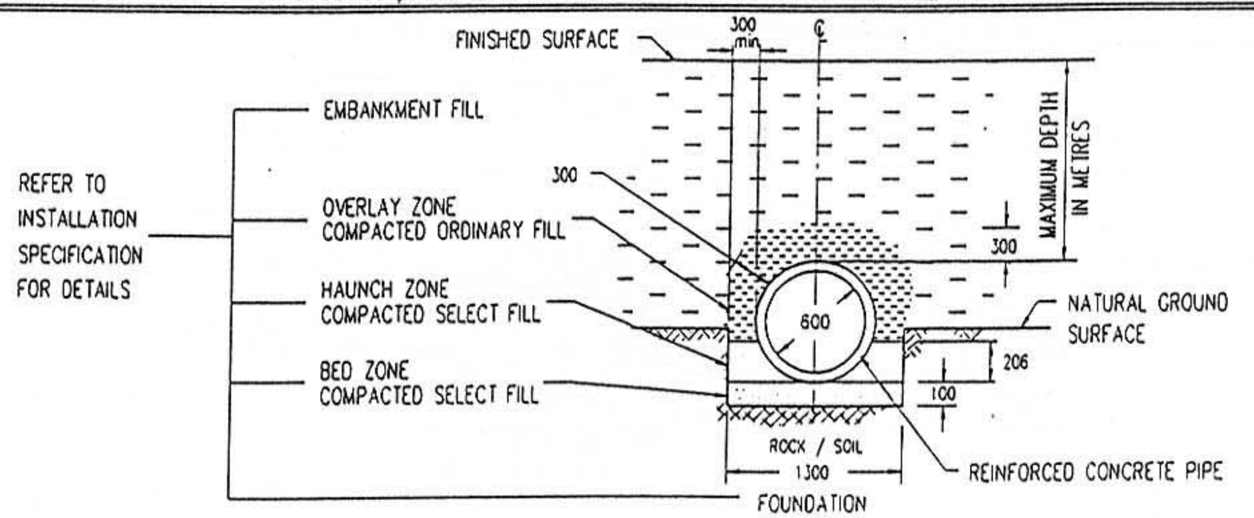


* SEE INTRODUCTION COMMENTS

MAXIMUM DEPTH IN METRES

	TRENCH WIDTH	PIPE CLASS 2	3	4	6	8*	10*	2	3	4	6	8*	10*	2	3	4	6	8*	10*
TRENCH INSTALLATION	1.2	6.2	>25	>25	>25	>25	>25	3.6	9.2	>25	>25	>25	>25	2.6	4.8	8.6	>25	>25	>25
	1.4	3.6	11.4	>25	>25	>25	>25	2.8	5.0	10.0	>25	>25	>25	-	-	5.4	13.2	>25	>25
	1.6	-	5.4	15.6	>25	>25	>25	-	-	6.0	>25	>25	>25	-	-	-	8.0	16.2	>25
	1.8	-	-	6.8	>25	>25	>25	-	-	-	9.6	>25	>25	-	-	-	-	-	17.4
	2.0	-	-	-	14.4	>25	>25	-	-	-	-	13.4	>25	-	-	-	-	-	-
	2.2	-	-	-	-	>25	>25	-	-	-	-	-	16.4	-	-	-	-	-	-
SOIL DESCRIPTION		SAND AND GRAVEL						CLAYEY SAND						WET CLAY					
TRENCH WIDTH GREATER THAN		1.4	1.6	1.8	2.0	2.4	2.6	1.4	1.4	1.6	1.8	2.0	2.2	1.2	1.2	1.4	1.6	1.6	1.8
EMBANKMENT INSTALLATION		3.0	4.4	5.8	8.8	11.8	14.6	2.8	4.0	5.4	8.2	11.0	13.8	2.6	3.8	5.2	7.8	10.4	13.0
	PIPE CLASS	X	Y	Z	1.5Z	2Z	2.5Z	X	Y	Z	1.5Z	2Z	2.5Z	X	Y	Z	1.5Z	2Z	2.5Z

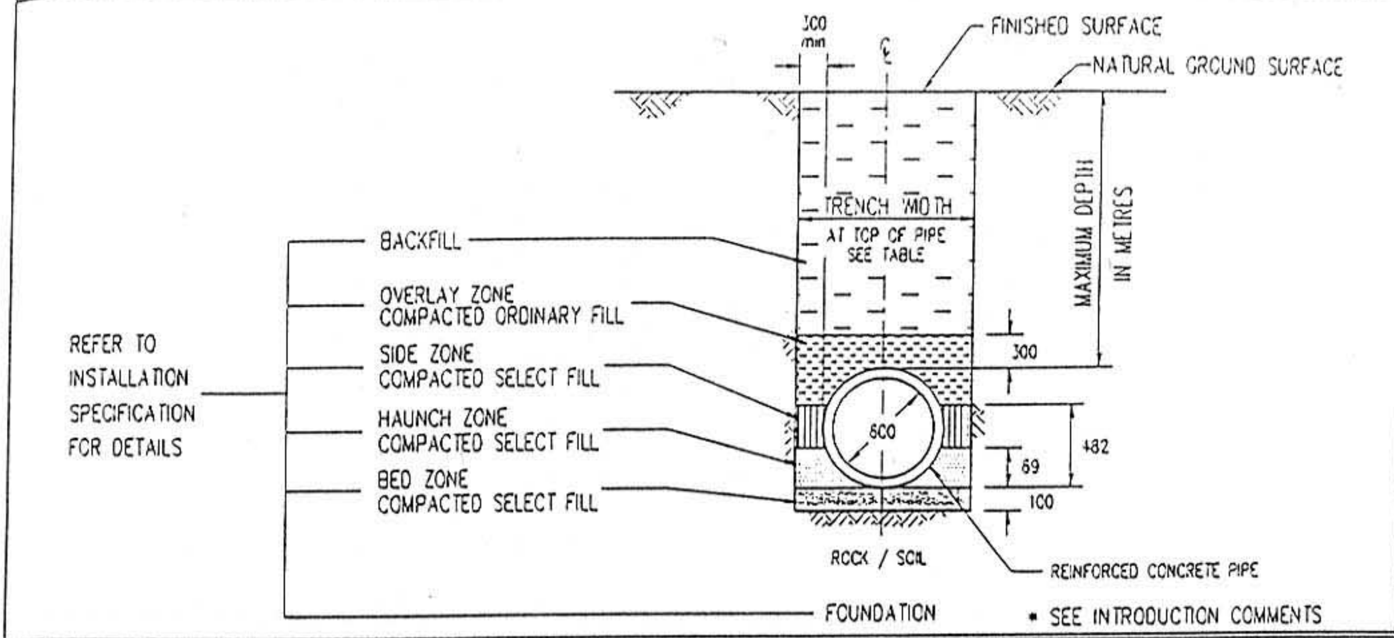
MAXIMUM DEPTH IN METRES



DATE OF ISSUE JUNE 1990	EMBANKMENT INSTALLATION	TYPE H2	600mm

PIPE SELECTION AND INSTALLATION

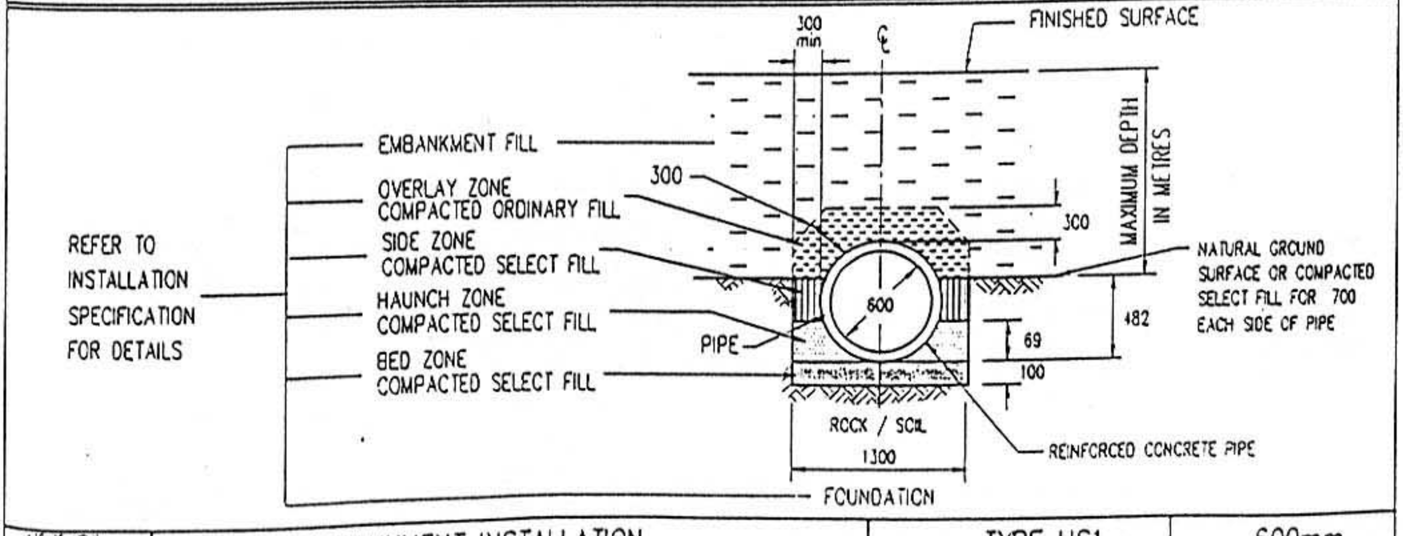
EARTH LOAD	TRENCH INSTALLATION	TYPE HS1	DIAMETER 600mm



MAXIMUM DEPTH IN METRES

	TRENCH WIDTH	PIPE CLASS 2	3	4	6	8*	10*	2	3	4	6	8*	10*	2	3	4	6	8*	10*
TRENCH INSTALLATION	1.2	6.2	>25	>25	>25	>25	>25	3.6	9.2	>25	>25	>25	>25	-	4.8	8.6	>25	>25	>25
	1.4	3.6	11.4	>25	>25	>25	>25	-	5.0	10.0	>25	>25	>25	-	-	-	13.2	>25	>25
	1.6	-	5.4	15.6	>25	>25	>25	-	-	-	>25	>25	>25	-	-	-	-	16.2	>25
	1.8	-	-	6.8	>25	>25	>25	-	-	-	9.6	>25	>25	-	-	-	-	-	17.4
	2.0	-	-	-	14.4	>25	>25	-	-	-	-	13.4	>25	-	-	-	-	-	-
	2.2	-	-	-	-	>25	>25	-	-	-	-	-	16.4	-	-	-	-	-	-
SOIL DESCRIPTION		SAND AND GRAVEL						CLAYEY SAND						WET CLAY					
TRENCH WIDTH GREATER THAN		1.4	1.6	1.8	2.0	2.2	2.6	1.2	1.4	1.4	1.8	2.0	2.2	1.0	1.2	1.2	1.4	1.6	1.8
EMBANKMENT INSTALLATION		3.4	5.0	6.8	10.0	13.4	16.8	3.0	4.6	6.2	9.2	12.4	15.4	2.8	4.2	5.8	8.6	11.6	14.4
	PIPE CLASS	X	Y	Z	1.5Z	2Z	2.5Z	X	Y	Z	1.5Z	2Z	2.5Z	X	Y	Z	1.5Z	2Z	2.5Z

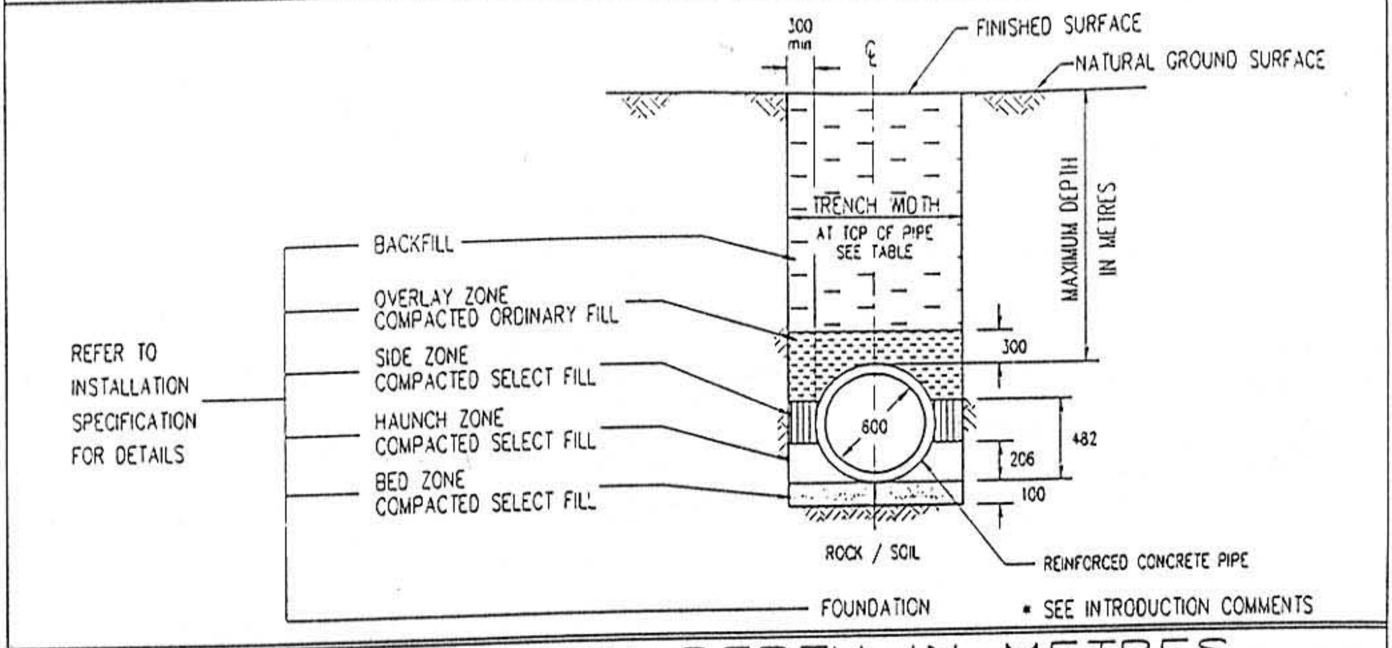
MAXIMUM DEPTH IN METRES



[illegible] 1990	EMBANKMENT INSTALLATION	TYPE HS1	600mm

PIPE SELECTION AND INSTALLATION

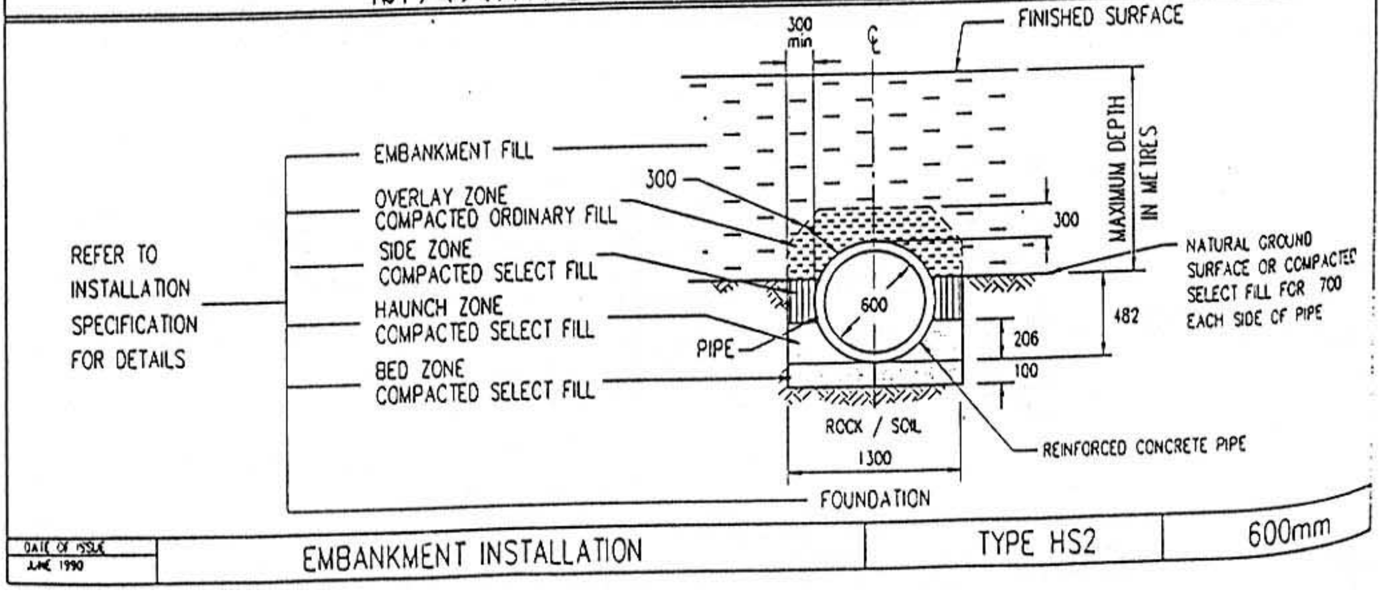
EARTH LOAD	TRENCH INSTALLATION	TYPE HS2	DIAMETER 600mm



MAXIMUM DEPTH IN METRES

	TRENCH WIDTH	PIPE CLASS 2	3	4	6	8*	10*	2	3	4	6	8*	10*	2	3	4	6	8*	10*
TRENCH INSTALLATION	1.2	>25	>25	>25	>25	>25	>25	5.4	>25	>25	>25	>25	>25	3.6	7.4	>25	>25	>25	>25
	1.4	5.8	>25	>25	>25	>25	>25	-	8.2	>25	>25	>25	>25	-	-	8.2	>25	>25	>25
	1.6	-	10.2	>25	>25	>25	>25	-	-	9.8	>25	>25	>25	-	-	-	13.2	>25	>25
	1.8	-	-	15.6	>25	>25	>25	-	-	-	>25	>25	>25	-	-	-	-	17.4	>25
	2.0	-	-	-	>25	>25	>25	-	-	-	-	>25	>25	-	-	-	-	-	20.2
	2.2	-	-	-	19.8	>25	>25	-	-	-	-	16.4	>25	-	-	-	-	-	-
SOIL DESCRIPTION		SAND AND GRAVEL						CLAYEY SAND						WET CLAY					
TRENCH WIDTH GREATER THAN		1.4	1.6	1.8	2.2	2.6	2.8	1.2	1.4	1.6	1.8	2.2	2.4	1.2	1.2	1.4	1.6	1.8	2.0
EMBANKMENT INSTALLATION		4.2	6.2	8.4	12.6	16.8	21.2	3.8	5.8	7.8	11.6	15.4	19.4	3.6	5.4	7.2	10.8	14.4	18.2
	PIPE CLASS	X	Y	Z	1.5Z	2Z	2.5Z	X	Y	Z	1.5Z	2Z	2.5Z	X	Y	Z	1.5Z	2Z	2.5Z

MAXIMUM DEPTH IN METRES



DATE OF ISSUE JUNE 1990	EMBANKMENT INSTALLATION	TYPE HS2	600mm

Concrete Pipe Association of Australasia

ACN 007 067 656

AUSTRALIAN OFFICE:
admin@cpaa.asn.au
www.cpaa.asn.au

NEW ZEALAND OFFICE:
26-30 Prosford Street,
(PO Box 47-277)
Ponsonby, Auckland, NZ
Phone (09) 378 8083
Fax (09) 378 6231

MEMBER COMPANIES:

ATHLONE CONCRETE PIPES
BCP PRECAST
CSR HUMES
HUME INDUSTRIES
HYNDS PIPE SYSTEMS
MIDLAND CONCRETE PIPES
ROCLA PIPELINE PRODUCTS

First published: 1997
Publication: S7/97