Technical Manual

Design



OPTIM®

DWV Sanitary Systems

Plumbing and Drainage Solutions

MARLEY by aliaxis

Quality Assurance

› Rigorous quality testing

› IANZ accredited laboratory

Certification

› Made to AS/NZS 1260 Standard

› ISO 9001 accreditation

› BRANZ Appraisal 1236

Proven Reliability

› Trusted since 1978

› Manufactured for the NZ market

Full Range

› Over 300 pipes and fittings

› Compatible system

Recyclable

› uPVC recycling programme

› ISO 14001 certified

› Use of recycled materials in pipes

Support

› Nationwide Territory Managers

› Award-winning customer service

Introduction

Marley NZ has been part of Kiwi homes and businesses for over 65 years, established in 1959 Marley is part of the Aliaxis group of companies. Aliaxis is a privately-owned business based in Belgium that employs 15,700 people across 44 countries, made up of more than 100 companies.

The information contained in this Design Manual relates to the Marley NZ range of OPTIM® uPVC pipes and fittings manufactured at sites in New Zealand. The manual includes Converge® RVASS system, Compakt® Boss Gully and the range of solvent cements have been included.

BRANZ Appraised
Appraisal No. 1236 [2023]

OPTIMAL OPTIM® DWV PERFORMANCE

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Disclaimer

This manual is designed to provide guidance to the Designer/Installer of the Marley OPTIM DWV range of pipes and fittings to comply with the requirements of the NZBC Clauses G13 and B2, as well as the requirements of AS/NZS 3500.2 – Plumbing and drainage, Part 2: Sanitary plumbing and drainage. It is not intended to substitute any of the regulations.

1. uPVC Properties

1.1 Material Properties

Mechanical Properties of uPVC @ 20°C

Density	1.42 – 1.48
Water absorption	0.12% in 24 hrs. @ 23°C
Hardness (Shore D)	80
Impact 20°C (Charpy 250µm notch)	20 KJ/m² (uPVC)
Impact 0°C (Charpy 250µm notch)	8 KJ/m² (uPVC)
Coefficient of friction (uPVC to uPVC)	0.4
Ultimate tensile strength	52 MPa
Elongation at break	50 – 80%
Short term rupture	44 MPa
Long term creep	28 MPa
Compressive strength	65 MPa
Long term creep modulus	0.9 – 1.2 GPa
Elastic tensile modulus	3.0 – 3.3 GPa
Elastic flexural modulus	2.7 – 3.0 GPa
Shear modulus	1.0 GPa
Bulk modulus	4.7 GPa
Poison ratio	0.4

Electrical Properties

Dielectric strength	14-20 KV/mm
Volume resistivity	2×10^{14} Ω.m
Surface resistivity	10^{13} - 10^{14} Ω
Dielectric constant 50Hz (10^6 Hz)	3.9 (3.3)
Power factor 50Hz (10^6 Hz)	0.01 (0.02)
Voltage breakdown	2000 volts/mm
Insulating strength	>500 MΩ

Thermal Properties

Softening point	79 - 84°C
Maximum continuous service temperature	60°C
Coefficient of thermal expansion	8×10^{-5}
Thermal conductivity	0.16 W/[Kg. °C]
Specific heat	1000 J/[Kg °C]
Thermal diffusivity	1.1 x 10-7 m²/S

Flammability Characteristics

Flammability (oxygen index)	AS 1530 Early Fire Hazard	45%
Ignitability index		9 - 10 (/20)
Smoke produced index		4 - 6 (/10)
Heat evolved index		0
Spread of flame index		*

*uPVC is self extinguishing. It does not support combustion when the source of ignition is removed.

These are typical properties only and are not to be construed as specifications

1.2 Service Temperature

Marley drains, wastes and vents are suitable for the continuous discharge of liquids at temperatures up to 60°C for vertical pipes and grade pipes, as well as intermittent discharges of liquid up to 90°C where the duration of the discharge does not exceed 90 seconds.

For discharge of liquids at temperatures above 60°C but not exceeding 75°C graded pipes and fittings must be continuously supported. uPVC must not be used for continuous discharge of liquids at temperatures exceeding 75°C.

1.3 Durability

Marley OPTIM DWV fully complies with G13/AS2 Table 1 Materials for drainage pipes and E1/AS1 Table 1 Acceptable pipe materials.

When installed and used in accordance with the installation instructions Marley OPTIM DWV will meet the requirements of the New Zealand Building Code (NZBC) Clause B2 for:

- 50 years for systems with difficult access, (e.g. under buildings)
- 15 years for systems with a moderate ease of access, but difficult to replace, (e.g. typical drainage system laid adjacent to a building foundation).

1.4 Weatherability

Marley OPTIM DWV has as part of the raw material makeup 1.5 PHR of Titanium Dioxide to provide UV protection during storage. The ultimate strength of uPVC does not alter markedly with age. With prolonged exposure to UV light, a loss of impact strength can be expected, although changes are minor and should not reduce the system's long-term performance.

Marley recommends that standard AS/NZS 2032 – Installation of uPVC Pipes, should be followed when storing uPVC pipe for extended periods.

> *"If the total period of exposed storage outdoors is likely to exceed 12 months, pipes and fittings shall be covered and stored in a manner that allows ventilation and prevents heat entrapment. Pipes and fittings may be stored in this manner indefinitely."*

Do not cover pipes and fittings with black plastic.

For above ground systems, extra UV light protection can be added by applying a coat of 100% acrylic paint. Pipes should be washed with detergent and water to remove any grease and dirt. If priming is required, use an alkyd-based general-purpose primer before the acrylic finishing coats. Additional occasional maintenance should be carried out to ensure the acrylic paint is in good order.

1.5 Impact Strength

Impact tests of all Marley OPTIM DWV pipe systems are carried out to AS/NZS 1260 and AS/NZS 1462.3 standards.

At low temperatures the impact strength of standard uPVC will be reduced, therefore care needs to be taken when cutting, handling or backfilling in cold conditions.

1.6 Biological Attack

Studies have found that uPVC will not deteriorate or break down under biological attack, as uPVC does not serve as a nutrient for micro or macro-organisms. Investigations have failed to discover a single case in which buried uPVC pipe system have suffered degradation or deterioration due to biological attack.

Once a uPVC pipe system has been successfully installed underground in normal water and sewer systems it is not susceptible to the normal processes of deterioration found in nature. It does not slime as readily as many other materials and will usually require less maintenance (blockage clearance).

1.7 Abrasion

The abrasion resistance of solid wall uPVC for main sewer lines has been shown to be superior to most other common piping materials.

Abrasion tests were performed by the institute for Hydromechanics and Hydraulic Structures of the University of Damstadt in Germany. Abrasion evaluation using river sand and gravel in unlined concrete pipe, lined concrete pipe, glazed vitrified clay pipe and uPVC pipe produced the following result.

Material	Cycle	Comment
uPVC, (Solid Wall)	Minimal wear at 260,000 cycles	Less accelerated than vitrified clay
Concrete, (Unlined)	Measurable wear at 150,000 cycles	
Concrete, (Lined)	Measurable wear at 150,000 cycles	Less wear than unlined concrete
Vitrified Clay, (Glazed)	Minimal wear at 260,000 cycles	Accelerated wear after glazing wore off at 260,000 cycles

1.8 Electrolytic Properties

uPVC is totally inert and therefore is non-conducting and non-magnetic, hence it will not be subject to electrolysis or corrosion when jointed to metal or other material.

uPVC cannot be used as an earth for electrical services.

1.9 Marley OPTIM Corrosion and Chemical Resistance in Drains

Sanitary drains generate significant volumes of hydrogen sulphide gas from bacterial action, which results in the generation of dilute Sulphuric and Sulphurous acids especially in turbulent areas. Marley OPTIM DWV has excellent resistance to Sulphuric Acid.

Period of contact	In many instances the rate of attack is very slow and is only significant if exposure is prolonged, concentrate, or at elevated temperature. If highly stressed, deterioration can involve absorption of the corroding medium, which leads to swelling, a reduction in tensile strength and a change in elongation at break.
Joints	Consideration must be given to the effects of any solution on solvent or rubber ring joints. DWV pipes are fitted with blended natural rubber rings complying to AS 1646 and encapsulated rings manufactured using synthetic EPDM Rubber with a polypropylene reinforcement component approved in accordance with EN681-1 and approved for contact with potable water.

For more information refer to the chemical resistance chart on the resource page of the Marley website. www.marley.co.nz

2. Product Data

2.1 Standards and Certifications

Marley NZ uPVC is manufactured in compliance with AS/NZS 1260 - PVC-U Pipes and fittings for drain, waste and vent applications. The range holds Branz Appraisal 1236.

Certifications:

- Bureau Veritas Lic No: 2365 – Marley OPTIM DWV (Manurewa)
- Bureau Veritas Lic No 2802 – Marley OPTIM DWV (Ashburton)
- Bureau Veritas Lic No: 2818 – Compakt
- WaterMark WMK20224 – OPTIM range of fitting
- WaterMark WMKA1246 – Converge Reduced Velocity Aerator Stack System

Pipes and fittings manufactured by Marley that comply with AS/NZS 1260 also meet the requirements of AS/NZS 5395 – Best Environmental Practice uPVC Pipe and Fittings.

ISO-Regulated Production Site:

- **ISO 9001:** Certified quality management system, encompassing blending, extrusion, injection moulding, fabrication, and warehouse facilities.
- **ISO 14001:** Certified environmental management system, helping organizations minimize the negative environmental impact of their operation

2.2 New Zealand Green Building Council

New Zealand Green Building Council (NZGBC) defines a "Responsible Product" as a product that has a Responsible Product Value (RPV) issued by an initiative recognized by them.

OPTIM DWV pipes and fittings are "Responsible Products" recognised by two approved product certification schemes registered in the Responsible Products Programme

EPD Australasia – Product-specific EPD:

For pipes and fittings manufactured in New Zealand

PIPA:

- AS/NZS 1254:2010, PVC-U pipes and fittings for stormwater and surface water applications
- AS/NZS 1260:2017, PVC-U pipes and fittings for drain, waste and vent applications

When these schemes are selected from the Score Checker, it will calculate an RPV that contributes towards Green Star and Homestar credits.

The RPV is the score given by NZGBC to an initiative.

2.3 Dimensions

All OPTIM DWV pipes are manufactured to comply with AS/NZS 1260 and as such have standard dimensions for the outside diameter, the wall thickness however changes based on the stiffness class of the pipe being manufactured, the below chart shows all OPTIM DWV pipe dimensions.

Nominal Size DN	Stiffness Class	Mean OD mm	Socket OD mm	Minimum Effective Sealing Length mm
32	-	36.35	32.05	-
40	-	42.95	38.35	-
50	-	55.85	50.95	-
65	-	68.90	63.10	-
80	-	82.50	76.00	-
100	SN6	110.20	107.00	45
100	SN10	110.20	106.35	45
100	SN16	110.20	101.40	45
150	SN4	160.25	152.25	47
150	SN8	160.25	150.25	47
150	SN16	160.25	147.65	47
175	SN4	200.30	190.30	65
175	SN8	200.30	186.90	65
175	SN16	200.30	185.10	65
225	SN4	250.35	237.55	75
225	SN8	250.35	234.65	75
225	SN16	250.35	230.75	75
300	SN4	315.45	299.65	85
300	SN8	315.45	295.05	85
300	SN16	315.45	290.85	85
375	SN8	400.50	375.40	95
375	SN16	400.50	369.00	95
475	SN8	500.00	469.80	105
475	SN16	500.00	460.80	105

2.4 Stiffness Classes

Pipe stiffness is the measure of a flexible pipe's resistance to deflection, (ovalization) under a load. A flexible pipe is any pipe that can deflect 2% without suffering damage. uPVC meets this requirement and is considered a flexible pipe.

Marley OPTIM DWV pipes are manufactured in different pipe stiffness classes to suit the performance requirements of the installation. They are designated by the Nominal Stiffness, (SN) in N/m/m as determined by the crush resistance test of AS 1462.22 Methods of test for plastics pipes and fittings, Method 22: Thermoplastics pipes – Determination of ring stiffness.

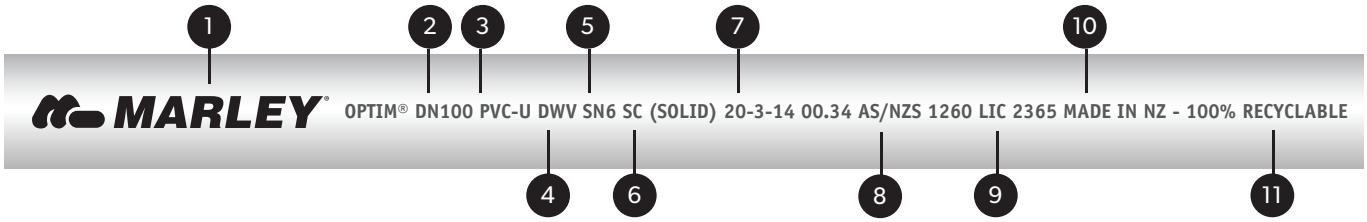
SN4 and SN6 – these pipes are suggested for plumbing and domestic use and for general municipal drainage.

SN8 and SN10 – suitable for general drainage and commercial installation where higher pipe stiffness is required to provide minimum deflection of installed pipes

SN16 and Greater Territorial Authority – this pipe is designed to meet the requirements of the Territorial Authority where very high long-term stiffness is required to provide minimal ovality due to high imposed traffic loads or very high coverage depths and to accommodate varying bedding performance to give long term asset cost performance.

2.5 Pipe Marking

All Marley OPTIM DWV pipes are continuously printed along the lengths with the following details at approximately one metre intervals.



1. Manufacturers name or Trademark
2. Designated size of the pipe, (Diameter Nominal)
3. Material
4. Drain, Waste and Vent applications
5. Stiffness class
6. SC, (Solid)
7. Date of manufacture (year/month/day/time)
8. Manufacturing standard
9. External certification licence number
10. Country of manufacture
11. Recyclability

2.6 Joint Systems

Solvent welded joints are typically used in smaller diameter pipes, to enable connection Marley supplies the following:



Marley Gold, (For both high and low pressure applications – manufactured to AS/NZS 3879)



Solvent Joint Primer (Pink Tint for all solvent jointed uPVC systems – manufactured to AS/NZS 3879)



Joint Lubricant for Rubber Ring Joints
Rubber Ring Joints are supplied as both a replaceable rubber ring and as an encapsulated ring, both are to be used in conjunction with joint lubricant.

3. Design

3.1 Socket Direction

Questions about bell direction are sometimes asked by designers, installers, and operators of uPVC pipelines. The questions fall into two categories:

1. Design-related – does the direction of flow in a uPVC pipeline matter hydraulically?
2. Installation-related – can uPVC pipe be installed by pushing the bell end over the spigot end? Or should the spigot end always be inserted into the bell?

Design: Is hydraulic design affected by bell direction? - No

The flow surface on the interior of a uPVC pipe is a smooth surface interrupted by a small gap at every joint. For flow in the spigot-to-bell direction, the flow encounters a square edge as it crosses the gap. For flow in the bell-to-spigot direction, the flow encounters a slightly rounded edge as it crosses the gap. In their research, Neale and Price found that there was a slight difference in hydraulics depending on bell direction, (because of the squared edge versus the rounded edge as described above). However, their conclusion was: "The head loss incurred by reversal direction is of such a small magnitude that it need not be considered for ordinary design purposes."

For flow, bell direction does not matter. Much more important is bell direction during installation, as discussed below.

Installation: Is pipe assembly affected by bell direction? - Yes

The answer to this question is a definite "Yes"

uPVC pipe joints are designed for insertion of the male spigot end into the female bell end. There are two reasons:

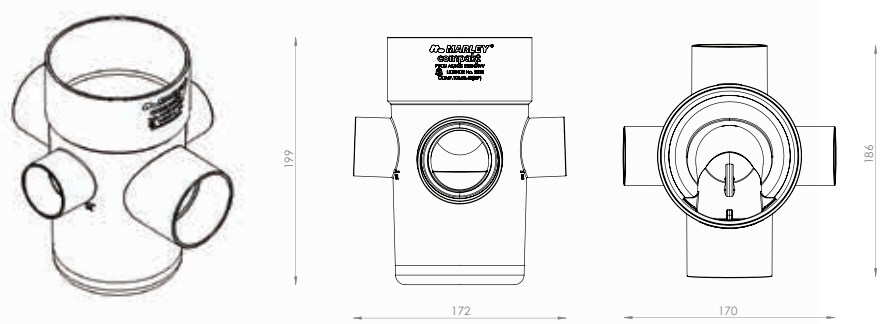
1. Leakage – pushing the larger bell end onto the smaller spigot end results in a greater chance of scooping soil into the joint, which would compromise the sealing capability.
2. Assembly force – straight alignment of bell and spigot reduces the force required to assemble the joint. It is easier to achieve correct alignment when the smaller spigot is inserted into the larger bell.

Always Push the Spigot into the Gasketed Bell: As explained above; to reduce potential joint problems it is important to install uPVC pipe by pushing the spigot into the bell. Said a different way, the bell should always be visible at the end of the installed pipe as the work progresses.

Reference PVC Pipe Association Technical Brief 11.23.2016 - "Flow Characteristics of PVC Sewer Pipe," Neale, L. and Price, R. (1964); Handbook of PVC Pipe, Uni-Bell (2013); Tech Brief: "Expansion Gaps for Gasketed PVC Pipe: Maximizing Joint Performance," Uni-Bell (2013); Tech Brief: "Gasketed PVC Pipe: The Importance of Insertion Lines," Uni-Bell (2013).

3.2 OPTIM Compakt – Boss Gully Trap

Compakt at 199mm tall is the shortest boss in the market. It is 20% shorter than standard uPVC Boss Gully traps so makes it easier for the installer to fit within the shortest joist heights. Compakt has four solvent weld connections with a 65mm outlet, one 50mm inlet and two 40mm inlets, all are at the standard 88°, with a removable flared siphon insert that improves flow and helps eliminate blockages.



*When connecting to a Robinhood STSLIMTAPKOHC, we recommend modifying the strainer to reduce the open area

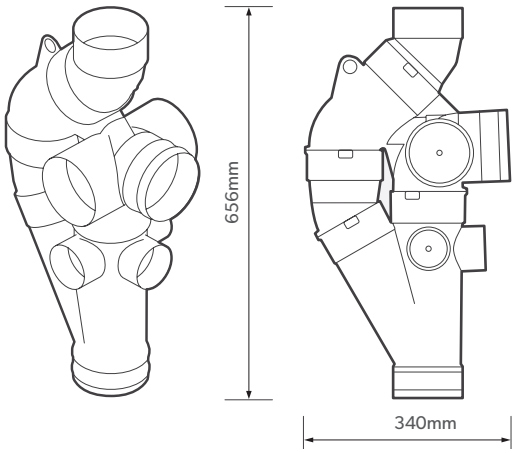
3.3 OPTIM Converge – Reduced Velocity Aerator Stack System, (RVASS)

An RVASS is a sanitary drainage stack system that uses aerator fittings such as the Converge at each floor level to connect branch lines into a vertical stack. The Converge reduces the velocity of the effluent in the stack and merges the vertical and graded horizontal flow while maintaining aeration.

The vent opening between the offset and entry chambers keeps the horizontal pipe ventilated while maintaining a core of air in the vertical stack that keeps positive and negative pressures within limits preventing trap seal breaches without additional vent lines.

In a fully vented modified system, the annular flow down the vertical stack can be disrupted causing turbulence when a graded horizontal flow is introduced causing negative pressure to build which syphons out the water seals of fixture traps, to solve this problem an additional stack is necessary.

By using Converge, a secondary stack isn't required which saves space, labour, and materials.

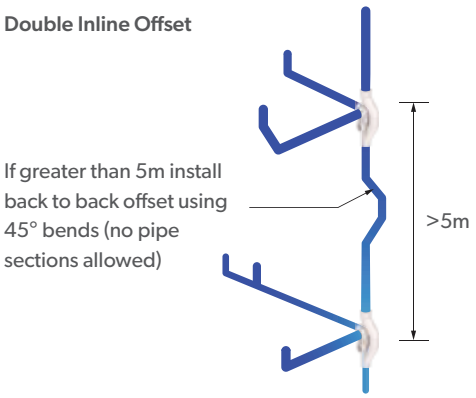


Length L (mm)	Width W (mm)	Height H (mm)
340	227	656

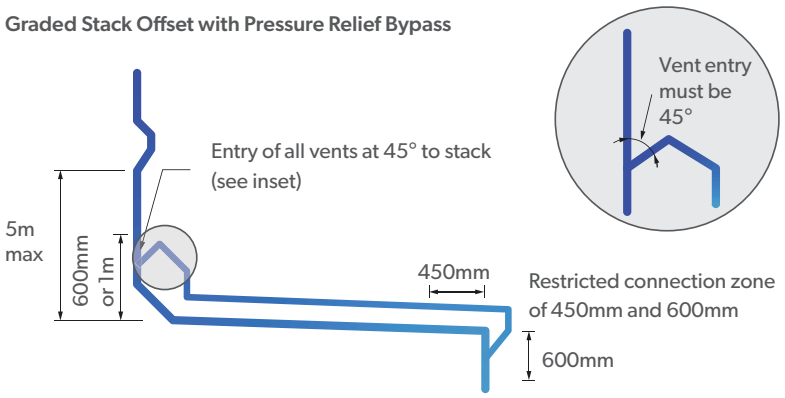
Required Converge Components for Installation	
CONV.100.PVC	Converge uPVC Aerator 100DN
111.100JL	100 DWV Access Fitting & Expansion Joiner
100SN6.100.6	OPTIM SN6 Pipe 100DN 6m

When installing the Converge an expansion/inspection fitting on every level is mandatory to absorb any pipe expansion and have a tension-free stack-aerator. It is recommended that inspection openings are provided on each floor for maintenance purposes. The expansion/inspection fitting 111.100JL should be installed just above the finished slab level.

Double Inline Offset



Graded Stack Offset with Pressure Relief Bypass



For more information review the Converge Technical Manual on the Marley website resources page, (www.marley.co.nz) and/or AS/NZS 3500.2 Section 11.

3.4 Elevated Drainage Principles, (EDP)

When installing plumbing systems at height Elevated Drainage Principles found in AS/NZS 3500.2 Clause 10.11 should be employed. Where unvented branch drains should be no more than 10m in length with a maximum of two WC's and a maximum loading of 30 fixture units. If any of these three points are exceeded additional venting will be required.

Note the requirements of EDP apply to the first four floor levels only above the invert level of the connection point to the boundary trap riser or inspection shaft. However, where pipework passes through basement levels before EDP commences then this pipework is considered drainage plumbing until it rises above ground.

Further requirements of AS/NZS 3500.2 prohibit connections into the vertical pipework unless it is the top floor connection or a vented sanitary stack so all junctions should be made into the graded pipework.

Review AS/NZ S3500.2 for full details relating to EDP.

3.5 uPVC Pipe Supports

Pipe supports are designed for two functions. To clamp a fitting which will create a fixed point and to give support to a length of pipe while allowing thermal movement. For pipe supports there is a difference between vertical and horizontal spacings between the NZBC and AS/NZS 3500.2, for the Plumber/Drainlayer Marley would suggest using the NZBC G13/AS1 detail as the dominant local code. For reference the two are shown below:

uPVC Pipe Dia.	Maximum Distance Between Supports NZBC G13/AS1		uPVC Pipe Dia.	Maximum Distance Between Supports AS/NZS 3500.2 Cl. 10	
	Vertical (m)	Graded Pipes (m)		Vertical (m)	Graded Pipes (m)
DN 32 – 50	1.0	0.5	DN 40 – 50	2.0	1.0
DN65 – 100	1.2	1.0	DN65 – 150	2.5	1.2
> DN100	1.8	1.2	>DN150	3.0	1.5

Pipe Support Requirements and Restrictions

- Shall be connected to the building structure
- Shall be designed to withstand loads applied
- If metallic must be protected against corrosion
- Shall be compatible materials
- Fixed points must be clamped securely, unless thermal movement has been allowed for
- Shall restrain the pipe from being able to move in a lateral direction
- Joints are subjected to minimal loads only
- Do not braze or weld sections of any material to the pipe surface and do not clamp, braze or weld to an adjacent pipe
- Do not connect uPVC pipe brackets, clips or hangars to stainless steel pipes

3.6 Pipe Bending Radius

Before attempting to induce any curvature, always joint two pipes when they are straight to avoid dislodging the rubber ring. Rubber ring joints can be deflected up to 3%. Greater changes in direction can be achieved using shorter pipe lengths or formed swept bends.

For smaller pipe sizes, uPVC is flexible enough to be subjected to limited bending, the curvature should be induced over the full length of the pipe. Joints should be well anchored to ensure the joint is not deflected more than 3%.
The minimum bend radius for uPVC shown below should not be exceeded:

- Non-Pressure Pipe = 150 x DN
- Pressure Pipe = 300 x DN

4. Hydraulic Design

4.1 Design Principles

Where pipelines are flowing full under gravity conditions, the grade of the pipeline gives a predicted head loss per length. However, special attention should be given to entry and exit losses with structures such as manholes which may have a significant effect.

For pipes at full flow, flow capacity can be calculated using pipe diameter, length and pipe gradient using the clean sanitary drain and mature sanitary drain graphs.

4.2 Sewerage Flows

The following data is based off the Colebrook-White formulas that are widely used for hydraulic sanitary sewer pipe design.

Q = Discharge m^3/second
D = Pipe Internal Diameter (m)
g = Gravitational Acceleration (9.8m/s^2)
L = Pipe Length (m)
H = Uniform Friction Head Loss (m)
Ks = Colebrook-White roughness coefficient
= 0.06 clean drain
= 0.6 mature drain (clean)
= 1.5 mature drain (silted)
v = Kinematic Viscosity of water 1.141 x 10^{-6} m^2/s
i = Hydraulic Gradient
V = Velocity metres/sec

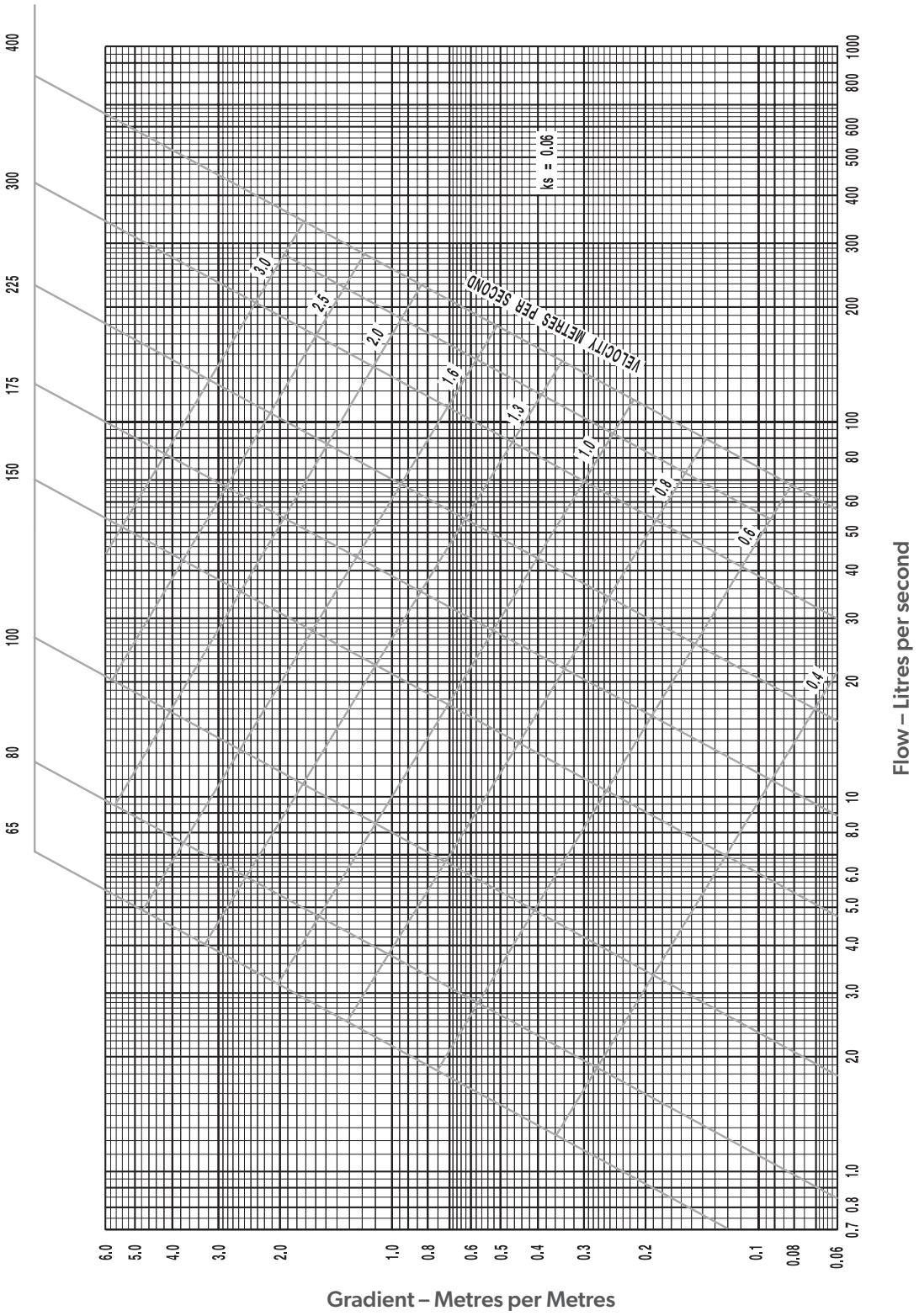
$$V = 2\sqrt{2gDi}\ \ \text{Log}\left[\frac{Ks}{3.7D} -+ \frac{2.5v}{D\sqrt{2gDi}}\right]$$

The Colebrook-White transition equation incorporates the smooth turbulent and rough turbulent conditions for a smooth pipe. The first term in the brackets tends to be zero and the second term predominates.

4.3 Flow Performance Graphs

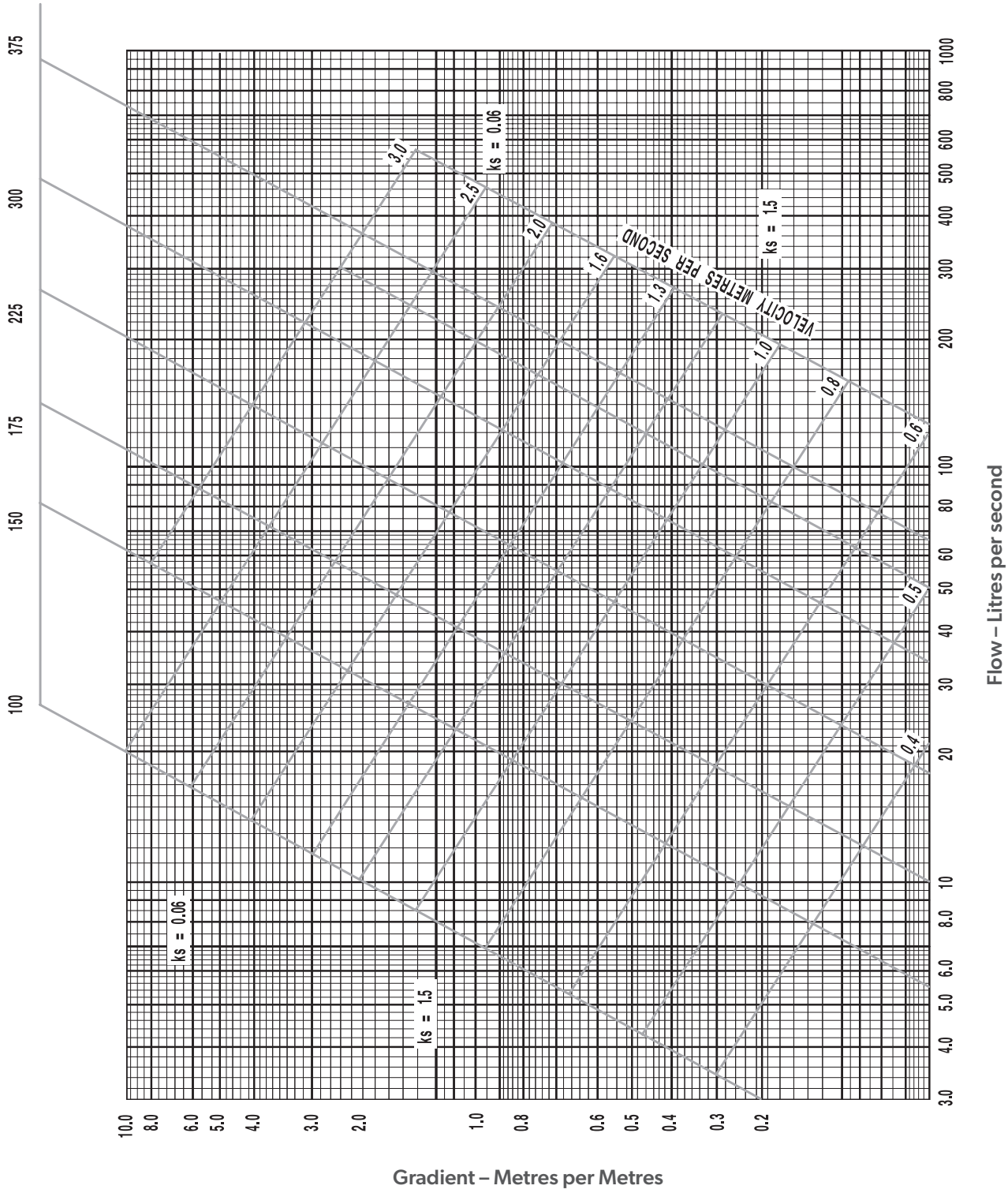
Flow Performance Clean Sanitary Drain

For the theoretical maximum flow condition that can be expected in the early life of a sanitary or stormwater drain with no grit or sliming a roughness value, (Ks) of 0.06mm can be selected.



Flow Performance Mature Sanitary Drain

With a mature drain the Ks values of 0.06 and 1.5 should be considered which covers most service installations with predicted average slime growth and some grit deposit.



4.4 Self-Cleaning Flow

The flow diagram is used to determine the dependence of gradient and flow rate, as well as the speed or velocity of the flow. For example, the diagram shows that the flow rate Q = 20 l/s and a gradient set at 5/mile, (5mm/m) and requires the use of a DN200 mm pipe. The capacity of the pipeline will be Q_t = 25.5 l/s and flow speed in a full pipe V_t = 0.9m/s.

If the minimum flow in the pipeline is estimated at e.g. 5 l/s, the fill ratio is $Q/Q_t = 5/25.5 = 0.2$

From the partial fill diagram, we can see that with this ratio, the relative height of the water surface $h/d_i = 0.3$, the relative flow speed $v/v_t = 0.81$ and the relation of the hydraulic radii $R/R_t = 0.72$. Based on these relations we can calculate the flow speed, the height of the water surface in the pipe and the hydraulic radius. For calculating the latter two values, the inside diameter of the pipe is determined: $d_{ID} = d_{OD} - (2 \times t)$, (t = pipe wall thickness).

In our example $d_{ID} = d_{OD} - (2 \times 4.9) = 190.2$mm. Flow speed v = 0.81 x 0.9 = 0.73 m/s, water height h = 0.3 x 190.2 = 57mm, hydraulic radius R = 0.72 x 190.2/4 = 34.2mm.

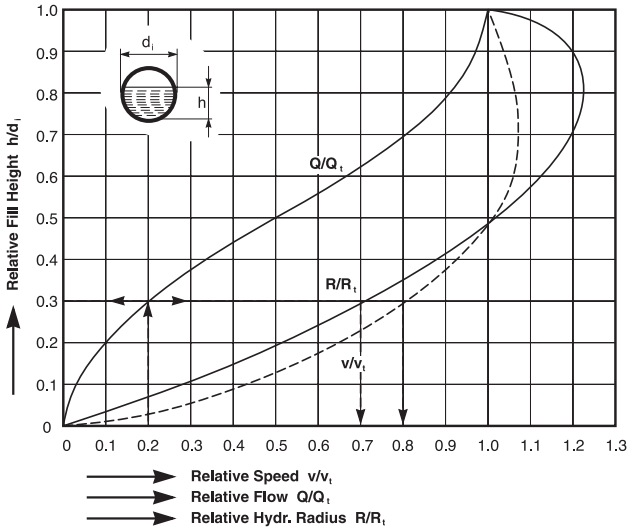
The self-cleaning properties of the pipeline can be estimated by calculating the friction stress from the formula.

T = y x g x I x R where:
T = friction of stress N/m^2
Y = density of water - = 1000 g/m^3
G = acceleration of earth's gravity = 9.81m/s^2
I = gradient m/m
R = hydraulic radius m

In our example, the friction stress is:
T = 1000 x 9.81 x 0.005 x 0.0342 = 1.68 N/m^2

According to various investigations, a sewer pipeline can be regarded as self-cleaning if its friction stress exceeds conservatively 1.5 /m^2.

Refer to ABCB Sanitary Plumbing and Drainage Pipe Sizing Report - Sept 2022



4.5 Minimum Gradients for Sewers

The minimum gradient for gravity sewer pipelines should preferably not be flatter than the grade required to achieve a boundary shear of 1.5 Pa at least once a day. The boundary shear stress is also dependent on the minimum dry weather daily peak (MDWDP) flow, as well as the gradient of the pipeline.

As a general rule of thumb, the pipe grade should not be flatter than the reciprocal of the nominal pipe diameter. Where it is not possible to achieve this grade, slightly flatter grades can be used, but potentially may result in on-going maintenance costs. Where flat grades are necessary, serious consideration should be given to the need for plumbing or the use of flushing tanks to ensure that thorough flushing occurs periodically. For new development areas where the MDWDP may be lower than necessary to achieve a flushing flow most days, it may be temporarily necessary to carry out flushing.

The traditional minimum gradient values used for concrete and ceramic sewer pipelines are conservative for smooth bore plastics such as uPVC and experience has shown that flatter grades can be used with confidence. There is some evidence that if the boundary shear stress is 1.0 Pa or higher, the pipeline will still be self-cleansing but grades this flat should be avoided if possible.

Very flat grades should be avoided due to the difficulty in ensuring that a continuous fall is maintained. Small misalignments in installation or those caused by settlement of bedding can easily result in areas of "ponding" in the pipeline and cause potential blockages.

As a general rule, the volume of flushing water should be sufficient to completely fill the main sewer line along the section of flat gradient. The connection from the flushing tank to the manhole must be capable of carrying the flushing flow as shown in the table. Appropriate backflow prevention should be provided on the water supply connection to the flushing tank.

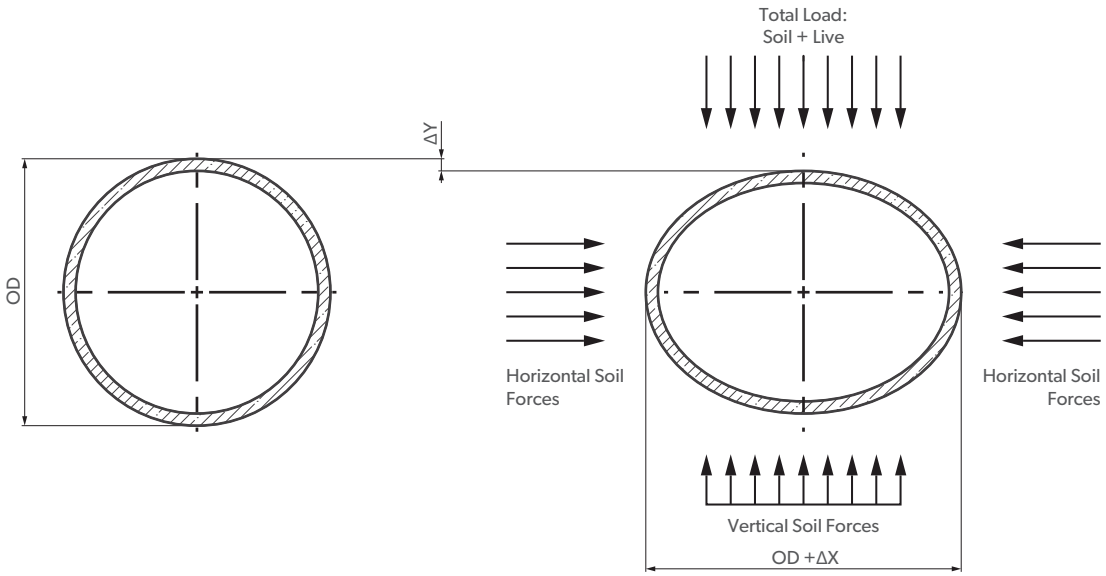
4.6 Deflection Limits

uPVC pipe systems are referred to as flexible pipe systems, meaning they can deflect under external load without distress.

This unique ability to deflect under load ensures that when soil and ground movement takes place, (soil consolidation in the first 3 years, earth movement and earthquakes) the uPVC pipeline integrity should be maintained.

Marley OPTIM DWV is not designed for pressure pipe performance, but for the stiffness characteristics, and their ability to withstand external soil and live loads.

Deflection in flexible pipes is resisted by the passive soil support from the soil surrounding the pipe, the trench width, the class/rating and the compaction of the bedding material. All must be considered when providing a performance statement on the pipe.



Undeflected uPVC Pipe **Deflected uPVC Pipe**

When uPVC pipe is subjected to load the pipe diameter will deflect, the sides will move outwards as the load forces the top downward. If the pipe is buried in a good compacted supportive soil the stiffness of the soil will resist the deflection.

A failure due to pipe deflection occurs when the pipe begins to experience inverse curvature, research shows us that this point is around 30% deflection. Marley recommends when calculating deflection 5% for short term, (6:1 safety factor) and 7.5%, (4:1 safety factor) for long term.

Deflection data collected from studies over the last few decades show the settlement and consolidation of the soil surrounding the pipe will result in an increase of the deflection over time. However, the majority of this increase will be experienced during the first 1 to 2 years, after this the deflection will stabilise.

It is expected that the initial pipe deflection during the first two years should not exceed 2.5% for small diameter pipe DN≤ 250 and 3% for pipes DN≥300.

4.7 Embedment Geometry

Embedment width, bedding and overlay – the width requirements are listed in the following table.

Bedding Minimum Values (mm)			
Nominal Pipe Size	Min. Bedding Depth	Side Cover	Min. Cover
DN75 ≥ ≤ DN150	75	DN + 200mm	100
DN150 > < DN300	100	DN + 200mm	150
DN300 > ≤ DN450	100	DN + 200mm	150

Refer to AS/NZS 2566.1 for further details.
For full details to manage Health and Risk associated with excavation work, refer to **"WorkSafe - Excavation Safety"**.

4.8 Support System (Shoring)

When trench support systems are used the embedment material shall be placed and compacted so that no loss of compaction results from removal of the trench side supports systems.

The trench support shall be removed in such a way as to ensure that the placing and compaction of embedment material occurs below the trench support systems and against the undisturbed native soil trench walls.

4.9 Compaction

Embedment material shall be placed in a manner to ensure uniformity of density in the side supports including the haunch support and overlay with no distortion, dislodgement or damage to the pipeline. Where required to be compacted, embedment material shall be placed in layers of thickness suitable for the method of compaction to achieve the specified density uniformly throughout. Typically, a 450mm layer is sufficient.

To prevent point load damage to buried pipes embedment material should be restricted in size according to the pipe diameter.

AS/NZS 2566 states the following:

Maximum particle size	
Pipe DN	Particle Size (mm)
<100	10
≥100 ≤150	14
> 150	20

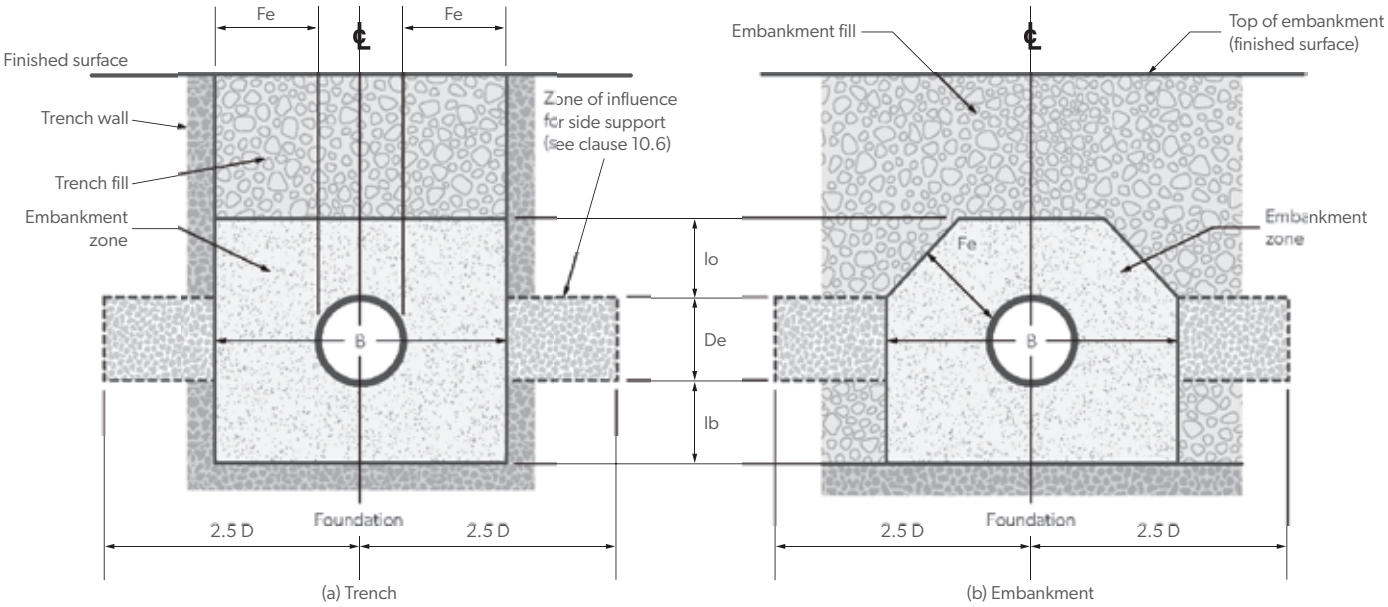
4.10 Soil Moduli

Native soil modulus – the native soil modulus, (E'n) for different materials and degrees of compaction are given in the following table in MPa.

Native soil is assumed to be the material present to a distance 2.5D, (zone of influence for side support) from the centre line of the pipe.

Effective combined soil modulus – the effective combined soil modulus of the embedment, (E'n) is calculated with the formula:

$$E' = \zeta E_e$$



Native Soil	Standard Soil Compaction E' MPa					
Material	**Soil Type AS 1726**	**E^N MPa**	**91%**	**92%**	**95%**	**97%**
Gravel – single size	-	MPa	7§	7§	10§	14
Gravel – graded	GW	9	5§	7§	10§	20
Sand and coarse grained soil with less than 12% fines	GP, SW, SP & GM-GL, GC-SC Etc.	4	3§	5§	7§	14
Coarse grained soil with more than 12% fines	GM, GC, SC, SM & GM-SC, GC-SC		1§	3§	5§	10
Fine grained soil, (LL <50%) with medium to no plasticity and containing more than 25% coarse grained particles	CM, ML, mixtures ML-CL, CL-CH & ML-MH	2	1§	3§	5§	10
Fine grained soil, (LL <50%) with medium to no plasticity and containing less than 25% coarse grained particles	Cl, CL, ML mixtures ML-CL, CL-CH & ML-MH	1	NR	1	3	7
Fine grained soil, (LL >50%) with medium to high plasticity	CH, MH & CH-MH	0.5	NR	NR	NR	NR

LL – Liquid Limit
§ - value commonly achieved
NR – No reliable modulus value

Refer to AS/NZS 2566.1 for further details

Soil Group descriptors shown below relate to the above chart explaining the soil types used in AS 1726.

Soil Group	Descriptor
Gravel (G), Sand (S)	Well Graded (W), Poorly Graded (P), Silty (M), Clayey (C)
Silt (M), Clay (C), Organic (O)	Low Plasticity (L), Medium Plasticity (I), High Plasticity (H)

4.11 Deflection Prediction

Deflection in flexible pipe systems such as uPVC can be predicted using the modified Spangler formula to take into account different loading conditions for the specific pipe material performances.

The E Modulus that is used to determine any long term performance must relate to the specific pipe material class and rating, as the different constructions offer different long term performances.

4.12 Design of uPVC Pipelines

The modified Spangler formula can be written as:

$$\Delta y = \frac{D \times K \times 10^{-3} (W^0 + W^1)}{8 \times 10^{-6} S^{DL} + 0.061 E^1}$$

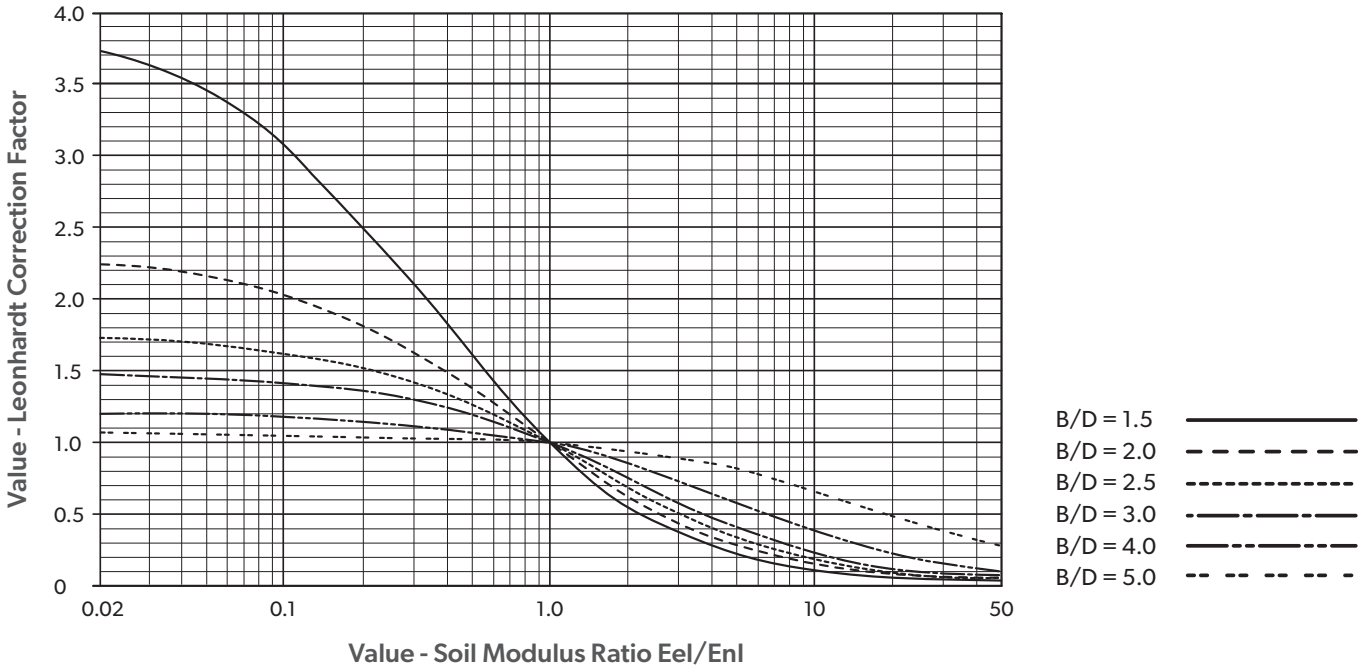
Where:

Δy = Change in diameter, (mm)
W = Loads on a pipe related to soil, (W^0) or traffic, (W^0) or live loads W^1 (kN/m)
K = Bedding deflection co-efficient is assumed to be 0.1 unless detailed engineering calculations show otherwise
D = Diameter at neutral axis of pipe wall
E = Effect combination of the soil modulus MPa

$$S^{DL} = \frac{E^{bL} \times I}{D^3} \times 10^6$$

Where:

E = Youngs modulus, (MPa) for the uPVC construction material used in the pipe
I = Moment of inertia of the pipe wall
= $t^3/12$ (mm^3)
t = Wall thickness, (mm)
r = Mean pipe radius, (mm)
D = Diameter of neutral sizes of pipe wall



4.13 Soil Load

The method of calculating the soil load on a flexible pipe is simply to take it as the weight of a column of soil above the pipe. This is called the "Prism Load" and is determined from the volume of soil above a metre length of pipe multiplied by the specific weight.

$W_D = pgDH$

Where:
W = Load per unit length on the pipe, (N/m)
P = Soil density, (kg/m^3)
D = Pipe diameter (m)
H = Cover height, (m)

Using the prism load is particularly conservative for flexible pipe laid in narrow trenches, as it ignores the friction effects both of the columns of soil adjacent to the column over the pipe and against the trench walls. These friction effects significantly reduce the load on the pipe.

4.14 Superimposed Live Loads – Road Vehicles

For shallow pipes, the live load (W^1) becomes significant and can be determined. The average intensity of the design live load at the top of a pipe due to multiple wheel or track vehicle loads, including impact effects is calculated from the following equation:

$$W^1 = \frac{\Sigma P}{L^1 L^2} \text{ á}$$

Where:
W^1 = Vertical design load kPa
ΣP = Sum of individual wheel loads kN
L1 = Length of the base of the live load, (m) measure perpendicular to the direction of travel of the vehicle at the top.
'A = Live Load impact factor
(1.4 – 0.15H but not less than 1.1)

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