



INFRAPIPE DESIGN MANUAL FOR TRENCH AND PIPE

PURPOSE

This design manual explains how a flexible pipe is designed to provide the optimum solution for any given scenario in accordance with the rules and requirements of AS/NZS2566. It shows the extent to which the elements of trench design determine a pipe strength calculation and how the pipe design is then produced, enabling a quick and easy understanding of the entire pipe design package from INFRAPIPE.

This design manual caters for open trench installation, for other situations such as embankments (where cover is created over a pipe) or micro-tunnelling please contact INFRAPIPE.

The purpose of good trench and pipe design is to find the most economical combination of trench construction and pipe cost. This manual will show how changes to trench design or pipe design can reduce the cost of the other.

BASIS OF THE DESIGN (PRINCIPLES)

A flexible pipe uses the support of the soil around to absorb and deflect the loads placed on it. It is buried in engineered fill in bedding, side support and overlay layers that are compacted to a required MDD (Minimum Dry Density).

Therefore, trench design drives pipe design with the following inputs to pipe design calculation.

- The surface loads (static & dynamic)
- The cover depth
- The quality and compaction of the material used as cover (trenchfill)
- The quality and compaction of the native soil underneath and to the sides of the pipe
- The angle of the trench
- The quality and compaction of the embedment material

The internal pressure required (and the diameter) are the performance inputs to pipe design.

Other pipe technologies offer just one or two standard designs to cater for a wide range of scenarios but the beauty of INFRAPIPE's KRAH system is that it can design and manufacture a pipe profile (from a selection of hundreds) that is best suited for the individual requirement, saving a lot of money – even changing along the line from one pipe to the next.

STANDARDS AND REFERENCES

INFRAPIPE and its products are certified to AS/NZS 5065:2005 and AS/NZS4130:2016, INFRAPIPE is certified to ISO 9001:2015 and this design manual is written to the requirements of AS/NZS 2566:1:1998 and AS/NZS2566.2:2002.

INFRAPIPE is also informed by a wider body of some 40+ standards (global, foreign and local), codes of practice and industry guides. [The full list can be found here](#) and interested parties should pursue further inquiries with INFRAPIPE.



Note that AS/NZS2033:2024 (*Design and installation of polyolefin pipe systems*), in an attempt to be a one-stop shop for all things small flexible pipe now takes some responsibility for trench design if ALL the following criteria are met:

- Ring stiffness greater than SN2
- Pipe diameter not greater than DN1100
- Minimum cover depth 0.8m
- Maximum cover depth 6m
- Depth of soil cover/pipe diameter ratio greater than or equal to 2
- Well or moderate embedment compaction

This has created a potentially ambiguous situation where [2033 covers some but not all requirements](#), uses differing terminology (see page 9) and what is stated in 2033 is an unchanged, incomplete repetition of 2566 and sometimes inaccurate – [it measures trench width at the crown not the springline](#). **Therefore, INFRAPIPE refers to, and will continue to apply, only AS/NZS2566.** Section 6 of AS/NZS2033:2024 (installation) begins as follows:

6.1 Scope of section

This section sets out specific requirements for the installation of buried pipes and fittings.

NOTE For further information, refer to AS/NZS 2566.

MORE INFORMATION ON STRENGTH

This document addresses pipe design (and strength) as it relates to trench design.

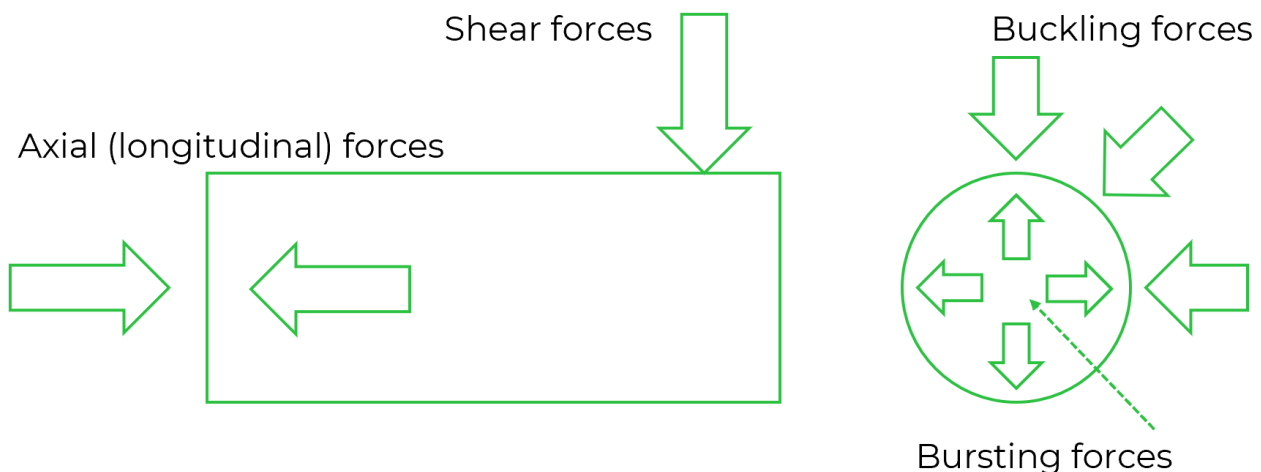
Pipes are required to consider and provide four types of strength as shown below.

Trench design requires Buckling Strength (the SN rating) only.

The requirement to provide bursting strength will add to the buckling strength of the pipe ([see here](#))

Shear forces and longitudinal forces are also discussed where relevant to [Deflection & Settlement](#)

For information on Bursting Strength (SDR/PN) and other information on longitudinal strength, shear force strength and pipe strength in general please see this Datasheet on Strengths, Tolerances, Alignment & Dimensions





SOME COOL PROJECTS



CONTACT OUR TEAM: infrapipe.co.nz sales@infrapipe.co.nz 09 869 3030 3 Averton Place East Tamaki, Auckland 2013 [f](https://www.facebook.com/infrapipe) [i](https://www.instagram.com/infrapipe) [in](https://www.linkedin.com/company/infrapipe) [yt](https://www.youtube.com/channel/UCqJ8K8K8K8K8K8K8K8K8K8K) **INFRAPIPE NZ**



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1. INFRAPIPE PAT (Pipe & Trench) Design Sheet
2. *Easypipe* Report including proofs
3. *Mickey* report (Pipe Design)
4. Buoyancy proof

OTHER DOCUMENTS

This design Manual is supported by the following INFRAPIPE technical documents. For a full list of all INFRAPIPE datasheets and design manuals please visit <http://www.infrapipe.co.nz>

- [Materials Datasheet](#)
- Strength, Tolerances, Alignment & Dimensions (STAD)
- Hydraulics, Gradients, Flow Rates & Velocities
- All the Tables

DISCLAIMER

This document is intended to clarify design terms and assist in finding and applying the rules of the design standards, particularly in early design stages when seeking approximate solutions, provisional costings or feasibility assessments. **Nothing in this manual relieves the obligation of a final design calculation by an appropriately qualified person.**

EMBANKMENT INSTALLATIONS & OTHER EXCLUSIONS

Due to their complex nature or infrequent application, this manual is not designed to cater for the following, for guidance contact INFRAPIPE:

- ✗ Embankments
- ✗ Submerged installations & outfalls
- ✗ Aboveground installations & bridges
- ✗ Pipes co-located vertically
- ✗ Micro-tunnelling or thrusting applications
- ✗ Applications with >20m cover or less than AS/NZS2566 minimum

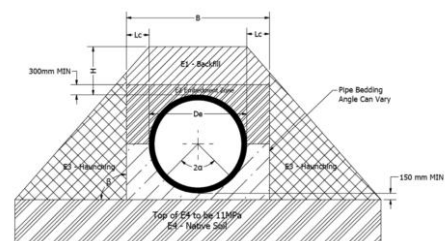


Figure 1 Embankment Trench Design

DEFINITIONS

The full list of definitions and abbreviations can be found [at the back of the document here](#). This diagram here shows the typical terminology used for pipes

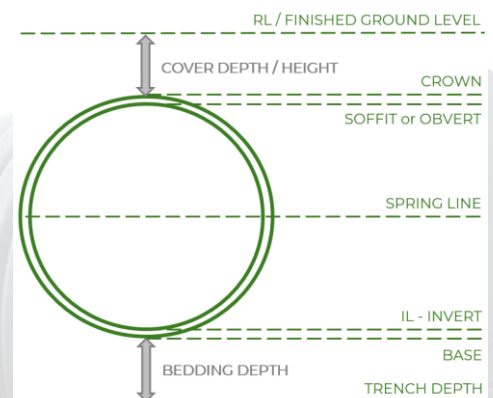


Figure 2 Pipe Design Terminology

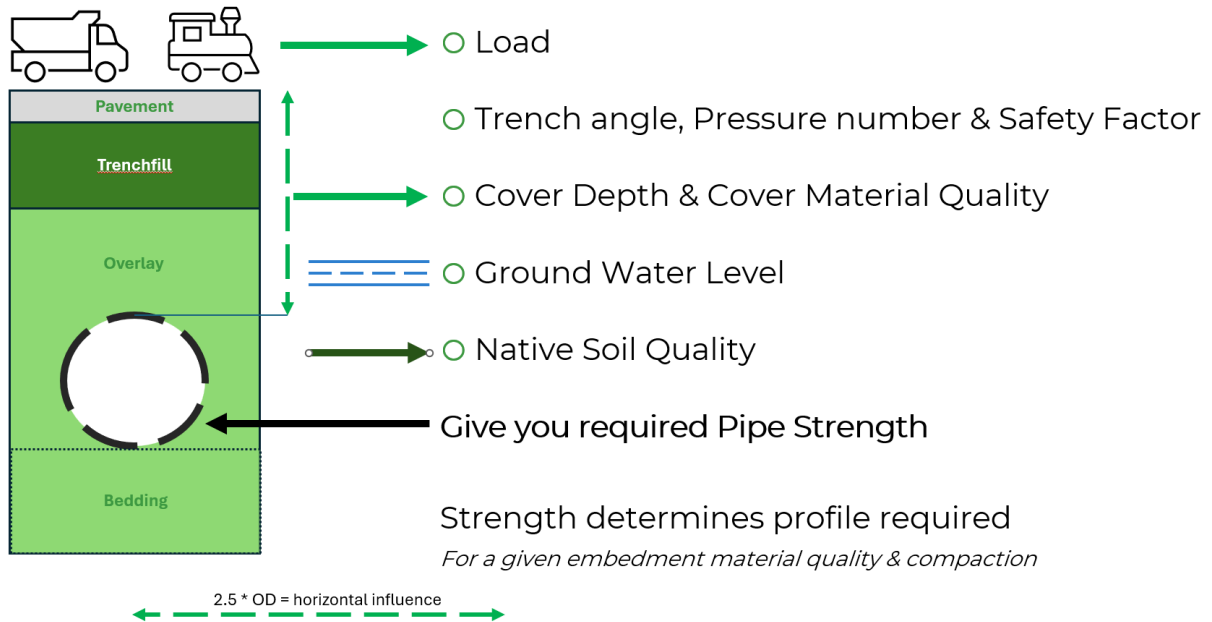


COMPONENTS OF TRENCH DESIGN

INFRAPIPE STANDARD DIAGRAM

Figure 3 Pipe Design Inputs from trench design

Pipe Design components





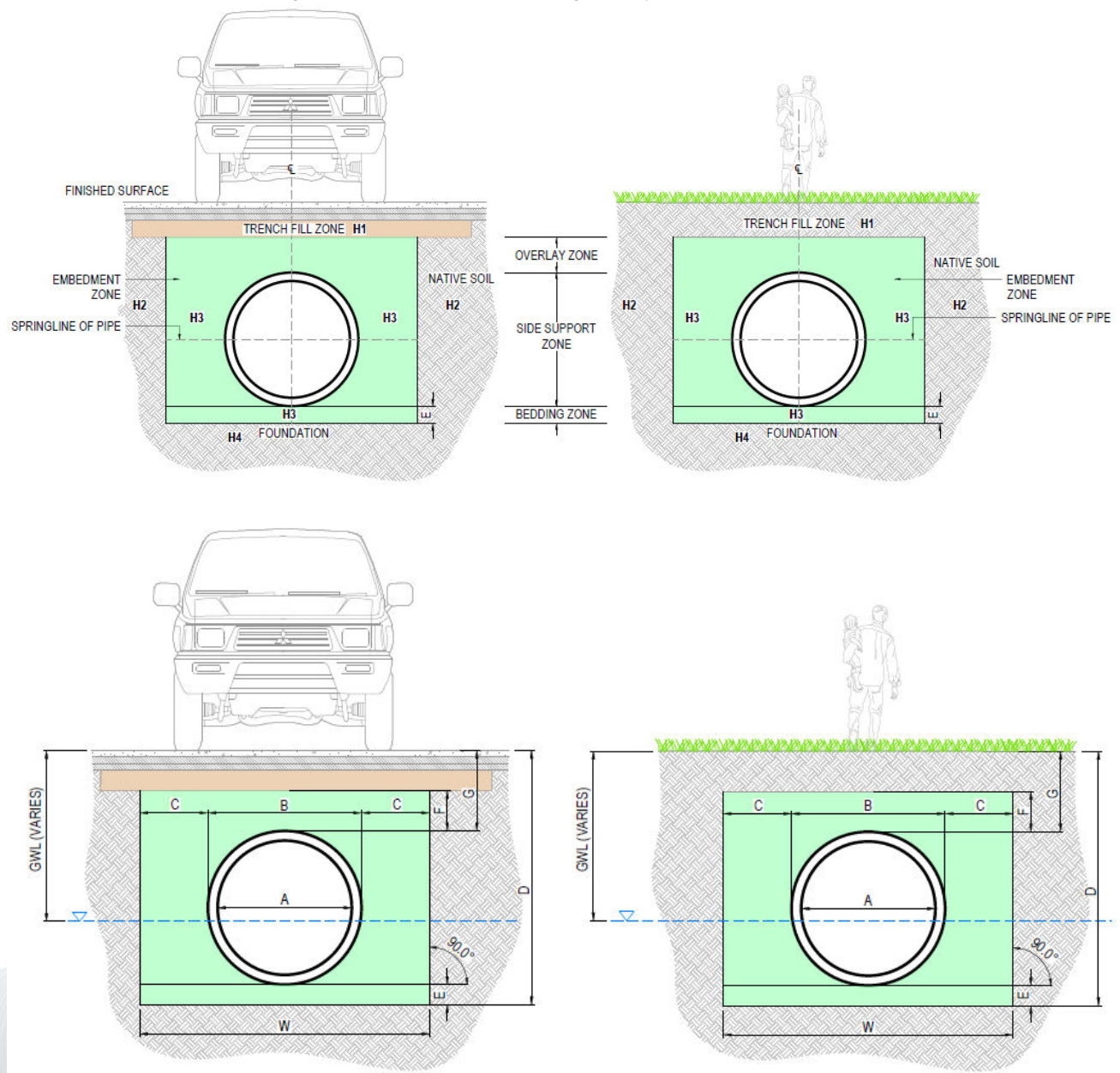
INFRAPIPE, AS/NZS2566 & EASYPEIPE SYMBOLS FOR TRENCH COMPONENTS

AS/NZS2566 uses dimension symbols which – because they have evolved from the original engineering papers - are too small to read, incomplete and overly complex for the practical applications the diagrams are mainly used for.

The *Easypeipe* software (used by INFRAPIPE) employs different symbols again with a diagram which is not designed for the first time reader and AS/NZS2033:2024 varies the terminology again! See page 10 below for comparison.

These diagrams are complicated by the need to refer to not just dimensions but areas (such as native soil and embedment material). **Therefore, INFRAPIPE uses the simple system of symbols and definitions below.**

Figure 4 INFRAPIPE Trench Design Components & Dimensions





Note the **word backfill** is widely used in a variety of contexts, and is therefore **avoided** here; the material used above the overlay zone of the pipe is **referred to as TRENCHFILL** (as per AS/NZS2566) to differentiate it from embedment material.

INFRAPIPE recommends the use of the same engineered fill for the bedding, the side support zone and the overlay (as per soil types below) though compaction may vary below and above the springline.

Table 1 Trench Design Dimensions and Material Zones compared

Easy-pipe	2566	2033	INFRA-PIPE	COMPONENT	CALCS	INF Class	Easypipe Class
	Di		A	ID (DN)			
	De	D	B	OD			
	Lc	Lc	C	SIDE SUPPORT WIDTH			
	D		D	DEPTH OF TRENCH	B+G+G		
D	Lb	Lb	F	THICKNESS OF BEDDING LAYER		E2	E2
	Lo	Lo	G	THICKNESS OF OVERLAY LAYER		E2	E2
A		H	H	COVER DEPTH USED			
			T	TRENCHFILL	H-G	E1	E1
C	B	B	W	WIDTH OF TRENCH (SPRINGLINE)	B+(2*C)		
			Z	EMBEDMENT ZONE	B+F+G		
			NB	NATIVE SOIL BASE		E4	E4
			NS	NATIVE SOIL SIDES		E3	E3

Note for Cover Depth Used, this is the value that has been used in the *Easypipe* calculation which may be the minimum or the maximum depending on the situation, [see here for more details](#)

SAFETY FACTORS USED IN CALCULATIONS

The following safety factors are applied in Pipe Design:

- ✓ Buckling Strength and SN Rating – [see here for more information](#)
- ✓ Buoyancy – [see here for more information](#)
- ✓ Internal Pressure – 1.25 is used unless otherwise requested

ZONES OF INFLUENCE

For both surface loads and buoyancy, INFRAPIPE Uses a 45 degree Zol (Zone of Influence)

DIN/ISO SN RATINGS

For the avoidance of doubt, INFRAPIPE works with the AS/NZS2566 & ISO 9969 calculation of ring stiffness. This differs in its calculation from the DIN 16961 rating (DIN16961 is typically a value 4* greater) which is not used.



Diagram illustrating the zone of influence for a side support. The diagram shows a circular foundation of diameter D_f embedded in a soil layer of thickness H . The foundation is surrounded by a zone of influence of width L_e . The diagram also shows the foundation's position relative to the soil layer and the zone of influence, with dimensions labeled as $2.5 D_f$ and L_p .

The diagram shows a cross-section of a thick-walled cylinder. The inner radius is labeled 'a' and the outer radius is labeled 'b'. The cylinder is subjected to an internal pressure 'P' and an external pressure 'F'. The cylinder material has a Young's modulus 'E2'. The cylinder is surrounded by a support material with a Young's modulus 'E1' and 'E3'. The support material has a thickness 'c' and 'd' respectively. A 90-degree angle is indicated for the support material.





MINIMUM DIMENSIONS

AS/NZS2566 requires the following minimum dimensions for INFRAPIPE pipe installations (Width at springline):

Table 2 Trench Dimensions

A – DN / ID	B - OD	C - Side	F - Bedding	G - Overlay	W - Width	Notes
450	542	300	150	150	1150	
525	621	300	150	150	1250	
600	720	300	150	150	1350	
700	842	300	150	150	1450	
800	962	300	150	150	1600	
900	1096	300	150	150	1700	
1000	1196	350	150	200	1900	
1100	1332	350	150	200	2050	
1200	1464	350	150	200	2200	
1350	1596	350	150	200	2300	
1500	1776	350	150	200	2500	
1600	1878	500	150	300	2900	
1800	2068	550	150	300	3200	
2000	2308	600	150	300	3550	
2300	2650	700	150	300	4050	
2500	2900	750	150	300	4400	
3200	3600	900	150	300	5400	

Notes:

- Width is based on the OD shown above which is for SN16 (and rounded up to the nearest 50mm)
- **The width dimensions are for a single pipe install.** For multi-barrelling [see here for minimum distances for parallel installation](#)

TRENCHWIDTH FOR 45 DEGREE ANGLE AT DIFFERENT LEVELS

Table 3 Trench widths for 45° trench slope. Note refers to Table 2 above, CD = Cover Depth

Vertical location	Width with 45° trench angle – Formula in mm	Code
Ground level	$W + (CD * 2)$	W1
Top of overlay	$W3 + (G * 2)$	W2
Crown	$W + B$	W3
Spring	Given: $(2 * C) + B$	W
Base of Pipe	$W - (B)$	W4
Base of Bedding	$W4 - 300$	W5



MINIMUM COVER DEPTH

The minimum amount of pipe cover (as required by AS/NZS2566), which is shown below, is required for these reasons:

- To ensure surcharge loadings, eg traffic and construction equipment, are not concentrated but instead are distributed over an adequate area
- To provide sufficient clearance to overlaying layers that require heavy mechanical compaction, eg road sub-bases
- To ensure that the pipe or side support is appropriate, having regard to the proposed land use and any foreseeable lowering of finished levels

Table 4 Minimum Cover as per AS/NZS2566

Loading condition	Minimum Cover (G) mm
Not subject to vehicle loading	300
Land zoned for agricultural use	600
Vehicular loading – no carriageway	450
Vehicular loading – sealed carriageway	600
Vehicular loading – unsealed carriageway	750
Pipelines in embankments or subject to construction equipment loads	750

INFRAPIPE also has a low cover design for 200KPA soil to 250mm or 300mm (light truck or heavy truck), [see below for more details](#)

The cover depth impacts the strength requirement in conflicting ways:

- Increased cover dissipates a load above
- Increased cover adds the greater weight of the soil above

It is logical therefore that **high load - higher cover and low load - lower cover are the optimal solutions.**

Furthermore cover also affects the risk of buoyancy in that the deeper the pipe the higher the GWL is relative to the pipe, but the greater the weight of the cover above to oppose the buoyancy.





MATERIALS, SOIL TYPES AND COMPACTION

Table 7 Trench component zones

Code	Zone	Notes
E1	Trenchfill	Compaction 95% except non-vehicular 90%
E2	Embedment Zone	G1 ≤ 20mm Compaction as below
E3	Native soil - side	Default 95% unless disturbed or rural
E4	Native soil - base	Default 95% unless disturbed or rural

- AS/NZS2566 requires G1 (engineered fill) for the embedment zone; that is the bedding zone, side support zone and overlay zone.
- Maximum particle size permitted is 20mm.
- Compaction should be 95% except non-vehicular 90%

The *Easypipe* software used by INFRAPIPE classifies four types of soil quality as shown in the table below.

Table 8 Material classification

MATERIAL CLASSIFICATION TABLE:

GRANULAR BACKFILL			COHESIVE BACKFILL
G1	G2	G3	G4
• Graded Crushed Rock • River Gravel and Beach • Gravel	• Valley Sand • Drift & Basin Sand • Dune Sand • Beach Sand	• Weathered Gravel • Clayey Gravel • Loamy Sand • Liquid Sand • Alluvial Clay	• Clay • Loess • Loam • Alluvial Marl

GROUP – SOIL ZONES AS PER DRAWINGS	SOIL DENSITY (KN/M3)	INTERNAL FRICTION ANGLE	MODULUS OF ELASTICITY IN N/MM2 AT VARIOUS COMPACTIONS RATES/MDD					
G1	20	35	85	90	92	95	97	100
G2	20	30	2.0	6	9	16	23	40
G3	20	25	1.2	3	4	8	11	20
G4	20	20	0.8	2	3	5	8	13
			0.6	1.5	2	4	6	10



PIPE DESIGN COMPONENTS

PIPE SIZE (DIAMETERS) AFFECTS SN RATING REQUIRED

Note that the SN rating for a given scenario is not constant over the full range of diameters.

It may change only gradually from one pipe size to the next but **it will change** because the ratios such as the pipe size in relation to the cover depth, GWL in relation to the pipe volume, and dimension minima such as side zones in relation to the diameter of the pipe are all affected by the size of the pipe.

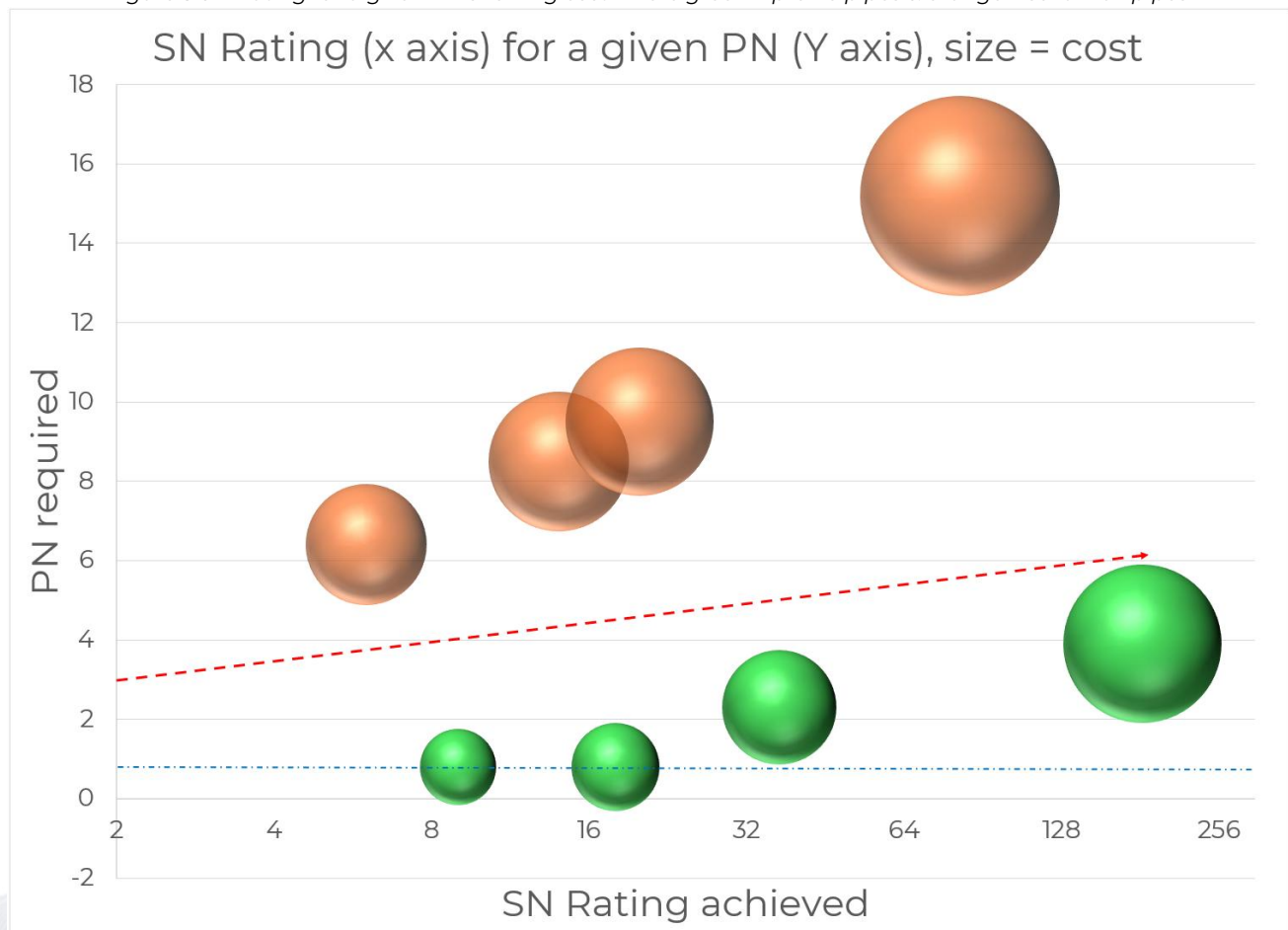
TYPE OF PIPE

This manual assumes that the correct pipe choice is made once the SN rating has been calculated.

Once the SN rating has been confirmed for the inputs, the choice between profile pipe and solid wall can be revisited but:

There is never a situation where an unpressurised solid wall pipe is a cheaper solution for the SN rating required.

Figure 5 SN Rating for a given PN showing cost where green = profile pipes & orange = solid wall pipes





INPUTS & OUTPUTS

The primary variable inputs to pipe design are as follows:

Table 9 Pipe Design Inputs

Input	Component	Example pipe
DN	Inner Diameter	1000
SF	Safety Factor (default A)	A
P1	Loadcase	HN-HO72
P2	PN	0.8
P3	MAX/MIN Cover Depth OR	2100
P4	MAX/MIN Depth FGL-IL	2100
P5	GWL	Crown of pipe – 1000mm
P6	Trench angle	90 degree
P7	E1 – Trenchfill	G1/95
P8	E2 – Embedment Zone	G1/95
P9	E3 – Native soil – side	G4/95
P10	E4 – Native soil - base	G4/95
P11	Depth of concrete pavement	

The principal external Outputs from pipe design are as follows:

Table 10 Pipe Design Outputs

Output	Component	Example pipe
SN	Stiffness (SN)	3.42
O1	OD (mm)	1114
O2	Cover Depth used (mm)	1000
O3	Pipe weight (kgs)	296
O4	Buoyancy (kg required)	0 or kgs required
PR	Profile	42-003.20

- The profile is the Core Tube size and Moment of Inertia and is how the pipe is defined.
- There are further [Design Outputs see below for more details](#)
- Note there can be a small area of circularity in that the SN rating is derived from the inputs, but the exact Cover Depth can be affected by the OD (which is an Output). This is handled by INFRAPIPE during pipe calculation

EITHER Min Cover Depth + Min RL for an OD dictates IL

OR IL + OD dictates Min Cover Depth for a given RL

HYDROLOGICAL REQUIREMENTS

This design manual assumes that the hydraulic requirements are known and have led to the appropriate choice of Diameter above. For more information on Hydraulics see this Design Manual and [for Mannings tables see this document](#).



THE STANDARD EXAMPLE PIPE

In order to best demonstrate the impact of any one trench design component on the required SN rating of the pipe, this section will refer to an 'Example pipe' (as shown above) and show the change to the SN rating from that one Input change alone. The Standard input is shown highlighted and in italics to assist with comparison

LOADCASES

INFRAPIPE can calculate the consequences of any load case but typically loads fall into one of the categories below:

Table 11 Pipe Design Inputs - Loadcases

Loadcase	SN RATING
Rural	2.42
Pedestrian	2.42
LD20	2.42
HD60	2.42
HN-HO-72	3.42
Kiwirail 80KPA UDL	47
Airport Class G	72



GROUND WATER LEVEL

The example pipe has GWL at the crown of the pipe. These comparisons below show the impact of moving the GWL:

Table 12 Pipe Design Inputs - GWL

GWL	GWL mm depth	SN Rating
Surface	0	5.49
500mm below surface	500	4.53
Crown	1000	3.42
Invert	2100	2.42



This shows impact of the buckling force of ground water!

COVER MATERIAL (TRENCHFILL) QUALITY

The quality of the material above the overlay zone ([which is the first 150-300 mm above the pipe](#)) can have an effect on the SN rating as shown below, but it is not very common to have poor soil above and a significant load. Note these results are unaffected by the extent of the compaction.

Table 13 Pipe Design Inputs – Trenchfill Quality

Cover Material	SN Rating
G1	2.42
G2	2.42
G3	2.42
G4	2.42





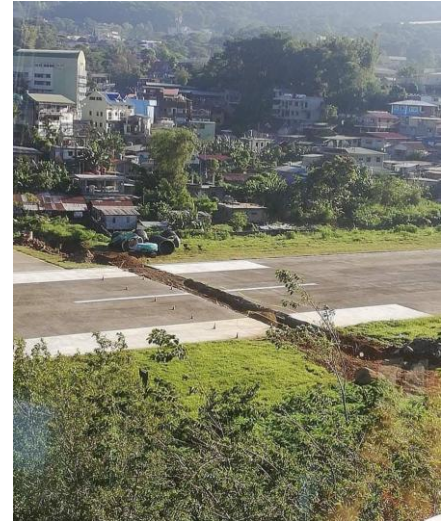
TRENCH ANGLE

New Zealand construction typically only uses either a 90 degree trench angle for a vertical trench (typically with shields) or 45 degrees for a battered trench. Stepped trenches (where steps of less than 1m are used to provide safety and access) are assessed as vertical trenches. While the effect is moderate, if the native soil quality is poor then the battered trench has a much greater effect:

Table 14 Pipe Design Inputs – Trench Angle

Trench angle	Native soil (side)	SN Rating
90	Good	2.42
45	Good	2.42
90	Poor	3.42
45	Poor	2.42

The runway installation to the right used a 90° trench angle



NATIVE SOIL QUALITY

Native soil affects the SN rating in two ways, through the sides and the base. The sides play an important part in absorbing the load deflected by the pipe, and if soil underneath is weak, then the pipe will receive less support and need to be stronger. The worlds largest desalination plant was built from KRAH pipes in the extremely poor soils of the Sinai peninsula:

Table 15 Pipe Design Inputs – Native Soil Quality

Side Quality	Base Quality	SN Rating
Good	Good	2.42
Poor	Good	2.42
Good	Poor	2.42
Poor	Poor	3.42



This desalination plant in Egypt was built on quicksand

PRESSURE NUMBER

The impact of increasing the PN (with all other parameters the same) will quickly push the pipe past the SN Rating required for the site but will do so at an extreme cost. Above PN2.5 solid wall pipe becomes more economical and the SN ratings rise exponentially as SDR17 = SN22, SDR13.6 = SN55, and SDR11 = SN92

Table 16 Pipe Design Inputs - PN

PN (Bar)	SN Rating
0.8	3.42
1.5	12.75
2.0	14.77
2.5	19.9





COVER DEPTH

As discussed above, cover depth is limited by AS/NZS2566 minima (without separate engineering to PS1, though low cover designs are available to 250mm).

Table 17 Pipe Design Inputs – Cover Depth (standard load)

Cover Depth m	SN Rating
600	3.86
1000	3.42
1500	3.42
2500	3.42
5000	8.28
10000	79



MINIMUM AND MAXIMUM COVER DEPTHS & COVER DEPTH USED

Both the minimum and maximum cover depths can have an effect on calculations. Low cover increases the impact of a load but greater cover adds the weight of the soil above (potentially including the water it may hold depending on GWL).

When cover depths vary along the trench INFRAPIPE will:

1. Require the minimum and maximum (G MIN & G MAX) as inputs
2. Assess the situation and use the value which will have the greater impact on the SN rating required.
3. Refer to this value as the **Cover depth used (CDU)**

THE IMPACT OF LOAD ON THE EFFECT OF COVER DEPTH

The greater the load, the greater the impact of cover depth. The table below is taken from some INFRAPIPE analyses for Kiwirail and show how a significant load magnifies the impact of depth:

Table 18 Pipe Design Inputs – Effect of Cover Depth with high load

Cover Depth m	SN Rating	Cover Depth m	SN Rating
0.6	37	5	16
1	25	10	16
1.5	19	15	20
2	14	20	34
2.5	13	25	183

CIRCULARITY AND THE RELATIONSHIP BETWEEN OD & COVER DEPTH

- In trench design, the IL and FGL or RL are typically fixed.
- This makes Cover Depth a product of the FGL less the Invert Level plus the ID and the Wall Thickness of the pipe
- However the strength required by the Cover Depth dictates the strength required and therefore the Wall Thickness of the pipe.

Therefore, theoretically the possibility could exist for circularity in calculation. Practically, a selection must be made from the available profiles and then refined (by trialling pipes until the most economical option that is suitable is determined) and this process obviates the risk of circularity.



SAFETY FACTORS

INFRAPIPE's pipe calculations use a Safety Factor of 2.5 which equates to a probability of failure of 10^{-5} or 1:100,000. This is classified Safety Factor A and is the default for all civil engineering applications. For rural or other lower-risk installations, Safety Factor B can be used which has a probability of failure of 10^{-3} or 1:1000.

ONLY use Safety Factor B in situations where:

- The application is stormwater AND
- There is no risk to life or limb
- The economic consequences of pipe failure are small

Table 19 Pipe Design Inputs – Safety Factor

Safety Factor	Loadcase	SN Rating
A	Pedestrian	2.42
B	Pedestrian	2.42
A	HN-HO 72	3.42
B	HN-HO 72	2.42



SN RATINGS FOR INFRAPIPE ARE NOT CONTINUOUS

The KRAH machine used by INFRAPIPE cannot make every exact SN rating (ie 14.1, 14.2, 14.3).

A pipe is made using a profile which is a combination of:

- The Inner Waterway Wall Thickness (S1)
- The core tube:
 - The size (diameter)
 - The spacing
 - The thickness of the PE in which the core tube is encased (S3)
 - The number of layers of core tube
- An Outer Layer (in some instances) Wall Thickness (S4)



This profile is in turn dictated by the tooling sizes available and the spacing they create, ie the core tube comes in sizes of 42,54,75,90,110,125 but with spacing determined by the width of the Waterway tool (75,100,125 etc.). The result is that the steps between the SN ratings that can be manufactured are irregular.

PIPE DESIGN CONSTRAINTS

All things being equal, the optimum solution for a pipe is the largest core tube possible (for the permissible spacing). The only constraint on this is OD, via the Wall Thickness. OD can be constrained because of:

- Cover Depths
- Adjacent services or other underground features
- Transport costs (especially around 2500,1250,833&625) or limits
- Installation constraints (including parallel spacing)



Figure 6 Summary of the effects of the Inputs to pipe design

The impact on pipe strength (SN) required

Cover Depth

Cover Depth mm	SN
600	3.8
1000	2.4
1500	3.8
2500	3.8
5000	8.3
10000	79

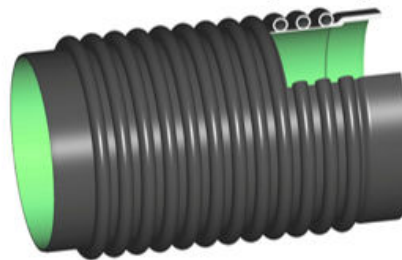
Loadcase

Loadcase	SN
Pedestrian	2.4
LD20	2.4
HD60	2.4
HN-HO 72	3.4
Kiwirail	47
Boeing 777	72

Trenchfill

Cover Material	SN
G1	2.4
G2	2.4
G3	2.4
G4	2.4

DN 1000 Example Pipe



Native Soil

Side Quality	Base Quality	SN
Good	Good	2.42
Poor	Good	2.42
Good	Poor	2.42
Poor	Poor	3.42

Trench Angle

Trench angle	Native soil (side)	SN
90	Good	2.4
45	Good	2.4
90	Poor	3.4
45	Poor	2.4

PN Required

PN (Bar)	SN
0.8	3.4
1.5	12.8
2.0	14.8
2.5	19.9

Groundwater Level

GWL	GWL mm depth	SN
Surface	0	5.5
RL -0.5	500	4.5
Crown	1000	3.4
Invert	2100	2.4

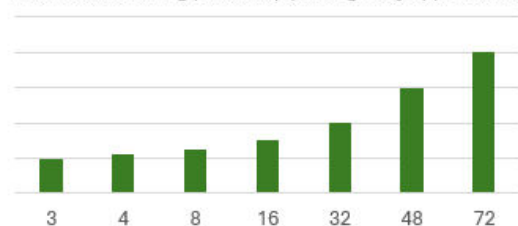
Safety Factor

INFRAPIPE always uses pipe design Safety Factor A – which is 2.5, giving a PF of 1:100,000 except for cases which are stormwater with no risk to life or limb and no significant cost from impairment

Safety Factor	Loadcase	SN
A	Pedestrian	2.42
B	Pedestrian	2.42
A	HN-HO 72	3.42
B	HN-HO 72	2.42

Cost and SN rating

The relationship between SN rating and cost, while it varies across diameters, broadly follows the trajectory below, where the difference is slender until passing SN16. Note this is minor compared to the 300%+ additional cost incurred when using pressure pipe for gravity applications!





DESIGN DOCUMENTS

An INFRAPIPE design package is comprised of the following elements:

1. Infrapipe PAT Design Sheet (APPENDIX 1)
2. *Easypipe* Report including proofs (APPENDIX 2)
3. *Mickey* report (Pipe Design) (APPENDIX 3)
4. Buoyancy proof (APPENDIX 4)
5. INFRAPIPE quote checklist

INFRAPIPE PIPE AND TRENCH (PAT) DESIGN SHEET

This sheet confirms the details of the proposed design. It includes:

- The Inputs from Page 15 above
- The Outputs from Page 15 above
- The Trench Dimensions
- The Safety Factor used
- Profile Design
- Gradient/Flow rate/Flow Velocity if required

Accompanying this Design Manual as Appendix One is an example PAT Design Sheet (for the standard example pipe)

EASYPipe REPORT

Easypipe is European software which analyses the performance of a pipe profile (and size) in a given trench design. It has been modified to provide calculations to meet AS/NZS2566 but some report headers still mention the German standard ATV-DVWK-A 127. Any references to ATV-DVWK-A 127 should be taken to mean AS/NZS2566.

Accompanying this Design Manual as Appendix Two is an example *Easypipe* Report (for the standard example pipe) with a Guide which shows the Inputs and Outputs and Clarifications

- *Easypipe* is not a raw calculator as such – it does not calculate the exact SN rating required for the inputs.
- *Easypipe* is a proof calculator, so for a profile (pipe design and its SN rating and moment of inertia) it calculates whether the profile satisfies the various proofs such as buckling.
- If the proof succeeds then INFRAPIPE will typically try a less strong pipe option (and so on, until it fails) to find the most economical solution by a process of elimination.
- If the proof fails then INFRAPIPE will select a stronger pipe option (and so on, until it succeeds).

MICKEY REPORT

Mickey is the name given to the proprietary pipe design software which accompanies a KRAH machine and is designed for AS/NZS2566. A *Mickey* report should be the same pipe DN, SN and profile as the *Easypipe* report. The *Mickey* report shows:

- The profile designs and dimensions
- The pipe weight
- Internal and external pressure
- Socket and spigot dimensions

Accompanying this Design Manual as Appendix Three is an example *Mickey* Report (for the standard example pipe)



BUOYANCY PROOF (IF REQUIRED)

INFRAPIPE can supply a buoyancy report which shows whether or not buoyancy is possible for a given design. Where buoyancy is possible, the report will be issued to show the outcome after the proposed mitigating measures. These measures will be detailed in a document which accompanies this buoyancy report.

[For more information on buoyancy see here](#)

Accompanying this Design Manual as Appendix Four is an example Buoyancy Proof (for the standard example pipe)

INFRAPIPE QUOTE CHECKLIST

This document confirms all the information that has been provided to INFRAPIPE, such as drawing numbers, installation methods, loadcases etc. It serves to pull the package together and confirms any miscellaneous information sources in addition to those referred to in the *Easypipe* report.

Location

1	Water table	
2	Relevant Geotech	

1. Water table
2. Relevant Geotech
3. Or quality of native soil
4. Acidity or other chemical soil conditions

Trench Design

5. Load levels
6. Cover levels (and type)
7. AND/OR stated SN rating:
8. Trench constraints
9. Trenching & bedding intentions (Native soil/engineered fill)

Pipe Performance

10. Internal pressure
11. Flow rate & velocity
12. Gradient
13. Operating temperature (if not 5-25C)
14. Other biological, chemical, seismic performance requirements

Pipe Design

15. Radius of bends (horizontal or vertical)
16. Inlet and Outlet
17. Access requirements
18. Connections to other pipes/fittings
19. Flow control
20. Perforation or other alteration

Fish Passage

21. Burial levels
22. Baffles
23. Any other requirements

Installation

24. Installation constraints
25. Installation Method
26. Freight and/or delivery to site
27. Site handling constraints



MOMENT OF INERTIA

The SN rating alone is not the entire expression of the strength of the pipe. *Easypipe* also requires the moment of inertia and the distance of inertia, the profile height (wall thickness) and the profile area radial. Two pipes of the same diameter with very similar SN ratings will not necessarily behave the same if they are different profiles.

INSTALLATION PROCESS ACKNOWLEDGEMENT (IF REQUIRED)

For an installation process other than a standard open trench, such as slip-lining, microtunnelling or other situation where clarity is required, INFRAPIPE will issue an accompanying Installation Process Acknowledgement. This document confirms that the warranty will not be affected by the proposed installation for that project. This is always project specific, and contains the following information:

- Required Actions
- Project Details
- Document References
- Methods authorized
- Tolerances
- Proof of compliance
- Exemptions and clarifications

This is normally provided once the purchasing process has commenced (but is implicit in the issue of the documents above)

TANKS

Tanks are typically accompanied by a scope document which confirms the scope for the tank and its systems and connections, for more information see this [Design Manual on Tanks](#) or this [Design Manual for Fire Supply Tanks](#)

ISO 9001:2015 CLARIFICATION

INFRAPIPE and all documents provided by it use the term Design as found in the everyday use of the word, that is a statement of the dimensions and components required to achieve the solution. This does not in anyway imply that INFRAPIPE conducts "Design" as defined by ISO9001:2015. INFRAPIPE applies a set of rules as created by the relevant standards, territorial authorities and pipe-extrusion equipment manufacturers, it does not create those rules.





ALTERNATIVE INSTALLATIONS

PARALLEL INSTALLATION

Under AS/NZS 2566.2, flexible pipelines can be installed with the following minimum distances between the OD of pipes:

Table 20 Parallel Spacing

INFRAPIPE	Compactable embedment material	Controlled low strength embedment material
100	100	50
150	100	50
225	150	75
300	150	75
375	200	100
450	200	100
525	300	150
600	300	150
700	300	150
800	300	150
900	300	150
1000	350	175
1100	350	175
1200	350	175
1350	350	175
1500	350	175
1600	440*	200
1800	495*	200
2000	550*	200
2300	633*	200
2500	688*	200
3200	880*	200

- Dependant upon exact OD,, formula is $0.25 * OD$

For installation of parallel pipes of different diameters, the spacing between them shall be the sum of the diameters divided by 2. AS/NZS 2566 is unclear on whether this is ID or OD, though OD would seem overly onerous.

CONCRETE OR FLOWABLE FILL (CLSM)

When pipes are encased in flowable fill, the MPA of the concrete is used for the native soil inputs as a data input rather than selection from a soil group.

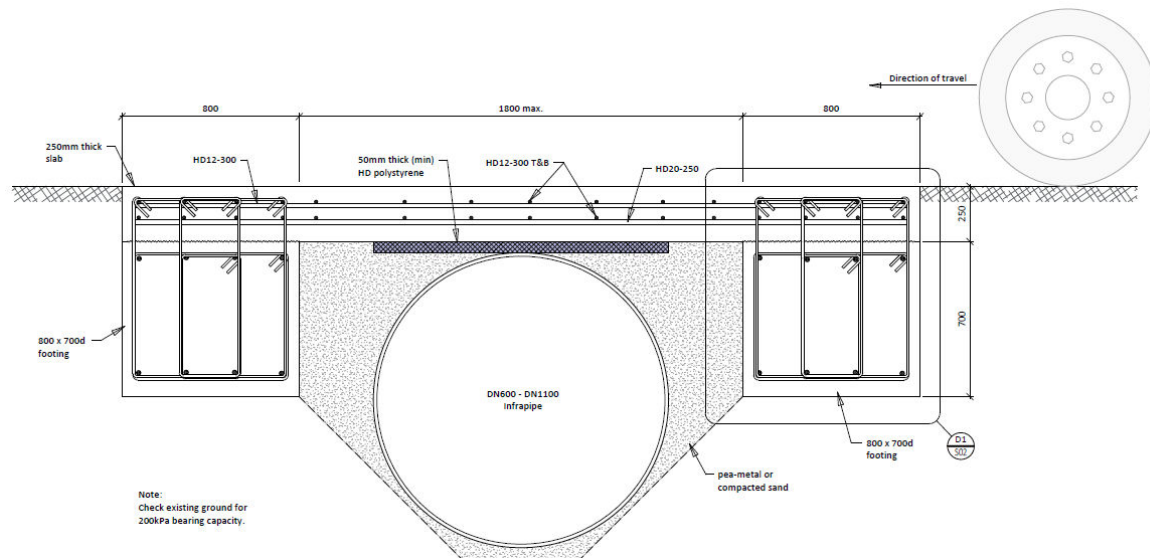


SHALLOW COVER

INFRAPIPE has commissioned a series of designs for DN225-1500 for installation in shallow cover situations to cover depth 250mm (light truck) or 300mm (HNHO72) with a ground load bearing capacity of 200KPA or more and require a slab poured onsite. Conditions of use are as follows:

- For single pipes only
- For pipe length installations of 12m or less
- The movement of the dynamic load must be perpendicular to the flow line of the pipe.

Figure 7 Shallow cover Design by INFRAPIPE



MULTI-BARRELLING

Due to the impact of depth on SN rating, there may be situations where multi-barrelling may permit a reduced pipe strength due to an increase in Cover Depth. Multi-barrelling also reduces flow velocity, reduces the risk of buoyancy, permits more flexibility with invert levels and gradients, and needs less deep excavation.

This comparison shows multi-barrelling options for the DN1000 for 1:100 gradient and a Relative Cost Index (RCI)

Table 21 Multi-barreling comparison

DN	Quantity	Flow Velocity	RCI
1000	1	9	100%
800	2	6.5	162%
700	3	5.7	219%

INSTALLATION UNDER STRUCTURES

This is possible – the structure is added as a static load, contact INFRAPIPE for more details



BUOYANCY

COMPONENTS OF THE BUOYANCY EQUATION

- Volume of the buoyant section of the pipe
- Weight of the pipe
- Weight of the soil above the pipe
- Effect of weight, fixings or other mitigation

SAFETY FACTOR

Whilst the Safety Factor used in buoyancy calculations may be determined by an individual relevant Territorial Authority, INFRAPIPE will use a Safety Factor of 1.25 (25%) as per NZS4404:2010 as a default unless advised otherwise.

DESIGN OUTPUT

The buoyancy report will confirm that the pipe, tank or manhole is not positively buoyant for a given GWL and trench design if the stipulated mitigation is provided (if appropriate). This mitigation can be in the form of:

- A design modification to add to the width of the pipe or tank to increase the effect of the soil weight (overlaying sheets of PE).
- A kg figure for weight which must be attached to the pipe, tank or manhole
- A design modification to secure the pipe or tank into the ground using one or more fixings of an appropriate strength.

DESIGN SOLUTIONS – DIAMETER

One other way to reduce buoyancy is to consider multiple pipes, which reduces the affect of the GWL by raising the pipes and, if pipes are judiciously spaced apart at a distance of 1 * their cover depth, maximises the efficient exploitation of the Zone of Influence of the weight of the soil above.

DESIGN SOLUTIONS – MECHANICAL SOLUTIONS FOR LOAD SPREADING

The use of PE sheets or other flexible material (with a suitable design life) laid over a pipe or tank can harness the weight of the wider soil above in opposing the buoyant forces.

DESIGN SOLUTIONS – ADDITIONAL WEIGHT

Precast or poured onsite weights, suitably attached to the pipe, tank or concrete will add their weight to the calculation plus, if relevant, the weight of any soil above them.

DESIGN SOLUTIONS – ADDITIONAL FIXINGS

The use of screw anchors or other ground fixings, if suitably attached to the pipe, tank or chamber, contribute their given load strength (for the native soil in question) to the forces opposing buoyancy.



ABBREVIATIONS & DEFINITIONS

Definition	Meaning
BW	Butt Weld
CD	Cover Depth
CF (W)	CollarFUSION (Weld)
COP	A KRAH profile design with two or more layers of core tube and one or more outer layers
CoP	Code of Practice
CPR	A KRAH profile design with one layer of core tube and one or more outer layers
CSA	Cross-Sectional Area of the pipe
CT	Core Tube
DM	Design manual
DN	Nominal Diameter – how the pipe is known. For INFRAPIPE this is also the ID
DS	Datasheet
EF	Electrofusion Weld/Joint
EL	Effective Length
ESDR	Equivalent SDR – shows the equivalent SDR performance for a profile pipe
FGL	Finished Ground Level
FP	Fish Passage
FPAG	Fish passage Action Group
FPG	Fish Passage Guidelines
FW	Fire Water – fire supplied for sprinkler systems or for use by FENZ
GA	General Arrangement
GWL	Ground water level
GR	Gravity – that is Gravity Pipe and PN of 1 or less
HAS	A system for joining laterals to KRAH pipes which cuts and then welds a fitting
HDPE	High Density Polyethylene (PE100) – the material used for INFRAPIPE KRAH profile pipe and solid wall pipe



HP	High Pressure – for INFRAPIPE, requirements of greater than PN3 (3 Bar). GR (Gravity) is 1 Bar or less and LP is 1-3 Bar
ID (& OD)	Internal Diameter. INFRAPIPE refers to the ID of its pipes; some competitors market their products under their Outer Diameter (OD) which can imply a capacity 15-20% greater.
IL	Invert level
IPT	In Pipe Transition where a KRAH pipe transitions in the pipe from profile to solid wall, or vice versa
ITP	Installation & Test Plan
LB	Loadbearing
LDPE	Low Density Polyethylene used for irrigation pipes and by non-certified manufacturers
KR	KRAH is a helically (spiral-wound) product manufactured using the INFRAPIPE KRAH machine
LO	Length Overall
LP	Low Pressure – that is between 1 and 3 Bar of internal pressure
MDPE	Medium Density Polyethylene used for its ductility in small bore pressure pipes such as domestic watermain in the house.
MH	Manhole
ML	Manufactured Length
MMR	Maintenance, Modification & Repair
NLB	Non Loadbearing – no vehicular loading
NZBC	New Zealand Building Code
OC	Odour Control
OFP	Overland Flow Path
P&G	Provisional & General costs – the costs of running the site
PE100	The standard grade of HDPE used for civil work
PN	Used in pressure applications and expressed in bar, this is the pressure rating of the pipe. Corresponds to SDR for solid wall pipe, ie for PE100 PN16 = 16 bar = SDR11
PP	Polypropylene. Used for the core tube of Krah pipes and SN16 CIVILPIPE. Similar in most characteristics to HDPE but stronger for its weight though less ductile.
PR	A KRAH profile design with no outer layer
RCI	Relative Cost Index expressed as a percentage to show the cost impact of changes where the first option = 100%

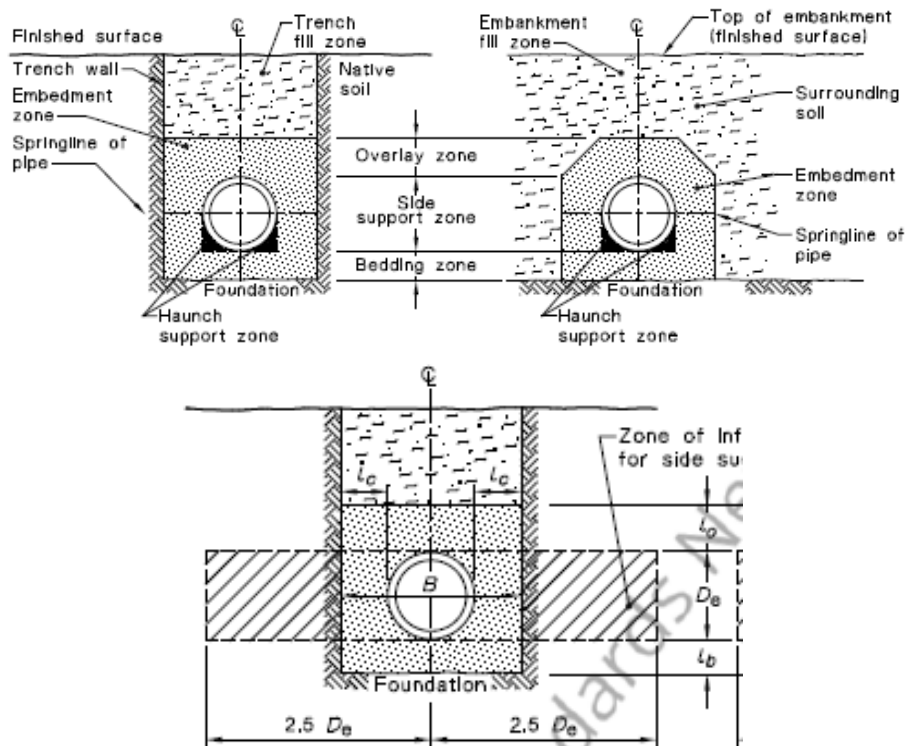


RL	Reduced level
SCR or HSCR	A crack resistant form of HDPE. This is not required for spiral wound pipes as the extrusion is radial not axial, preventing the polymers from propagating any cracks longitudinally (profile pipes cannot propagate cracks due to the profile shape)
SDR	Standard Dimension Ratio – the ratio between WT and OD for solid wall Pipe, ie SDR has a WT of 1/11 the OD
SiDR	Standard Internal Dimension Ratio. Used overseas but not so much in NZ, this is the ratio of the wall thickness (WT) to the Inner Diameter (ID) NZ prefers to use SDR which uses the OD
SF	Safety Factor (for SN, PN or buoyancy calculations)
SKT	Socket
SN	Ring Stiffness – the strength of the pipe
SPG	Spigot
SW	Solid Wall or Stormwater. Solid wall is pipe is used for pressure applications 2Bar+, fabrication and some manholes and chambers
SWE	Solid Wall End
TA	Trench Angle or Territorial Authority
TCO (WLC/WoLC)	Total Cost of Ownership – also known as Whole life Cost or Whole of Life cost
TMP	Traffic Management Plan – the term TMP is often used as an abbreviation to refer to the costs of traffic management
TW	Twinwall (pipe such as CIVILPIPE) or Trade Waste
VW	Solid wall pipe (in INFRAPIPE's pipe design software)
WM	??
WT	Wall Thickness - the difference between ID and OD
WW	Waste Water
WWPS	Wastewater pump station
WWTC	Wastewater terminal chamber
WWTP	Wastewater treatment plant
ZoI	Zone of Influence – that area in the soil affected by a force from a load not directly above or below it, typically calculated at a 45 degree angle



OTHER DRAWINGS

From AS/NZS2566



From As/NZS2033

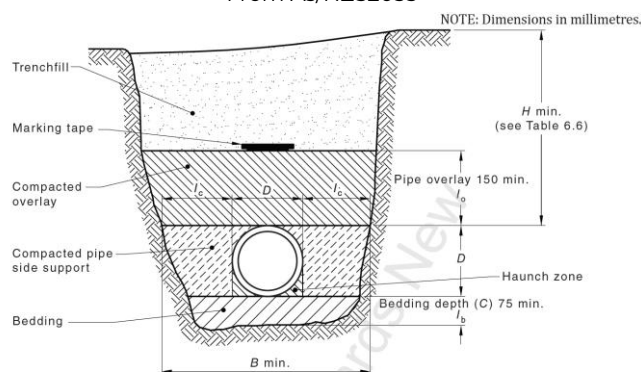


Figure 6.3 — Typical installation in a trench

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