EUROFLO®
TECHNICAL BROCHURE
250MM – 1200MM SN8

INDEX

INTRODUCTION

EUROFLO® is a high-density polyethylene corrugated pipe designed for non-pressure drainage systems.

This technical manual has been created for designers, engineers and specifiers in both public and private industries. It describes the product and the calculation methods for the correct use of EUROFLO®.

This manual applies to the following SN8 EUROFLO® (OD) sizes: 250mm, 315mm, 400mm, 500mm, 630mm, 800mm, 1000mm, 1200mm

All EUROFLO® comes in 5.8M lengths.

STANDARDS

Production of EUROFLO® is checked by external and internal laboratories in compliance with EN ISO 9001:2015, EN 13476-3, and AS 5065:2005 standards.

AS/NZS 5065:2005 (R2016) Polyethylene and polypropylene pipes and fittings for drainage and sewerage standards.

In accordance with the Ministry of Business, Innovation and Employment this standard specifies the requirements for polyethylene (PE) and polypropylene (PP) pipes and fittings for sewerage and drainable applications, above and below ground, inside and outside of buildings, and intended to be used where the pipeline is operating under gravity flow and the operating pressure is low. It includes requirements for both plain and structured wall pipes and fittings.

EUROFLO® is a PE pipe made to this standard and recommended for all drainage applications.

Pipes manufactured to this standard are intended to be installed in accordance with AS/NZS 2033, AS/NZS 3500.2, AS/NZS2566.2, AS/NZS 3500.3, WSA 02 and other utility/ authority requirements.

AS/NZS 2566.2:2002 specifies the requirement for the installation of buried flexible pipelines, field testing and commissioning of buried flexible pipelines with structural design in accordance with AS/NZS 2566.1

AS/NZS 2566.1:1998 specifies a practice for the structural design of buried flexible pipelines which rely upon side support to resist vertical loads. The practice applies to pipes with outside diameters equal to or greater than 75mm, initial ring-bending stiffness equal to or greater than 1250 N/m/m and long-term ring-bending stiffness equal to or greater than 625 N/m/m.

1. GENERAL

1.1 DRAINAGE SYSTEMS

All pipes from reliable manufacturers and installed correctly, will give good technical results. Without going into details on the use of all various materials, we will emphasise those concepts which all designers and users should take into account when assessing these systems.

The main requisites of drainage pipes are:

- good hydraulic characteristics, durable for the specified uses;
- suitable resistance to internal pressure even in the case of temporary overpressure;
- good resistance to external loads;
- excellent bidirectional watertightness of joints on a short and long term;
- excellent resistance to chemical and electrochemical aggressions;
- resistance to abrasion;
- reduced adherence to deposits;
- easy cleaning with modern techniques;
- easy and quick assembly and laying;
- competitive price.

To be more specific about the characteristics described above:

- the compliance of each material with the project requisites must be checked on the basis of reasonably foreseeable design parameters, especially as regards to hydraulic characteristics (inside diameter and absolute roughness value);
- resistance to chemical, electrochemical aggressions and abrasion must be checked according to waste waters;
- resistance to internal pressure and watertightness even on a long term, apply to all pipes but above all those pipes with spigot joints whose key element is the socket length and the seal characteristics;
- watertightness must be bidirectional: most problems in the existing drainage systems that also affect the treatment plants are caused by groundwater or leaks from the joints;
- high pressure or mechanical cleaning systems may damage some materials causing misalignment of certain types of joints or even failure of the internal pipe wall.
- as regards to costs, it should be pointed out that instead of comparing the pipe cost the comprehensive cost of the whole system must be taken into consideration, including laying costs, time and all maintenance costs connected with the life cycle to install the pipe.

EUROFLO® perfectly meets a wide range of drainage requirements, performing well in some of the toughest drainage environments. Details regarding various material properties and resistance limits are found in Section 2.

1.2 PLASTIC PIPES

The first plastic material which was used for drainage and drainage systems was PVC (polyvinyl chloride) because of its ease of installation and competitive cost. While PP (polypropylene) has always been used for special applications (high temperatures and industrial field), HDPE (high density polyethylene), in its extruded solid wall version, has been used only occasionally as too expensive.

In the '80s, the first HDPE pipes up to 3.6 m in diameter were successfully used as they combined a very good resistance to aggressive wastewater with other important characteristics such as lightness, high ring stiffness and competitive costs. This is how products in Europe (being the early pioneers) such as Bauku, Henze, KWH were manufactured and patented and are still available in their last versions. With the new licences, the different types of walls were later developed which lead to the manufacture of the EUROFLO® pipe.

The characteristics of plastic structured pipes have very good resistance to aggressions by piped waters, resistance to laying and working stresses, ease of installation, long life with little maintenance and a very good cost/efficiency ratio, if used in a correct way, make of this pipe the material of the future.

1.3 RIGID PIPES AND FLEXIBLE PIPES

The first thing to do when dealing with drainage pipes is to distinguish between rigid pipes and flexible pipes.

Rigid pipes are pipes whose ring section cannot undergo horizontal or vertical deflections without the pipe being damaged. AWWA (American Water Works Association) classifies as stiff pipes those pipes where a 0.1% deflection may cause damage while semi-stiff pipes are those enduring up to 3% deflection. Rigid pipes are those made of cement, asbestos cement, cast iron, stoneware.

Flexible pipes are pipes where an external stress may cause deflection of the ring section (according to AWWA → 3%) without damage. Flexible pipes are typically made of plastic. The deflection, whether on a short or a long term basis, can reach higher values without damage or signs of failure of the pipe structure but are incompatible with the correct hydraulic operation of the piping system.

The key parameter of flexible pipes is ring stiffness which depends both on geometrical data (moment of inertia of the wall) and on the characteristics of the material (modulus of elasticity). This element is calculated geometrically for solid wall pipes and by means of experimental tests for structured wall pipes or for pipes manufactured using composite materials.

For solid wall pipes, the ring stiffness (SN) can be calculated through the formula of the modulus of elasticity (E) whose elements are the pipe material, the moment of inertia (I) and the mean diameter of the pipe (Dm):

$$SN = E \cdot \frac{I}{D_m^3} \quad \text{in Pa}$$

where:

E = modulus of elasticity of the material, in Pa

D_m = mean pipe diameter, in m

I = moment of inertia, in m4/m

The modulus of elasticity of the material is particularly important for evaluating the concept of "flexibility". The order of magnitude of the modulus of elasticity (E) in rigid pipes is greater than in flexible pipes, as shown below:

- asbestos cement 2.5·10^4 MPa
- concrete 3.0·10^4 MPa
- clay 5.0·10^4 Mpa
- cast iron 10.0·10^4 Mpa
- ductile iron 17.0·10^4 MPa
- PVC 3.6·10^3 Mpa
- PP 1.4·10^3 Mpa
- HDPE 1.0·10^3 Mpa

It must be said that in most cases a high modulus of elasticity means "fragility" if the material's impact strength is not as high as in polyethylene.

Another factor which affects stiffness is the moment of inertia of the wall (I). To obtain a suitable ring stiffness in pipes with a low modulus of elasticity, you need to work on the moment of inertia of the pipe wall, $I = s^3/12$, and, therefore, on the real or "apparent" thickness (better known as "equivalent" thickness). To avoid high thicknesses and high weights and expensive costs, the moment of inertia can be increased using geometric profile features such as ribs.

Ring stiffness in structured pipes is obtained by means of experimental tests with the method mentioned in UNI EN ISO 9969 standard and the following formula:

$$SN = \left(0.0186 + 0.025\frac{y}{Di}\right)\frac{F}{L \cdot y} \quad \text{in Pa}$$

where:

F = force which is necessary to obtain the desired deflection, in N

L = length of pipe sample, in m

y = bending of pipe diameter, in m

Because of their visco elasticity, plastic pipes which are subject to a steady load generally lose their shape over time. This is called "creep". The stress/creep ratio is called "creep modulus", not to be mixed up with the modulus of elasticity of the material.

Considering that the moment of inertia is not easy to calculate for structured pipes even with a modulus of elasticity depending on the creep, the long term behaviour has been determined through experimental tests. Ring stiffness on a long term is calculated by dividing the ring stiffness by the creep modulus extrapolated at a certain time given by the reference standard.

Times are chosen considering that once installed, the pipe is subject to an immediate deflection followed by a slow progressive deflection over time. Time varies depending on soil conditions and methods of installation but is not longer than two years: this datum has been adopted as extrapolation time.

1.4 INTERACTION BETWEEN PIPE AND GROUND

All pipes laid in an excavation or an embankment are subject to external loads caused by the weight of covering materials, the weight of other products resting on it (static loads) and by dynamic loads caused by means of transport passing directly on it or near the pipe.

In all pipes laid in excavations and subject to external loads there is an interaction between the pipe, the backfilling and the excavation wall. In other words, the "backfilling-excavation walls" offer resistance against pipe deflection.

Analysis and calculation methods are different for rigid and flexible pipes. Ground settling around the pipe is different, as shown in figure 1.1, depending on whether the product is a flexible or rigid pipe.

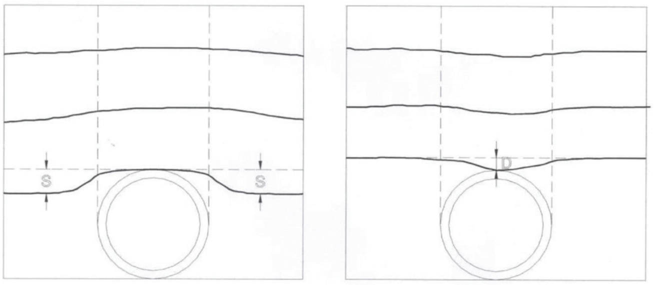

Figure 1.1: Ground settling for flexible pipes and rigid pipes

Deflection values in stiff pipes are negligible or minimal before failure. The ground counterthrust results in a simple decrease of wall stresses due to the side load of the ground which is comparable to a "hydrostatic thrust" and which can be represented by a triangular load.

In flexible pipes, deflection can reach higher values; the side counterthrust results in a limitation of deflection and therefore the vertical load value is lower. This is the reason why it is so important during installation that a sufficient contrast is reached by compacting the sidefill in order to limit deflection to acceptable values. Figure 1.2 shows the behaviour of a pipe subject to external loads.

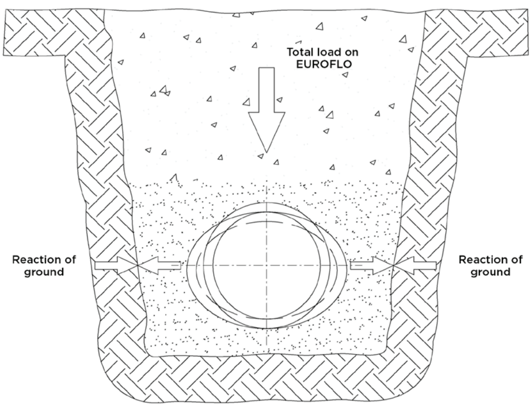

Figure 1.2: Flexible pipe subject to external loads

In short, the greater the "stiffness" of the backfilling and structure around the pipe the higher the resistance of the pipe to external stresses. The "backfilling - ground" reaction, which can be called profile stiffness, can be put in connection with the modulus of elasticity "e" of the backfilling which strongly depends on the compaction level, and with the unchanged modulus of elasticity of the excavation's walls. We will later see how the profile stiffness prevails, in order to reduce deflections, over pipe stiffness.

The methods of calculations which are generally used for flexible pipes (studies made by Spangler, Watkins, Barnard) consider that the "e" value (modulus of elasticity or module of passive resistance of backfilling) is not steady while, in practice, the "module of deflection" or "secant modulus" E′ = e r (where r is the duct radius), which is expressed in Pa, is steady. E′ values generally depend on the type of material and compaction percentage; the engineer has to choose correctly based on the local conditions and the backfilling requirements.

2. THE MATERIALS

2.1 POLYETHYLENE

Polyethylene (PE) is a thermoplastic material which is obtained by polymerization of ethylene monomer, a by-product of oil, characterised by high molecular weight chains (CH2=CH2). Several ethylene polymerization processes have been developed over the years in the attempt to improve the physical and chemical characteristics of polyethylene such as resistance to internal pressure on a long term and resistance to high temperatures and processability.

An important parameter through which the mechanical characteristics of the different types of polyethylene used for pipes can be identified is MRS (Minimum Required Strength): after examining several samples at different temperatures and pressures for up to 1000 hours, the regression curves are built from which the MRS is extrapolated as ring stress which ensures a 50-year life at 20°C. MRS values (in Mpa) multiplied by 10, determines the polyethylene type: the polyethylene which is mostly used for pipes is PE100 (with MRS equal to 10 MPa). By dividing the MRS by a coefficient of safety (usually 1.25 for aqueducts) the ring stress called project sigma is obtained.

For structured pipes, the classification test is made on solid wall pipe samples made of the same material. The values which are taken into account for polyethylene pipes are 4.0 MPa for the 165-hour test at 80° C and 2.8 MPa for the 1000-hour test at 80° C.

2.1.1 ALLOWABLE TENSION AND MODULUS OF ELASTICITY

Polyethylene used for EUROFLO® has the well-known technical characteristics like all thermoplastic resins and viscoelastic materials: the modulus of elasticity and the deflection under load depend on temperature and time.

The UNI EN 13476-1 standard provides for the following additional characteristics:

modulus of elasticity, E	≥800 MPa
average density	≈940 kg/m³
average coefficient of linear thermal expansion	≈0.17 mm/m K
thermal conductivity	(0.36 - 0.50) W K^{-1} m^{-1}
specific heat capacity	(2300 - 2900) J kg^{-1} K^{-1}
surface resistance	› 10^{13} Ω
Poisson's ratio	0.45

2.1.2 RESISTANCE TO CHEMICAL AND ELECTROCHEMICAL AGGRESSIONS

The resistance to chemical aggression of polyethylene is well-known. This characteristic is also described by the UNI EN 13476-1 standard for which *"piping systems conforming to this standard are resistant to corrosion by water with a wide range of pH-values such as domestic wastewater, rainwater, surface water and ground water. If piping systems conforming to this standard are to be used for chemically contaminated wastewater, such as industrial discharges, chemical and temperature resistance must be taken into account".*

Moreover, polyethylene is not exposed to electrochemical aggressions as it is electrically inert.

The resistance of polyethylene-made products to biological aggressions is often widely discussed. While biochemical attacks by mildews or enzymes or even insects is practically inexistent, it is not clear if the attacks by rodents, moles or rats is really a danger. There is no evidence of this fact but signs of bites have been found on some old lead-stabilised PVC pipes.

It can then be said that the polyethylene pipe is resistant to aggression from the environment and should be noted that it does not release noxious substances in the environment.

2.1.3 RESISTANCE TO ABRASION

Over the last few decades, abrasion or erosion of different materials has been the subject-matter of several studies and discussions in order to understand mechanisms and the effects and endurance of materials exposed to fluids containing abrasive substances. The effects of this phenomenon, which concerns both storm water and wastewater, have been studied by making tests on two control parameters: the amount of abraded material over a certain time or the time necessary to "perforate" the pipe manufactured using a given material. Both test data and real facts are available in literature but because of the instability of the parameters which characterise this phenomenon (type and material of particulate and corresponding sedimentation speed, flow speed, slope, whether cavities are present or not, mechanical parameters and initial roughness of the pipe inner surface, etc.) univocal conclusions have still not been reached.

Abrasion can be classified as shown below:

- penetration: the particle "cuts" into the material and is later released leaving a cavity into the pipe's material;
- ploughing: the particle cuts a groove and the material which is accumulated before or laterally is later removed;
- cut: the particle acts like a cutting tool and removes the particles of material;
- fracture: the particle creates a fracture in the surface layers.

Abrasion mainly takes place in the lower part of the pipe but localized turbulence may expand it to the entire wall. This is caused by friction, rubbing, rolling, cutting (both by pulling and turbulence) or impact and the harder and more irregular the particle, the more noticeable this phenomenon will be.

According to EN 476 standard, only clay pipes used in drainage systems must be tested for abrasion as any defects on the vitrified surface may cause localized abrasions. The same standard relating to structured wall pipes (UNI EN 13476-1) provides for that "pipes and fittings conforming to this standard are resistant to abrasion". As far as polyethylene is concerned, it can be said that conditions being equal, it better resists abrasion than other materials.

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Specific tests made by the Institute for Plastics of Darmstadt have proven this to be true. This is also suggested by the results of the tests made to calculate the time required for equal amounts of material to be removed from the inner wall of different types of pipes, conditions being equal (sand in water, 15/85% ratio, 10 m/s speed):

cement: 20 hours

steel: 34 hours

PVC: 50 hours

clay: 60 hours

PE: 100 hours

To check these results, an abrasion test was made by the Darmstadt Institute (D). The methods used by the Institute according to the German standard DIN 19566-2, are later described (the same test method is included in the EN 295-3 standard).

TEST METHOD ACCORDING TO DIN 19566-2

Resistance to abrasion must be tested according to point 5.2.

After 100,000 cycles, the depth of abrasion "a" must not be higher than 1/3 of the wall internal thickness of the pipe "$s_{i\text{-}min}$". One longitudinal half of pipe, 1000 mm long, is frontally closed by plates, filled with a mixture of water, sand and grit and covered with another plate. This half pipe is inclined longitudinally by ±22.5° first on one side and then on the other side so that the control material movement produces the abrasive effect to be controlled.

The abrasive material to be used is natural quartz grit in unbroken round grains with a granulometric curve meeting the following requirements:

$M = d_{50} = 6$ mm

$U = d_{80}/d_{20} = 8.4$ mm/4.2 mm = 2 mm

where:

M = medium size of grains, in mm

U = non-uniformity grade

$d_{50}/d_{80}/d_{20}$ = grain size in mm of which 50/80/20% of grains (percentage referred to weight) has a smaller size.

The control abrasive material is inserted into the sample to be examined according to the diameter shown in table 2.3. Water is then added up to 38±2 mm of the filling height.

DN (mm)	Test material (kg)
250	4.5
300	5.0
400	5.8
500	6.5

Table 2.3: Amount of abrasive material used according to diameter

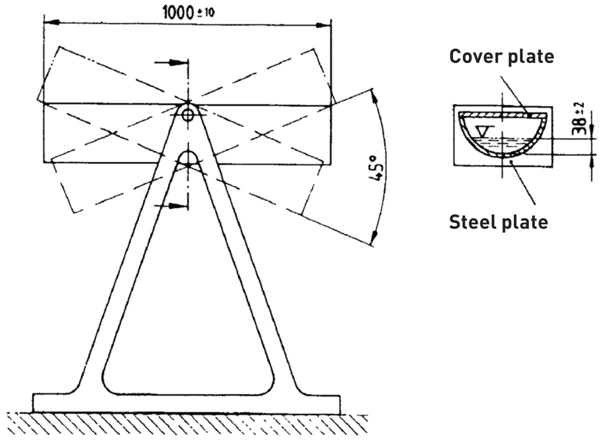


Figure 2.1: Abrasion test

The sample examined must be tested for 100,000 cycles (abrasion with slipping and oscillation). Oscillation must be sinusoidal with a 20 cycles/min. frequency. At the end of the programmed cycles the abraded thickness must be measured by comparing it to the initial value. The end areas corresponding to 150 mm on both sides must be ignored. The average "a_m" of the values measured in the groove for the remaining 700 mm of sample is to be taken into consideration. Thickness "a" of the bottom line must be measured after 25,- 50,- 75,- 100,000 cycles. To determine the abrasion curve inclination, a_m must be measured up to 400,000 cycles. After 100,000 cycles, new abrasion material must be used.

The following is the integral translation of the certificate issued by the Darmstadt Institute.

Report number: 544/98

Pipe material: High density polyethylene

Nominal diameter: DN 250

Manufacturer: P&F Global s.r.l.

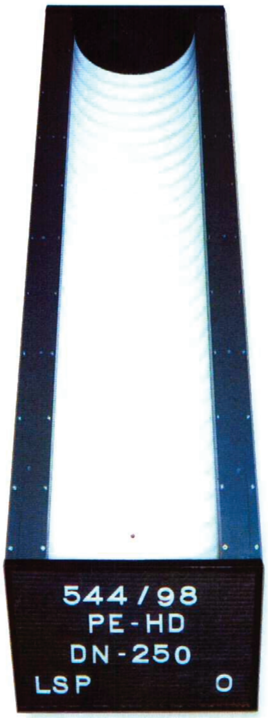
I - 25046 CAZZAGO SAN MARTINO (BS)

Via E. Mattei, 10-12-14

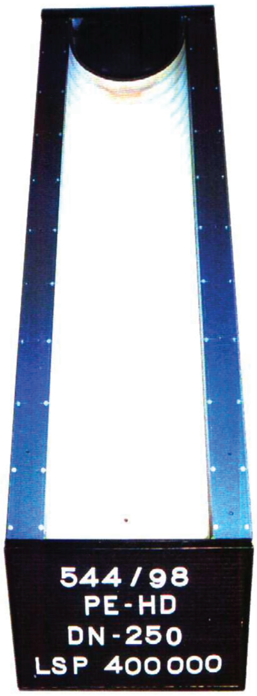
The pipe examined is made of high density polyethylene. The pipe diameter is DN 250 mm.

RESULT:

The half pipe cut lengthwise has been tested for abrasion for 400,000 cycles in order to obtain reliable results. Each test has been stopped after 25-, 50-, 100-, 150-, 200-, 300-, and 400- thousand cycles and abrasion was measured. The test was made according to DIN 19566 standard, part 2ª (appendix 1). The test method has been developed by our laboratory and is well-known as "Darmstadt Method". This method corresponds to the test provided for by national specifications for different types of plastic pipes, such as polyester, PVC, fibreglass-reinforced plastic pipes. The photographs which were taken at the beginning and at the end of the test clearly show the effects of abrasion.

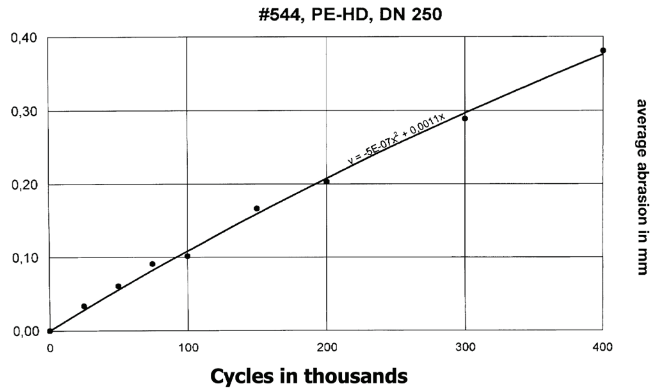


Pipe PE-HD, DN 250



Pipe PE-HD, DN 250 after 400.000 cycles

The graph shows abrasion am, measured during the tests according to the number of cycles. As can be seen, the pipe abrasion is almost linear compared to the number of cycles.



Measurements can be interpolated by the second degree function $a_m = 0.0011 \cdot (\text{cycles}/1000) - 5 \cdot 10^{-7} \cdot (\text{cycles}/1000)^2$

This function indicates that after 100,000 cycles a_m = 0.105mm. Values of this type were measured only in high density polyethylene pipes of a very good quality.

2.1.4 TEMPERATURE AND THERMAL EXPANSION

According to the EN 476 standard, pipes and fittings for drainage systems must be suitable to resist to 45°C for diameters up to 200mm and 35°C for higher diameters.

The linear thermal expansion coefficient of polyethylene is $1.7 \cdot 10^{-4}$ °C^{-1}. The change in size of structured wall pipes is not a requirement provided for by the standard except as a cause of separation of layers or cracking. Expansion may be a significant factor during installation as abnormal tension or joint slipping may occur because of mistakes made during installation.

Nevertheless, it can generally be said that a structured wall pipe linear expansion is lower than that of the solid wall pipes made of the same material. This statement is based on the fact that the structure expansion coefficient values are the same for the whole exposed surface but expansion or shrinkage is partially fought by the elements of the same structure and more evident in a radial direction. This was proven by several laboratory tests made on EUROFLO® and on a smooth polyethylene pipe with the same diameter and made of the same material. The test pieces were conditioned at -10°C and +70°C and their length was compared with the values measured at room temperature. EUROFLO® elongation was on an average 50% lower compared to the solid wall pipe. Therefore, it can be said that the apparent expansion coefficient of EUROFLO® is $1 \cdot 10^{-4}$ °C^{-1}.

Tests have been also carried out to check changes in the outside diameter depending on temperature. Due to the complex mechanism of longitudinal and rib expansion, it has been proved that at -10 °C and +70 °C the change compared to the initial value at room temperature is not higher than ±0,5 %.

3. THE PRODUCT

3.1 THE PROFILE

The EUROFLO® profile is designated as a 'Type B' profile according to the AS/NZS 5065:2005 standard, that is, a "pipe with a plain inside surface and a solid or hollow helical or annular ribbed external surface."

EUROFLO® manufacture is carried out using manufacturing equipment developed for a special type of structured wall which was studied and developed in Germany: the profile has a semicircular top which was specially developed to increase load resistance. Figure 3.1. shows the profile in detail.

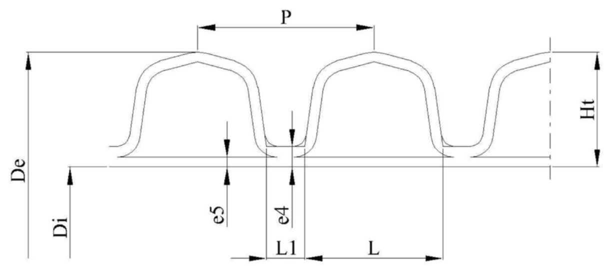


Figure 3.1: Profile of EUROFLO® pipe

where:

D_e : outside diameter

D_i : inside diameter, which is greater than the minimum diameter indicated by the standard

e_5 : thickness of internal wall

e_4 : welding thickness

P : spacing of the rib

L : rib width

L1 : space between ribs

Ht: : rib height

Though values D_i, H_t, P, L, L1, are within the standardization limits, they have been chosen by the manufacturer based on ring stiffness.

The wave shape of the upper part of the rib, which is typical of diameters from DN/OD 250 mm, gives the possibility to change the ring stiffness from SN 4 to SN 8 kN/m² by acting on rib thickness.

3.2 DIMENSIONAL CHARACTERISTICS

Table 3.2 shows the guaranteed manufacturing values and their corresponding tolerances; the limits provided for by the UNI EN 13476-3standard are given in brackets. Values as given in table 4.8 of the AS/NZS 5065 standard are similar in value.

DN/OD (mm)	De (mm)	Di min (mm)	e5 (mm)
250	250 (-1.5/+0.8)	218 (≥ 209)	1.4
315	315 (-1.8/+1.0)	273 (≥ 263)	1.6
400	400 (-2.4/+1.2)	344 (≥ 335)	2.0
500	500 (-3.0/+1.5)	427 (≥ 418)	2.8
630	630 (-3.7/+1.9)	533 (≥ 527)	3.3
800	800 (-4.8/+2.4)	691 (≥ 669)	4.1
1000	1000 (-6.0/+3.0)	855 (≥ 837)	5.0
1200	1200 (-7.2/+3.6)	1024 (≥1005)	5.0

Table 3.2: Sizes and relative tolerances

The values for the inside diameter which were adopted for all classes of EUROFLO® are higher than the minimum values provided for by both the AS/NZS 5065 and UNI EN 13476 standard; this is due to the fact that the different stiffness classes are obtained by modifying the rib thickness and not by changing the height and/or the spacing of ribs.

3.3 PRODUCTION

EUROFLO® production is based on a special co-extrusion technology which is shown in figure 3.3.

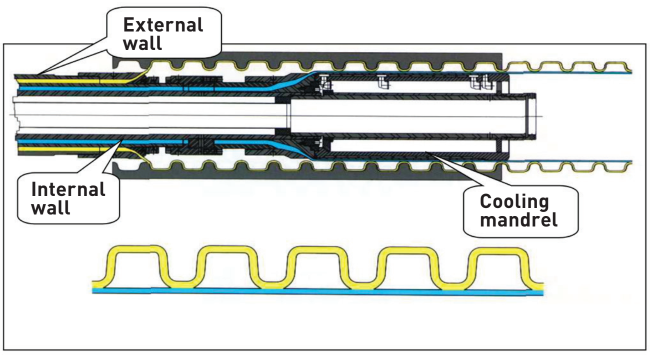


Figure 3.3: Production scheme of corrugated pipe.

The plant includes an extruder head with two concentric dies (where the term "co-extruded" comes from) that release the material, and a group of moving dies (caterpillar movement) that form the external corrugations.

In short, the manufacturing process includes the following phases:

- the grains of polyethylene are conveyed from the storage bins to the hoppers placed on the extruders. The extrusion capacity of the two extruders is different depending on the amount of material used for the two walls; the inner wall corresponds approximately to 2/5 of the pipe overall mass. The plant production capacity is 1200 kg/h with production speed from 3 to 0.3 m/min according to diameter.
- the external die produces a "pipe" which is pushed and sucked by the dies so that the fluid material rests on the internal wall of the die and takes the shape of the corrugation.
- the internal die forms the internal wall of the pipe by extruding a pipe with thickness e5 (refer to figure 3.1) whose circular shape and inside diameter are controlled by the cooling mandrel.
- near the cooling mandrel, the corrugation, which is already formed but still at high temperature, merges with the internal layer. This process allows understanding of how thickness e4 (refer to figure 3.1) is different from the sum of the two walls. The extrusion speed and the die feed speed are calibrated in order to ensure a homogeneous structure with optimal geometrical parameters; the adjusting parameters (speed, die temperature, vacuum degree, air pressure) are controlled by a software while vacuum and air are controlled by special valves.
- the pipe is first cooled by water cooled dies that keep a steady temperature. The pipe is later water cooled and cut at the desired length at the section between the ribs.

4. NORMATIVE REFERENCE

The manufacture of EUROFLO® polyethylene corrugated pipe is subject to the AS/NZS 5065:2005 standard (Polyethylene and polypropylene pipes and fittings for drainage and sewerage applications). Rigorous testing has proven EUROFLO® pipelines to perform well in compliance with this standard.

The standard is divided into five parts and includes appendices as follows:

- Part 1: Scope and General;
- Part 2: Materials;
- Part 3: Performance requirements;
- Part 4: Pipes;
- Part 5: Fittings.
- Appendices A & B

The standard covers information related to two different types of structured-wall pipes:

- Type A1: Sandwich construction or hollow-wall construction with axial hollow sections;
- Type B: A pipe with a plain inside surface and a solid or hollow helical or annular ribbed external surface.

and two different plastic materials:

- PE (polyethylene);
- PP (polypropylene);

Laid out within the standard are clear guidelines and limits on material and pipe classification performance following recognized best practice. Products manufactured to meet this standard hence comply with national and international best practice and can be assumed fit for their intended application.

It is to be noted that special attention should be given to Section 4.1.4 of the standard where information is laid out for pipes of Type B Construction, which EUROFLO® is part of. If at any point it is suspected pipes are not up to standard, important dimensions such as minimum mean internal diameter may be checked against this section of the standard.

Laid out in this normative reference is an overview of the performance of the pipe and it's constituent materials as it relates to the 5065 standard.

4.1 TESTS ON THE MATERIAL

Section 2 of the AS/NZS standard describes required characteristics of materials used to manufacture pipes and fittings, and notes tests to be undertaken to ensure compliance with the standard. Clauses 2.2.1 though to 2.2.10 deal with material requirements such as composition, volatile content, Mass melt flow rate, thermal stability, tensile properties etc. Table 4.1 below presents some requirements of the standard, including prescriptions, parameters and test methods.

Characteristics	Prescriptions	Test parameters		Test method
		Characteristic	Value	
Density	≥ 930 kg/m³	Temperature	(23 ±2)°C	ISO 1183-1
Melt flow rate	0.2g/10min ≤ MFR ≤ 1.1 g/10min	Temperature	190°C	ISO 1133
Thermal stability – Minimum Oxidation Induction time	40 minutes	Temperature	200°C	ISO-11357-6
Environmental Stress Cracking	No failure in less than 24hr	Stress	15% Yield Stress	AS/NZS 1462.25

Table 4.1: Required characteristics of materials of PE pipes and injection molded fittings

4.2 PERFORMANCE REQUIREMENTS

Section 3 of the AS/NZS standard details performance requirements of PE and PP pipes and fittings along with tests to be performed on them. Very concise information is given on thermal stability, ring flexibility and stiffness requirements of pipes, and test requirements on fittings and seals such as hydrostatic pressure, liquid infiltration and stiffness.

4.3 DIMENSIONAL AND APPEARANCE CHARACTERISTICS

Laid out in Section 4 of the AS/NZS standard is the main body of information concerned with the pipes themselves and deals with information like dimensional requirements, marking and freedom from defect requirements.

like the Europeans, the AS/NZS standard categorizes pipes either by the inside or outside diameters so that pipes can be manufactured with nominal inside or outside diameters. The standard prescribes the minimum size of both outside inside diameter (depending on the series), the internal wall thickness and length of couplers/sockets. Many tables are given which cover this information from a range of nominal outside diameters (DN). EUROFLO® is only made to DN/OD range.

As regards the appearance of pipes, the standard prescribes that:

- visible surfaces of pipes shall be smooth, clean and free from grooving, blistering, or any other surface irregularity resulting in defects causing the pipe not to conform with dimensional requirements of the standard;
- the material shall not feature visible impurities or pores
- pipe spigot ends shall be cleanly cut square to the axis of the pipe.

4.4 PERFORMANCE CHARACTERISTICS

Performance of finished EUROFLO® pipeline and fitting products can be explained regarding the following characteristics:

- mechanical;
- physical;
- functional.

These characteristics must be proven by tests which simulate extreme critical situations that may occur during storage, transport or installation in the yard in order to test how pipes behave.

4.4.1 MECHANICAL CHARACTERISTICS

The AS/NZS 5065 requires pipeline products to demonstrate certain mechanical characteristics suchs as ring stiffness and ring flexibility. Table 4.2 below shows the mechanical tests that need to be carried out on the pipes whatever their material.

Characteristics	Prescriptions	Test parameters		Test method
		Characteristic	Value	
Ring stiffness	≥ than classification			AS/NZS1462.22
Creep ratio	≤ 4, at 2 year extrapolation			ISO 9967
Impact strength	TIR ≤ 10%	Type, mass of striker Fall height Test temperature Conditioning medium	See EN 13476-3 (0 ± 1) °C Water/Air	ISO 3127
Ring flexibility	See AS/NZS 5065	Deflection	30% of outside diameter	AS/NZS1462.22

Table 4.2: Mechanical characteristics of pipes

The ring flexibility test made according to AS/NZS 5065 standard, test piece to be subject to deflection at a steady speed to achieve a 30% variation. During and at the end of the test, the test piece must show no cracking in any part of the wall structure, wall delamination, ruptures or delamination.

One of the aims of the test is to check how pipes behave when they are subject to high loads in the yard that may cause excessive deflection. Of course, the resistance of a single length of test piece to these deflections is guaranteed but not the hydraulic capacity of the pipe and, above all, the watertightness of the entire pipe-coupler system. Figure 4.1. shows the test carried out at the external laboratory.

Figure 4.1: Test piece of corrugated pipe DN 315 with 30% deflection of outside diameter

An impact test which has been performed on EUROFLO® pipes as required by the EN standards (AS/NZS 5065 does not require an impact test), consists in transmitting a corrugated pipe test piece an impact energy caused by a beam falling from a predetermined height. Before the test, prepare a number of pipe sections 200 (±10)mm long and subject them to 25 blows along the equidistant lines traced on the test piece. Before the test, the test pieces must be conditioned in a refrigerating room for about two hours at (-10 ±2)°C to keep them at 0°C when moved from the refrigerating room to the machine according to the reference standard. The beam weight varies from 1.0 kg (outside diameters of 160mm) to 3.2 kg (outside diameters greater than 315mm). The beam falls from 2000mm. At the end of the test, the test piece must show no visible signs of settling or cracks that may let water penetrate from inside to outside and vice versa.

This test allows to see how the pipe behaves in case of accidental drop of coarse material during the backfilling stage when installation is made at low temperature.

4.4.2 PHYSICAL CHARACTERISTICS

The physical characteristics of all EUROFLO® componentry are guaranteed by a series of various tests as required by the AS/NZS 5065 as well as European standards. Table 4.3 below gives an overview of these physical tests which must be carried out on polyethylene pipes and fittings. In addition to routine Type Tests, Batch Release Tests are also required by the AS/NZS 5065 in order to prove compliance with the standard. Prescriptions of these tests are covered by sections 3, 4 and 5 of the 5065 standard.

Characteristics	Prescriptions	Test parameters		Test method
		Characteristic	Value	
Resistance to heating - Oven test	≤ 13% pipe shall show no delaminations, cracks or bubbles	Temperature Immersion time Thickness ≤ 8 mm Thickness > 8 mm	(110 ±2) °C 30 min 60 min	Method A of UNI EN ISO 580 (air)
Thermal Stability - Oxidisation	Minimum oxidation inducation time – 10 minutes	Temperature	200 °C	ISO/TR 10837
Dimensional	Characteristics must conform with prescriptions of relevant AS/NZS 5065 and AS/NZS 1462.1 clauses	Dimensions of pipes Effective length of pipes Spigot ends of Pipes Sockets formed on pipe ends Dimensions of fittings	To conform with relevant clauses of AS/NZS 5065 and 1462.1	AS/NZS 1462.1 AS/NZS 5065 Clauses 4.4 and 4.5
Freedom from Defects	Characteristics must conform with prescriptions of AS/NZS 5065 clause 4.6	Freedom from defects	Defects shall not affect performance or function of the pipe in service	AS/NZS 5065 clause 4.6

Table 4.3: Physical characteristics of PE pipes

The oven test, which is carried out according to the ISO 580 standard, consists in cutting a test piece 300 (±20)mm long and then cut it longitudinally in two to four identical parts according to diameter. The sample is put into an oven for 30 minutes if the wall thickness is lower than 8mmor 1 hour if the wall thickness is higher than 8mm at (110 ±2)°C. Once the sample is taken out the oven and cooled at room temperature, all defects, ruptures, bubbles, delaminations or any other faults must be measured. The aim of the test is to see how the outer pipe wall behaves in case of high temperature as it may occur in a yard during summer.

4.4.3 FUNCTIONAL CHARACTERISTICS

Table 4.4 indicates the functional tests which are carried out on plastic structured wall pipes as required by European standards. The test, which is represented in figure 4.2, is carried out to evaluate the watertightness of the system which is composed of a corrugated pipe, a jointing coupler and an elastomeric seal. The standard (EN 1277), according to which the test is made, is the same as for PVC solid wall pipes and generally more comprehensive the the AS/NZS 5065 which gives prescriptions for performance of joints and elastomeric seals refer to test methods from AS/NZS 1462.8 and 1462.13

The test is made at three different pressure levels:

- 0.05 bar corresponding to standard operation;
- 0.5 bar corresponding to a flow rate peak;
- -0.3 bar corresponding to operation with groundwater.

In the first two cases, the test is made visually: after 15 minutes there must be no signs of water leaks; in the third case, after 15 minutes the pressure measured by means of a pressure gauge and displayed on a screen must not be lower than 10% compared to the initial test pressure.

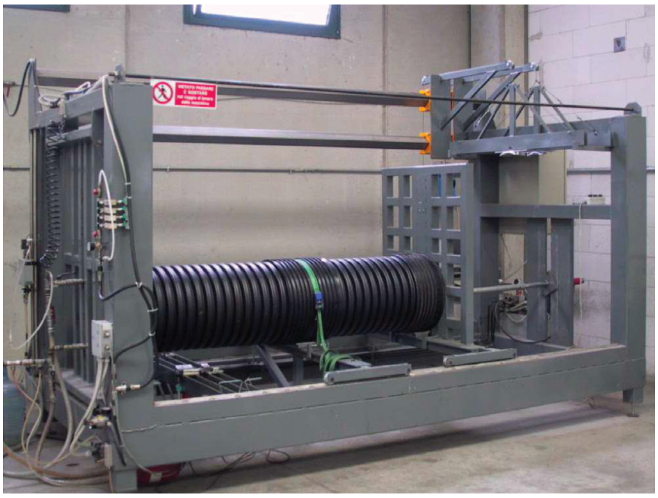


Figure 4.2: Leak test on DN/OD 500 polyethylene corrugated pipe

Characteristics	Prescriptions	Test parameters		Test method
		Characteristic	Value	
Tightness elastomeric seal joint of ring		Temperature	(23 ±2) °C	EN 1277
		Spigot deflection	10 %	Condition B
		Socket deflection	5 %	
		Difference	5 %	
	No leakage	Water pressure	0.05 bar	
	No leakage	Water pressure	0.5 bar	
	≤ - 0.27 bar	Air pressure	- 0.3 bar	
		Temperature	(23 ±2) °C	EN 1277
		Joint deflection for:		Condition C
		De ≤315	2°	
		315 < De ≤630	1.5°	
		630 < De	1°	
	No leakage	Water pressure	0.05 bar	
	No leakage	Water pressure	0.5 bar	
	≤ - 0.27 bar	Air pressure	- 0.3 bar	

Table 4.4: Performance requirements

Tests are made not only on aligned pipe sections but also in the case of:

- a different diameter deflection (equal at 10% of the pipe and 5% of coupler);
- an angular deflection of the system which may vary, depending on diameter, from 1° to 2° to which a value for the angle determined by the pipe manufacturer must be added. P&F Global ensures 1° more for all diameters compared to those provided for by the standard.

The functional tests simulate any irregularity which may be present during installation at the yard such as incorrect alignment of bars or a different load on the pipe and the coupler.

4.5 CONTROL MARKING

Control marking of pipes is in compliance with the AS/NZS 5065:2005 standard. In particular, the following elements are identified on each pipe:

- standard number;
- nominal diameter DN/OD;
- name or trademark of manufacturer;
- class of stiffness (indicated by SN);
- ring flexibility (RF30);
- material PE;
- code of application area (code U for applications outside buildings);
- month, year and factory of manufacture;

Marking can be printed directly on the pipe or applied by labels provided that they are readable as according to type a (durable even when in use).

4.6 PRODUCTION CERTIFICATES AND QUALITY MARKS

Production of EUROFLO® is checked by external and internal laboratories in compliance with EN ISO 9001:2015, EN 13476-3, and AS 5065:2005 standards. For each type or batch of pipes P&F Global draws up an inspection report of the finished product that includes the test results of:

- dimensional checks (made on inside diameter, outside diameter and "e_5" internal wall thickness);
- resistance to deflection according to AS/NZS 1462.22 for determining ring stiffness;
- flexibility test with 30% deflection and checking the absence of defects and cracking;
- resistance to impact and checking the absence of cracking or breakage;
- heat test with detection of defects or separations of layers.

Additional tests as required are carried out during production of EUROFLO products. Test records are validation during annual third-party certification audits.

4.7 TECHNICAL SPECIFICATIONS

Designers, contractors, public or private customers who have to prescribe or buy a pipe for drainage systems must draw up comprehensive specifications to identify the characteristics of the desired pipe which include, in addition to the prescriptions on raw materials, the other parameters which are typical of the pipe.

The typical specifications for structured wall pipes such as EUROFLO® standardized on the outside diameter are as follows.

High density polyethylene co-extruded twin-wall pipe, smooth and grey internally and corrugated and black externally for non-pressure underground drainage pipes, are manufactured in compliance with AS/NZS 5065:2005, and are provided in stiffness classes SN 8. They are produced in 5.8 meter lengths with jointing by means of an HDPE coupling, PIIP, and EPDM lip seal. The pipe must be manufactured by an ISO 9001:2015, ISO 14001:2015 and ISO OHSAS 18001:2018 certified company and must have the following features:

- Nominal outside diameter OD minimum inside diameter ID (-> to the minimum according to reference standard).
- SN ring stiffness measured on product test pieces according to AS/NZS 1462.22.
- Resistance to abrasion tested in compliance with EN 295-3 standard.
- Watertightness of jointing system certified at 0.5 bar under pressure and
- 0.3 bar negative pressure for 15 minutes according to EN 1277 standard.

5. CALCULATIONS

5.1 HYDRAULIC CALCULATIONS

5.1.1 HOW TO CALCULATE PIPE FILLING FLOW RATE

To calculate the flow rate of a pipe operating with a free water surface flow, the steady motion formula is generally used and in particular, the Chézy formula:

$$v = \chi\sqrt{R \cdot i}$$

where

v medium speed of fluid in m/s;

x coefficient of conductance which depends on relative roughness e/R, on Reynolds (Re) number and on the section shape;

R hydraulic radius defined as the ratio between the surface of the flow section (A) and the profile of it touching the channel (P);

i slope in m/m.

In case of a circular pipe, A and P are expressed by the following formulae with variables as defined in Figure 5.1 below.

$$A = r^2 \cdot cos^{-1}[\frac{r-h}{r} - (r-h) \cdot \sqrt{2rh - h^2}]$$

$$P = r[\frac{\pi}{90} \cdot cos^{-1}\left(1 - \frac{h}{r}\right)]$$

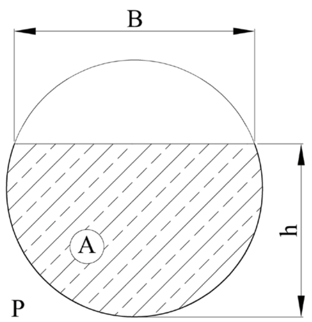


Figure 5.1: Geometrical quantities for flow rate calculation

In the case of deflection of plastic pipes, the resulting ellipsoid area decreases compared to the area of the initial circle; the perimeter being unaltered, the hydraulic radius decreases proportionally. Hydraulically speaking, a deflection within the admitted limits of 5-6% is negligible for flow resistance. Therefore, it can be reasonably said that flow parameters are unaltered even in the case of small deflections.

In the case of an eddy flow, the coefficient of conductance does not depend on the Reynolds number and can be expressed by empirical formulae for which this coefficient is related to the coefficient of roughness and the hydraulic radius.

Among all the formulae, those mostly used are:

a) Bazin

$$\chi_B = \frac{87}{1 + \frac{\gamma}{\sqrt{R}}}$$

b) Gauckler-Stricker

$$\chi_{GS} = K_S\sqrt[6]{R}$$

where γ and KS are parameters connected with pipe roughness.

Therefore:

$$v_B = \chi_B\sqrt{R \cdot i}$$

$$v_{GS} = \chi_{GS}\sqrt{R \cdot i}$$

In practice, the choice of one formula instead of another is of less importance than the definition of roughness. To define this parameter refer to section 5.1.3.

5.1.2 HOW TO CALCULATE SOLID PIPE FLOW RATE

In drainage systems, it is sometimes necessary to also test the pipes under pressure such as in the case of flow rate peaks, heavy rain, traps used for crossovers or outlet pipes of pumping systems.

In this case, the pressure drop per unit of length of pipe is expressed by the following formula:

$$J = \frac{\lambda \cdot v^2}{2 \cdot g \cdot D_i}$$

The dimensional friction coefficient λ depends on the relative roughness of the pipe and on the Reynolds number. In the case of eddy flows, the coefficient is generally expressed by the Prandtl-Colebrook equation:

$$\frac{1}{\sqrt{\lambda}} = -2 \cdot \log\left[\left(\frac{2.51}{R_e \cdot \sqrt{\lambda}}\right) + \left(\frac{k}{3.71 \cdot D_i}\right)\right]$$

where:

$Re = v\ Di/\nu$	Reynolds number;
Di	inside diameter in m;
v	medium speed in m/s;
ν	kinematic viscosity of the fluid at operating temperature (for water ν varies from $1.52 \cdot 10^{-6}$ m²/s at 5°C and $0.661 \cdot 10^{-6}$ m²/s at 40 °C).

For drainage systems, except in special cases, the density used is $\gamma = 999 \approx 1000$ kg/m3 and kinematic viscosity ν = 1,142 ·10-6 m²/s (corresponding to 15 °C).

Based on the two above-mentioned formulae, the speed can be calculated by the following formula:

$$v = 2 \cdot \log\left[\left(\frac{k}{3.71 \cdot D_i}\right) + \left(\frac{2.51}{D_i \cdot \sqrt{2 \cdot g \cdot D_i \cdot J}}\right)\right] \cdot \sqrt{2 \cdot g \cdot D_i \cdot J}$$

Therefore flow rate is:

$$Q = \frac{V \cdot \pi \cdot D_i^2}{4}$$

5.1.3 PIPE ROUGHNESS

In the hydraulic field, one subject for discussion has always been the roughness value to be applied in the formulae for calculating the flow rate mentioned in the preceding sections.

When the material is new, the roughness characteristics are unimportant; as time passes by, a biological slime layer grows on the bottom and the walls of the pipe which, together with deposits, determines the hydraulic roughness of the piping system. The increase of roughness due to the use, which occurs in all materials, depends on organic substances adhering to the pipe walls and, above all, on flow rate speeds.

Each manufacturer declares its pipes are "smooth" with very low roughness. Table 5.1 shows a partial example of different values for coefficient k, which are supplied by several sources.

Material	Low or 'smooth' (mm)	High or 'rough' (mm)
Steel	0.01	0.1
Cast iron	0.01	1
Cast iron with bitumen or cement coating	0.03	0.2
Plastic materials in general	0.01	0.1
HDPE	0.007	0.5
New centrifuged cement	0.03	
New smooth cement	0.2	0.5
New coarse cement	1	2
Stoneware	0.1	1

Table 5.1: Variability of roughness coefficient

By examining the table we can conclude that even for the same materials there are different points of view and the values are often suggested without indicating their application limits and without considering natural aging and deterioration of operating pipes. The designer should therefore correctly consider the operating conditions and, above all, in case of a comparison among several materials, choose homogeneous sizes.

The same variability can be found in the international regulations: Austria: OWWV - R5 (Directives for drainage hydraulic calculation):

k = 0.4 ÷1.0 mm for long pipes;

k = 1.0 mm for long conveying pipes;

k = 1.5 mm for normal pipes

Switzerland:	SIA 190 and Doc. 38 - Ducts
	k = 0.1 mm for smooth plastic pipes; k = 1.0 mm for rough cement pipes
France:	Instruction techniques relative to urban sanitation networks
	The Bazin formula is used, with k between 0.16 and 0.46 mm
England:	Code of Practice CP 2005, Drainage
	It provides the "Charts for the Hydraulic design of Channels and pipes" with k = 0.003≈60 mm. The designer is responsible for choosing the value.
Germany:	ATV 110, k = 0.25 mm for rainwater and linear drainage systems and k = 0.5 mm for drainage systems with foul wastewater or drainage systems with manholes or special components, it being understood that the localized flow resistance must be added when calculations are made.

By keeping in mind the prescriptions of the American Society for Testing Materials (ASTM) and Water Pollution Control Federation (WPCF), the values of roughness parameters suggested for drainage systems are indicated in table 5.2.

Material	Colebrook ε (mm)	Gauckler-Stickler K_s ($m^{1/3}\ s^{-1}$)
Concrete with smooth formworks	0.3 - 1.5	90 - 70
Concrete with rough formworks	1.5 - 6	70 - 60
Brick masonry		
Concrete pipes	0.3 - 3	90 - 67
Stoneware pipes		
Plastic pipes		
Cast iron pipes		
Asbestos cement pipes		

Table 5.2: Coefficients of roughness

For EUROFLO® a conservative number to use for Colebrook is 0.6 and for Gauckler-Stickler 80. All plastic pipes should use the same value.

The table below shows the predefined values of Gauckler-Stickler KS parameter used by the calculation programme MOUSE by the Danish Hydraulic Institute to simulate the hydraulic behaviour of drainage systems. This calculation programme separately measures flow resistance when inspection manholes, merging and direction change are present.

Material	Gauckler-Stickler K_s ($m^{1/3} s^{-1}$)
Smooth concrete	85
Normal concrete	75
Rough concrete	68
Stoneware pipes	80
Plastic pipes	
Cast iron pipes	70
Asbestos cement pipes	

Table 5.3: Coefficients of roughness used by the software MOUSE

5. 2 STATIC CALCULATIONS

Along with hydraulic tests, flexible pipes must be subject to static tests. In particular, it must be checked that the selected pipe is laid according to the project instructions and is not subject to excessive deflection. This section focuses on presenting examples of static calculations based on European methods and it should be noted that AS/NZS 2566.1:1998 Buried Flexible Pipes, Part 1: Structural Design, contains further static calculation requirements in the design of pipe systems within New Zealand and Australia.

Pipe stiffness can be said to generally depend on the native ground condition, the embankment material in the area surrounding the pipe and its compaction, the covering height, the load conditions and the pipe limits. Structural calculations as shown in the following pages may be applied in determining the appropriate pipe stiffness and deflection values of certain pipes under certain loading and site conditions. Results should be compared with and evaluated against requirements of the AS/NZS 2566.1 Standard.

Table 5.5 below gives and indication of the minimum suggested stiffness class for pipes installed in traffic areas depending on the embankment material and the covering thickness. Note that only class SN8 is available in New Zealand.

For cover refer to ASNZS2566.1 However table 5.5 is what should be worked to for best practice.

Embankment material group	Class of compaction[2]	Pipe stiffness[1]					
		Undisturbed native ground group					
		1	2	3	4	5	6
		For covering thickness ≥ 1m and ≤ 3m					
1	W	4	4	6.3	8	10	**
2	W	-	6.3	8	10	**	**
3	W	-	-	10	**	**	**
4	W	-	-	-	**	**	**
		For covering thickness ≥ 3m and ≤ 6m					
1	W	2	2	2.5	4	5	6.3
2	W	-	4	4	5	8	8
3	W	-	-	6.3	8	10	**

1) Specific ring stiffness

2) W (good) maximum class of compaction

**) structural project needed to determine the trench details and the pipe ring stiffness

Table 5.5: Minimum ring stiffness suggested for traffic areas Soils are divided in three types (granular, cohesive and organic soils) and six sub-groups as shown in table 5.6. Organic materials (group 5 and 6) must not be used as backfilling.

Soil group	Type of soils		
		Name	Example
granular soil	1	Single-size gravel, highly screened gravel, mix of gravel and sand, mix of poorly- screened gravel and sand.	Crushed rock, river gravel, morainic gravel, volcanic ashes
	2	Single-size gravel, mix of sand and gravel, mix of poorly-screened gravel and sand.	Dune sand and alluvial deposits, morainic gravel, coast sand
granular soil	3	Gravel with silt, gravel with clay, sand with silt, sand with clay, poorly-screened mix of gravel, silt and sand	Gravel with clay, sand with soil, alluvial clay
cohesive soil	4	Inorganic silt, fine sand with silt and clay, inorganic clay.	Soil, alluvial marl, clay
organic soil	5	Organic silt, clayish organic silt, organic clay, clay with organic mix	Superficial layer, tufa sand, sea limestone, mud, soil
organic soil	6	Peat, other highly organic soils, sludge	Peat, sludge

Table 5.6: Types of soils

The class of compaction is defined depending on the compaction degree expressed in Proctor (SPD) reference density according to the different types of materials, as shown in table 5.7.

Class of compaction	Embankment material group			
	4	3	2	1
N (not)	75÷80 %	79÷85 %	84÷89 %	90÷94 %
M (moderate)	81÷89 %	86÷92 %	90÷95 %	95÷97 %
W (well)	90÷95 %	93÷96 %	96÷100 %	98÷100 %

Table 5.7: Proctor index for the different classes of compaction

Two other methods are later described which are used for the static tests on the pipe: the Spangler method and the method provided for by ATV German standard.

5.2.1 SPANGLER METHOD

The analysis of flexible pipe-soil structural system has been developed at the University of Iowa, by Spangler and Marston. Based on the later studies made by Barnard and others, the Spangler formula has been changed into the universally known formula used to calculate the flexible pipe deflection.

The modified Spangler formula is the following:

Deflection = (load on pipe)/(pipe stiffness + soil stiffness): and is calculated with the following formula:

$$\Delta_v = \frac{(d_1 \cdot p_o + p_t) \cdot K_X}{8 \cdot SN + 0{,}061 \cdot E'}$$

where:

Δ_v deflection, in m

d_1 self-compacting factor (1.5 for moderate compactions and 2 for medium compactions with limited covering height)

p_o soil load, in N/m

p_t load due to traffic, in N/m

K_x bedding factor

SN long-term ring stiffness, for diameter, in Pa

E' secant modulus of soil, in Pa

The formula does not contain the data concerning the trench which affect the calculation of the load. In the case of a narrow trench excavation (B ‹ 3De and B ‹ H/2), the ground load weighing on the pipe unit of length can be calculated by the following formula:

$$p_0 = C \cdot \gamma_t \cdot D_e \cdot B \quad \text{in N/m}$$

where:

C coefficient of ground load

γ_t specific weight of filling material weighing on the pipe, in N/m3

D_e pipe outside diameter, in m

B width of excavation measured on the top of the pipe, in m

In the following formula:

$$C = \frac{1 - e^{\left(\frac{-2 \cdot K \cdot \mu \cdot H}{B}\right)}}{2 \cdot K \cdot \mu}$$

where:

H covering height measured on the top of the pipe, in m

μ coefficient of friction between the filling material and the excavation sidefill material

K (1– sinφ)/(1+ sinφ) = Rankine coefficient, where φcorresponds to the internal angle of friction of the embankment.

φ changes depending on the type of soil as is shown in table 5.8.

Type of soils	φ
non-cohesive soil	35°
slightly cohesive soil	30°
mixed cohesive soil	25°
cohesive soil	20°

Table 5.8: Data on coefficient φ

In the case of “wide trench or embankment”, the total load weighing on the pipe (prismload) is expressed as:

$$p_0 = \gamma_t \cdot D_e \cdot H$$

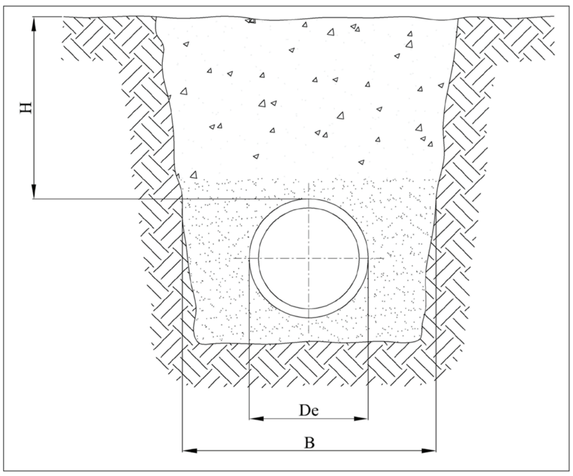


Figure 5.1: Elements for calculating deflection

The surface load pt includes load Qs caused by the structures resting on the trench (foundations, walls, etc.) and load Qt caused by traffic. The formula is derived from the Boussinesq theory through which the vertical stress caused by a surface load in any point under the surface:

$$\sigma_z = \frac{3 \cdot Q}{2 \cdot \pi \cdot H^2} \cdot \left[\frac{1}{1 + \left(\frac{r}{H} \right)^2} \right]^{\frac{5}{2}}$$

where:

σ_z = vertical stress, in Pa;

Q = total surface load = $Q_t + Q_s$, in N

H = covering height, in m

r = horizontal distance from load point, in m

The stress is also distributed on a width corresponding to the horizontal diameter of the pipe and of a unit length. The P_t unit load is then:

$$p_t = \sigma_z \cdot D_e \qquad \text{in N/m}$$

In the case of a load applied on the pipe vertical line, with a maximum stress, r = 0 and so the unit load for length unit is

$$p_t = \frac{3 \cdot Q \cdot D_e}{2 \cdot \pi \cdot H^2} \qquad \text{in N/m}$$

The loads Qt caused by traffic are shown in table 5.9.

Load class	Total load Q (kN)	Load per wheel Q (kN)
Heavy traffic	600	100
Medium traffic	450 300	75 50
Light traffic	120 60	20 20
Cars	30	10

Table 5.9: Loads from traffic

The p_t load can be permanent or occasional; generally, it is considered as permanent though practically speaking, it should be considered as occasional (except in case of a car park) and so able to cause elastic reactions such as stress and deflection. In fact, the traffic load can result in settling caused by cyclic stress (which, in stiff pipes, may turn into fatigue failure) and not for overcoming of allowable stress and deflection. Considering the Q_t load as permanent, like in the formula, is a matter of safety for plastic materials.

As you can see from the formulae, the load p_t decreases with the square of the covering depth and it is therefore prevailing compared to ground load with covering heights lower than 1.5 - 2m. Table 5.10 and the diagram in figure 5.2 show an example of how ground loads, traffic loads and total loads change depending on the covering height. As can be seen, the effects of traffic load decreases as covering increases.

The following data have been considered:

- EUROFLO® pipe diameter: 800mm
- stiffness class: SN8 kPa
- trench width: 1.8m
- filling: sand (γ= 17.2 kN/m3; μ= 0.75; K = 0.25; φ= 0.33°)
- traffic load: Q_t = 100 kN

H (m)	0.5	1	2	3	4	5	6	7
P_o (kN)	6.5	12	23	31	37	43	47	51
P_t (kN)	153	38	10	2.2	2.4	1.5	1.1	0.8
P_{tot} (kN)	159	51	32	35	40	44	48	52

Table 5.10: Loads depending on covering height

LOAD DIAGRAM

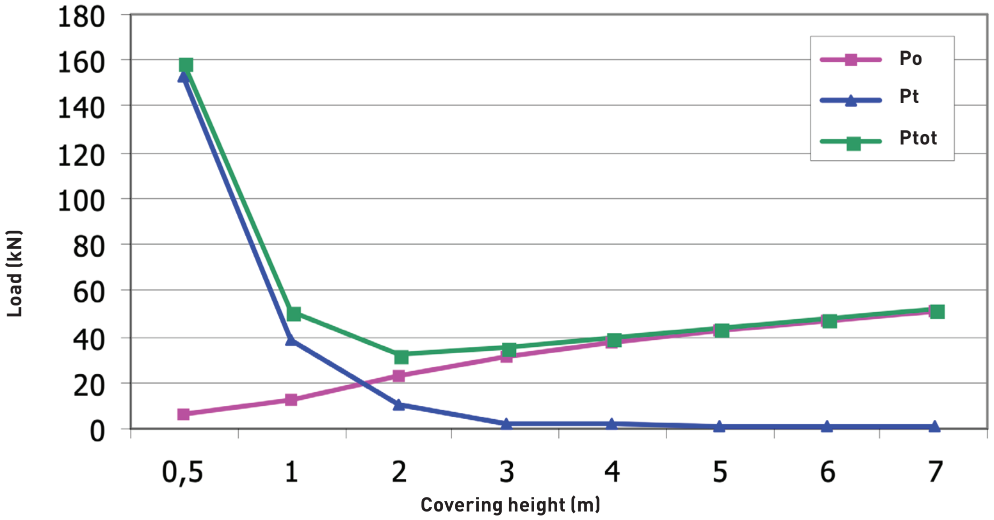


Figure 5.2: Diagram of loads depending on covering height

The formula used to calculate deflection contains the section modulus of soil or secant modulus, E' = e r where "e" is the modulus of elasticity of soil and "r" is the pipe radius. E' is a constant for all pipe diameters and depends on the type of soil and its compaction degree. The classification generally used for defining this material is the same as used by the ASTM 2487 American standard shown in table 5.11.

	Material in bulk	Compacted material		
Proctor index		<85%	85÷90%	>95%
Relative density		<40%	40÷70%	>70%
Type of soil	E' (N/mm²)			
Small particle size soil LL > 50	0	0	0	0.35
Medium and high plasticity soils	(careful analysis recommended)			
Small particle size cohesive soil LL > 50. Medium and low plasticity soils with less than 25% of coarse particles.	0.35	1.38	2.76	6.9
Small particle size soil LL > 50. Medium and low plasticity soils, with more than 25% of coarse particles. Coarse particle size soils with more than 12% of fine particles	0.69	2.76	6.9	13.8
Coarse particle size soil with less than 12% of fine particles	0.69	6.9	13.8	20.7
All-in aggregate (crushed rock)	6.9	20.7	20.7	20.7
Accuracy in terms of difference between calculated and real deflection (in %)	±2%	±2%	±2%	±0.5%

Table 5.11: Values of the soil section modulus

The lower values in the table are generally used for calculating the initial deflection as compaction is greater on a long and medium term due both to pedestrians crossing the excavation area and the soil self-compaction under its weight. For the long-term deflection the (lag factor) dl.is applied. In any case, we need to consider that the compaction degree, and so E', increases in time.

The formula used contains a load multiplier p (total load) a steady increment factor of the load itself, the deflection constant, corresponding to 1.5. ASTM applies only to p0, the "lag factor" corresponding to 1.5 but suggests to use 2 in case filling is made with loose materials.

Kx, the bedding factor, which is contained in the numerator of the deflection formula is connected with the supporting angle as shown in figure 5.3. The values of the constant Kx, depending on the supporting angle, are shown in table 5.12.

Angle 2ϑ	0°	90°	120°	180°
Kx	0.110	0.096	0.090	0.083

Table 5.12: Values of bedding factor depending on the supporting angle.

As the angle increases, the value of the constant, and so the deflection, decreases. Kx values can be interpolated linearly. The decrease of deflection between the punctual support and the maximum support is 24.5%. For all flexible pipes (but also for stiff pipes for which support is very important) it is advisable to create a bedding to reach a supporting angle between 90° and 120°. The maximum support can be obtained by careful compaction of side fill up to 30 cm above the top of the pipe.

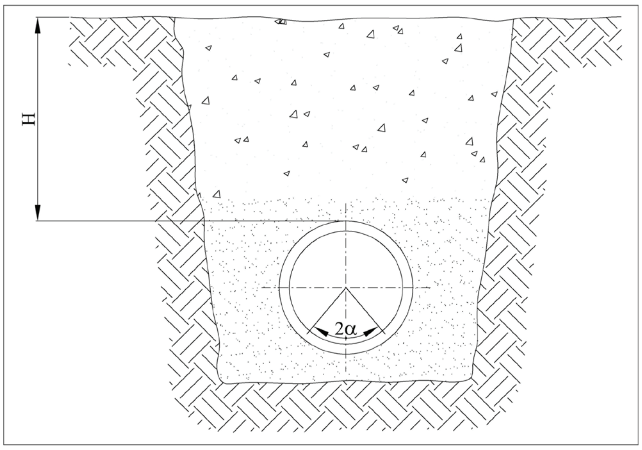


Figure 5.3 Identification of supporting angle

5.2.2 METHOD ATV-DVWK-A 127E

The most complete calculation method used for static tests on drainage pipes in Europe is the method suggested by ATV-DWK-A 127 E (Static Calculation of Drains and Drainages) which was developed in August 2000. This method takes into account all the situations that may be encountered in practice: the various types of materials used for covering, the compaction conditions of the material covering the pipe and the backfilling. It follows a description relating to the formulae used to calculate deflection and buckling pressure.

The linear deflection of the pipe Δd_v is calculated with the following formula:

$$\Delta d_v = \frac{c_{v,qv} \cdot q_v + c_{v,qh} \cdot q_h + c_{v,qh*} \cdot q_h^*}{S_R} \cdot 2r_m$$

where:

c_v coefficient of deflection;

q_v vertical load from ground load, from the load of any static load on the soil and from the dynamic load from traffic;

q_h, q_h*side loads;

S_R pipe stiffness;

$2r_m$ mean pipe diameter.

The percentage deflection δ_v can be calculated as follows:

$$\delta_v = \frac{\Delta d_v}{2 \cdot r_m} 100 \quad \text{in } \%$$

The aim of the calculation is to check if the long-term deflection is lower than the 6% limit indicated by ATV.

The vertical load qv is calculated by the following formula:

$$q_v = \lambda_{PG} \cdot p_E + p_v = \lambda_{PG} \cdot (\kappa \cdot \chi_B \cdot h + \kappa_0 \cdot p_0) + p_v \quad \text{in kN/m}^2$$

where:

λ_{PG} concentration factor around the pipe depending on the trench width compared to the pipe (suitable for a narrow trench);

κ, κ_0 reduction factors from the theory of the storage bin;

χ_B specific weight of ground surrounding the pipe, in kN/m3;

h covering height, in m;

p_0 static load on the soil, in kN/m²;

p_v load due to traffic, in kN/m²

The side pressure q_h is calculated by the following formula:

$$q_h = K_2 \cdot \left(\lambda_B \cdot p_E + \chi_B \cdot \frac{d_e}{2} \right) \quad \text{in kN/m}^2$$

where:

q_h pressure due to the presence of material on the pipe sides;

K_2 constant that compensates the different approaches to the linearization of experimental data which take into account the system stiffness;

λ_B concentration factor that takes into account the ratio between the trench width and the pipe diameter;

p_E vertical pressure caused by surface loads;

χ_B specific weight of ground in kN/m3.

The side pressure of reaction of bedding q_h* is calculated as follows

$$q_h^* = \frac{c_{h,qv} \cdot q_v + c_{h,qh} \cdot q_h}{V_{RB} - c_{h,qh}^*} \quad \text{in kN/m}^2$$

where:

$$V_{RB} = \frac{S_R}{S_{Bh}} \quad \text{with } S_{Bh} = 0{,}6 \cdot \xi \cdot E2$$

C_{h1}, C_{h2} coefficients of deflection depending on the supporting angle;

V_{RB} stiffness of the system which is given by the ratio between pipe stiffness and the horizontal stiffness of bedding;

ξ correction factor of the horizontal stiffness of bedding.

Beside deflection tests, sometimes also the resistance to buckling needs to be tested or the pipe burst pressure; in particular, this must be done when the pipe is free, as in the external plants where the pipe head is free or when cement agglomerates are used during the initial phase of pipe covering.

The safety factor for analysing pipe stability is given by the ratio between the critical buckling pressure and the vertical load:

$$\chi = \frac{\text{crit } q_v}{q_v}$$

where:

$$\text{crit } q_V = 2 \cdot \kappa_{v2} \cdot \sqrt{S_R \cdot S_{Bh}}$$

Instability tests are much more important in the case of external pressure due to the hydrostatic head of groundwater. In this case, the safety factor is calculated as follows:

$$\chi = \frac{\text{crit } p_e}{p_e}$$

where:

$$\text{crit } p_e = \kappa_e \cdot \alpha_D \cdot S_R$$

where α_D is the penetration coefficient, depending on values VRB and rm/s as shown in figure 5.4.

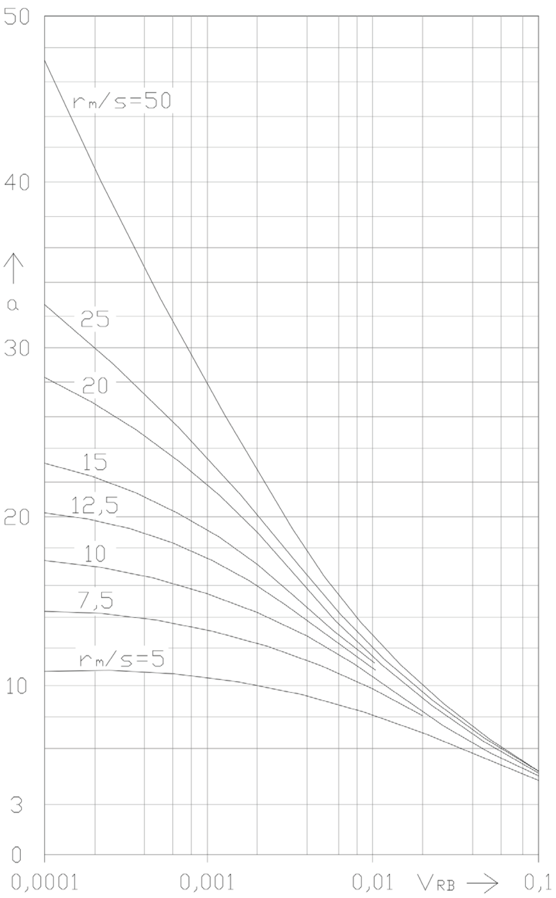


Figure 5.4: Penetration coefficient

The external water pressure is the hydrostatic pressure for the pipe axis

$$p_e = \chi_w \cdot h_w$$

The simultaneous action exerted by the vertical load and the water external pressure allows to define the coefficient of safety depending on buckling, which is calculated by the following formula:

$$\chi = \frac{1}{\frac{q_v}{\text{crit } q_v} + \frac{p_e}{\text{crit } p_e}}$$

In high density polyethylene pipes, the coefficient must be higher than 2.5.

5.2.3 METHOD OF CALCULATION

Here is a guide to the calculation used. It indicates all the variables that must be introduced in the programme, their dimensions, their units of measure and notes (if any). The example concerns the pipes series DN/OD; these same indications also apply to EUROFLO® pipes standardized on the inside diameter.

1. Outside diameter, in mm

DN	250	315	400	500	630	800	1000	1200
De	250	315	400	500	630	800	1000	1200

Table 5.13: Outside diameters of pipes

2. Moment of inertia of wall, in cm4/cm

DN	250	315	400	500	630	800	1000	1200
J_4	0.138	0.254	0.523	1.009	1.984	4.069	7.823	15.376
J_8	0.275	0.552	1.107	2.007	4.034	8.460	15.942	28.557

Table 5.14: Moments of inertia of pipes

J_4 and J_8 refer to the pipes classified with nominal stiffness SN 4 and SN 8 kN/m_2 respectively. The moments of inertia have been measured based on the real production profile.

3. Covering height of pipe on top of the pipe, in m

The German ATV standard does not indicate the covering height for static loads while the minimum covering height for dynamic loads is 0.6m, according to EN 1295/2 and EN 1046 standards. The French standard Number 70 indicates 0.8m as the minimum value.

4. Trench width near the upper pipe top, in m

The calculation programme indicates that the maximum width of the trench must be four times the outside diameter of the pipe and assumes vertical excavation walls.

5. Supporting angle at excavation bottom, in degrees

For EUROFLO® we suggest using 180°. This value is used for a filling of at least 30cm on the top of the pipe and with a workmanlike compaction.

6. Road loads, in kN

Three types of motor vehicles are considered, which are classified according to the weight and bearing area of wheels, as shown in table 5.15.

Standard vehicle	Total load	Load per wheel	Bearing area per wheel	
	kN	kN	Width in m	Length in m
HLC 60	600	100	0.6	0.2
HLC 30	300	50	0.4	0.2
HGV 12	120	40 rear	0.3	0.2
		20 front	0.2	0.2

Table 5.15: Road loads according to the type of vehicle

7. Modulus of elasticity, in N/mm2

ATV provides for two options to calculate deflection: one is based on the modulus of elasticity of the material and the other is based on the nominal stiffness of the concerned pipe. The programme Ecocalc is based on the first option. The modulus of elasticity is the ratio between the stress applied and the deflection in the linear part of the deflection. According to ATV, the value of high density polyethylene is 800 N/mm2 on a short term and 200 N/mm2 on a long term (50 years). As to polypropylene with a high modulus of elasticity, a value such as 300 N/mm2 can be used on a long term.

8. Load uniformly distributed on the pipe, in kN/m²

The loads which are distributed uniformly on the pipe are due to the accumulation of loose materials or temporary buildings.

9. Groups of soils

The filling soils are classified in 4 groups (G1 to G4) as set out in table 5.16 below. The modulus of elasticity of each group depends on the degree of compaction and the internal friction angle of the ground. Table 5.16 shows the specific weights, the friction angle and the secant modulus ES for the different groups depending on the degree of compaction of the soil.

Groups of soils	Specific weight kN/m3	Friction angle	Modulus ES according to Proctor index in N/mm2					
			85%	90%	92%	95%	97%	100%
G1	20	35°	2.0	6	9	16	23	40
G2	20	30°	1.2	3	4	8	11	20
G3	20	25°	0.8	2	3	5	8	13
G4	20	20°	0.6	1.5	2	4	6	10

Table 5.16: Secant modulus depending on the type of soils

Soils are classified depending on their position with respect to the pipe:

E1: covering ground on the pipe;

E2: filling soil surrounding the pipe;

E3: existing soil near the covering and filling ground surrounding the pipe;

E4: soil under pipe bedding.

Figure 5.5 shows the different types of soil.

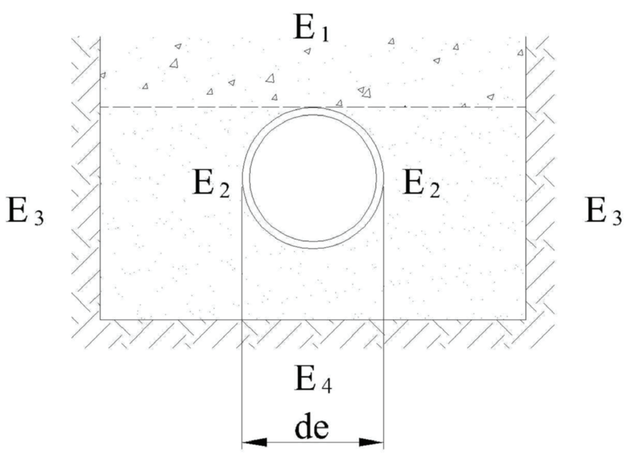


Figure 5.5: Identification of the different types of soil

10. Backfilling conditions

The backfilling conditions are four (from A1 to A4) and are characterised by the different ways of filling the trench on the pipe.

	Description
A1	Backfilling is compacted in layers on the natural soil without checking the degree of compaction. It is also used when portable sheet piles are used.
A2	Vertical covering sheet piles of the trench which are progressively extracted during filling. Backfilling is not compacted. Washing-in of the backfill (suitable for soils of Group G1 only).
A3	Vertical covering sheet piles of the trench extracted after compaction.
A4	Backfilling is compacted in layers on the existing natural soil and degree of compaction is checked as provided for by ZTVE-StB. Backfilling condition A4 is not applicable to soils of Group G4.

Table 5.17: Types of backfilling.

11. Condition of covering soil (soil surrounding the pipe).

The conditions of the covering soil are four (from B1 to B4) and are characterised by different stratifications around the pipe.

	Description
B1	The material is compacted in layers without measuring the degree of compaction.
B2	Covering made by means of sheet piles and compaction made after their removal.
B3	Covering made by means of sheet piles and compaction made before their removal.
B4	The material is compacted in layers on the natural soil and degree of compaction is measured. This condition is not applicable to soils of Group G4.

Table 5.18: Types of covering soils.

5.2.4 EFFECTS OF TRENCH ON DEFLECTION

All methods used to calculate a deflection in a pipe subject to external loads are based on one key element: the trench width. In the same conditions, the lower the trench width the higher the resistance to deflection of a pipe subject to loads.

By convention, the value of trench width is measured near the upper pipe top. If there is no heavy stress, deflection in flexible pipes occurs on the horizontal surface through the axis where the "supporting" reaction takes place, which is due to backfilling and the trench walls. Nevertheless, reference is made to the upper pipe top for the sidefill to be taken into account, in terms of side pressure, which is distributed along the entire height of the pipe.

As regards the trench classification, the ATV standard indicates as 4De the limit between a narrow trench and a wide trench or embankment; they have also been defined as shown below:

narrow trench $B < 3De < H/2$

wide trench $3De < B < 10De < H/2$

embankment $B \geq 10De > H/2$

The deflection change is not depending on trench width. In particular, the calculation for a wide trench/embankment leads to values which are higher both than those corresponding to B = 4De and B = 10De. The concept on which this limit is based, which also involves a different calculation, is that for distances a number of times greater than the pipe diameter the trench side is not reacting together with the backfilling while the load of the surrounding soil is exerted which can be compared to a hydrostatic load. Practically speaking, it is assumed that the only reaction comes from the horizontal component of the weight of the surrounding soil.

Figure 5.6 clearly shows how the excavation width affects deflection, conditions being equal. In this case, we have examined an EUROFLO® DN/OD 800 pipe placed 2 m deep and subject to heavy loads; the covering material used is the same excavation material (G3). As the trench width is increased, the percentage deflection increases with an asymptotic trend. If the material surrounding the pipe (G3) is replaced with a material of a better quality (G1), the deflection decreases as the trench width increases.

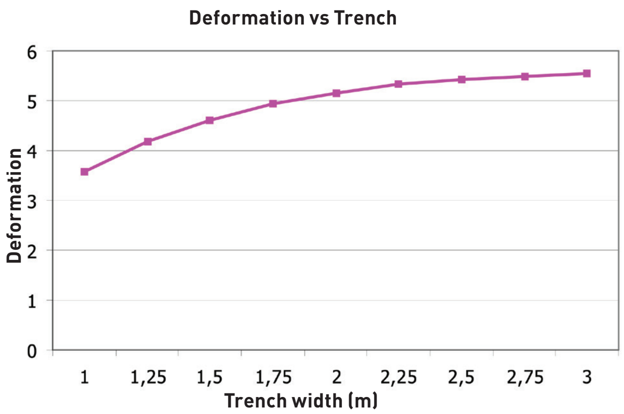


Figure 5.6: Effects of the trench on deflection

5.3 CURVATURE RADII AND BENDING MOMENTS

To calculate the curvature radii, it can be assumed that thickness reacting at the bending moment is the welding thickness of the two walls (e4); in this case, the minimum curvature radius can be determined as shown below:

$$R = \frac{E \cdot D_m}{2 \cdot \sigma}$$

where:

R = curvature radius, in m

E = modulus of elasticity of the material, in Pa

$D_{m(e4)}$ = mean diameter, in m

σ = applied stress, in Pa.

The theoretical curvature radii so obtained are 13 to 14 times the diameters. It is important to point out that the rib does not allow to reach the theoretical value. R values generally suggested for EUROFLO® are 40/50 diameters.

5.4 OVERHANGING PIPES

In overhanging pipes, the distance of supports has to be fixed to avoid the maximum deflection is exceeded in time. As polyethylene is a viscoelastic material, the part of overhanging pipe is subject to deflection in time; therefore, it is necessary to calculate the deflection value generated during operation, based on the distance from supports and the creep modulus of elasticity. The distance between the supports may also change depending on the heat conditions of EUROFLO®.

Deflection is calculated on an EUROFLO® pipe fixed at its ends and subject to a load distributed uniformly which is represented by the weight of the fluid being conveyed. The deflection obtained on the centre line is expressed with the following formula:

$$f_{\max} = \frac{1}{384} \frac{W_{tot} l^4}{E_c J}$$

where:

W_{tot} = overall load on pipe in N/mm

l = distance between supports in mm

E_c = flexural modulus of elasticity in N/mm^2

J = transversal moment of inertia of the pipe in mm^4/mm

The deflection value adopted should not be higher than 3% of the distance between supports. Supports must always be placed near the connecting couplers or the slip couplers so that the pipe can freely move.

6. USE AND INSTALLATION

A correct installation is, together with the quality and characteristics of the material, one of the key aspects of the final results. This section describes different types of connections of EUROFLO® pipes (couplers and seals or welds), general instructions for correct installation and instructions for making tests. It is noted that these instructions are for general reference only and all installations of EUROFLO® products within New Zealand must be performed in compliance with guidelines and perspcriptions given in AS/NZS 2566.2-2002.

6.1 CONNECTION BY COUPLERS

The characteristics of jointing couplers manufactured for P&F Global (length and thickness) are in compliance with the AS/NZS 5065:2005 standard. These are high-density polyethylene products made by injection molding up to DN/OD 630 and by rotomolding starting from DN/ID 600.

The most important geometrical element of the coupler is the inside diameter which must be in compliance with the outside diameter of the EUROFLO® pipe. P&F Global coupler lengths are remarkably higher than those provided for by the standard. This allows the insertion of at least 2-3 ribs on each side to ensure the pipe concentricity. A second sealing can also be added at each end to improve watertightness (up to diameter DN/ID 800).

The seal is made using EPDM, a material ensuring high resistance to chemicals contained in wastewater and which can be compared to that of polyethylene. The seal must be installed between the first two ribs (between the second and the third rib for EUROFLO® DN/OD 160) after the pipe end and diameter from DN/OD 200 to DN/ID 600 have a symmetrical section, to ensure the operator does not permit fitting errors. The special shape and position of the seal and the coupler length ensure that the seal is neither damaged during installation nor an angular deflection occurs which may cause several deflections and consequent leaks.

Insertion must be made after the coupler inside has been lubricated. This operation must be carried out using levers or by applying a steady thrust or axial pulling and making sure that connection is correct and the seals and/or the coupler are not damaged.

6.2 CONNECTION BY WELDING

One advantage of EUROFLO® pipes is that connection can be made by butt welding. The space between ribs and the length between the ribs allow proper welding. Welding being a delicate operation, it must be carried out by qualified and authorised welders. Do not forget that butt welding is used to seal the pipe but does not ensure a geometrical stiffness comparable with that of the coupler because the real thickness is lower than that of the smooth pipe having an equal ring stiffness.

Welding technologies and machines are the same used for polyethylene smooth pipes; also, times and pressures are the same used for welding pipes with small thickness (PN 2.5 or PN 3.2). Each supplier of welding equipment supplies a table indicating the recommended times and temperatures.

One cycle which is often used is the one described below:

1. pre-heating: visual formation of the seam with (0,5+0,1·e4) mm height
2. heating: t2 = 15 · e4, in s
3. disc removal: t3 ← 3 + 0.01 · Di, in s
4. achievement of welding pressure: t4 ← 3 + 0,03 · Di, in s
5. welding: t5 → 3 + e4, in s
6. cooling: t6 = complete cooling, depending on thickness and external temperature.

Heating must be made carefully in order to avoid heating the rib.

6.3 INSTALLATION AND LAYING

This section describes how to install and lay the polyethylene corrugated pipes for drainage systems. It is important to point out that transport, installation and laying procedures are not dissimilar from those of other plastic pipes.

Installation should be made according to ASNZS2566.2-2002: Buried Flexible Pipelines, Part 2: Installation.

6.3.1 PIPE TRANSPORT AND ACCEPTANCE

EUROFLO® pipes are transported like all other standard pipes. Because of their reduced weight and considerable ring stiffness, the pipes can be piled up.

Pipes up to diameter DN/OD 500mm are generally supplied on pallets while starting from diameter DN/OD 630mm to diameter DN/OD 1200mm are supplied loose.

Upon receipt, the pipe must be checked for compliance with the supply as according to the specifications and contractual conditions. Pipe acceptance must comply with the directions provided for by the supply specifications or the special general conditions.

All pipes, joints and special components must be delivered to the building yard with the corresponding markings or labels indicating the manufacturer, the nominal diameter and the class of usage. Upon demand, P&F Global supplies the reports with the results of the tests carried out by the internal laboratory on raw materials and finished product. The acceptance tests made on pipes, joints and special components carried out internally for production are regularly made according to the reference standard and what has been agreed with the certification bodies.

6.3.2 UNLOADING AND STORAGE AT THE YARD

Loading, transport, unloading and all operations must be made with great care and using appropriate means according to the pipe type and diameter and by adopting all the necessary measures to avoid bursts, cracks or other damage. Along with the information following, Section 2 of AS/NZS 2566.2 also gives clear instructions give clear instructions on transportation, handling and storage requirements.

Avoid impacts, deflections or excessive projections, sliding, contacts with other parts that may damage or deflect the pipes.

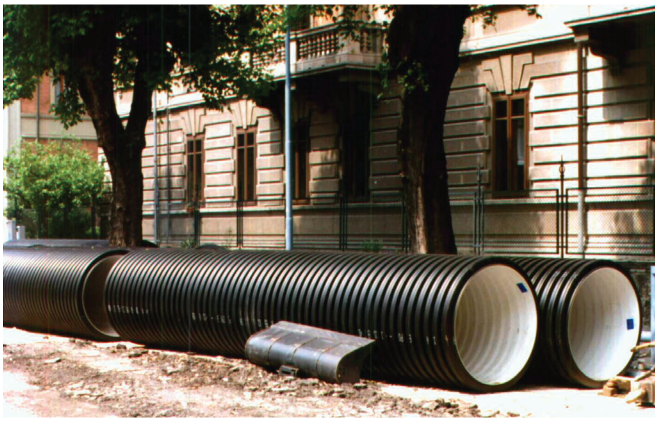
The yards must be equipped with the suitable means and supporting surfaces to rest the pipes, the special components and fittings that need to be installed. Unloading must be carried out either directly with the entire pallet or individually depending on how the pipes are transported.

When corrugated pipes are used, avoid hooks on the pipe ends and always use non-abrasive belts or ropes.

6.3.3 PIPE PILING-UP

The pipes must be piled up by putting them on a flat and stable surface protected from the risk of fire and from the sun if the pipes are subject to deflection caused by temperature changes. The pile base must rest on well spaced out boards or a supporting bed. The pile height depends on the pipe diameters in order to avoid deflections on the pipe base and for easier handling. The piled-up pipes must be blocked with wedges to prevent rolling. Moreover, protective measures must be adopted to avoid the pipe socket ends are damaged. The first layer of pipes resting on the ground must rest on a uniform surface to avoid deflections and damage to the pipe external surface.

Until the moment when they are used, joints, seals and material in general must be stored in closed spaces and inside boxes protected from the sun or other heat sources, away from oils or grease and must not be put under loads. To extract the pipes follow the same procedures as for unloading and transport and avoid sliding.



6.4.4 EXCAVATIONS

Section 4 of the AS/NZS 2566.2 standard give extremely clear instructions on excavations for laying drainage pipes.

The first recommendation is that the specification should suggest using a narrow trench whose width is 2 to 3 times the diameter, at least up to 1m above the upper pipe top. The walls, at least in this area, should be vertical and sufficiently stable (stability can be ensured by means of proppings or sheet piles) to protect the persons who work inside the excavation. The sheet piles must be immediately removed after partial embankment and before compaction. In the case of an embankment or large trench, we suggest that a contrast area to the covering material is prepared to restore a narrow trench.

Limits are put to the minimum size of the trench: according to the directions of NZ standards testing of drainage and manifolds), the minimum width must be the highest value among those shown in table 6.1 and 6.2.

DN	Minimum trench width (OD + x) in m		
	Reinforced trench	Non-reinforced trench	
		$\beta > 60°$	$\beta \leq 60°$
≤ 225	OD + 0.40	OD + 0.40	
225 < DN ≤ 350	OD + 0.50	OD + 0.50	OD + 0.40
350 < DN ≤ 700	OD + 0.70	OD + 0.70	OD + 0.40
700 < DN ≤ 1200	OD + 0.85	OD + 0.85	OD + 0.40
	OD + 1.00	OD + 1.00	OD + 0.40

Table 6.1: Minimum trench width according to the DN nominal size

Trench depth	Minimum trench width in m
< 1.00	not required
1.00 ≤ p ≤ 1.75	0.80
1.75 ≤ p ≤ 4.00	0.90
p > 4.00	1.00

Table 6.2: Minimum trench width according to trench depth

If two or more pipes are laid in the same trench, according to the standard a minimal horizontal distance is required between the two pipes:

- 0.35 meters up to DN 700 included;
- 0.50 meters for pipes larger than DN 700.

6.4.5 BEDDING

Once the pipes, joints and special components have been carefully checked and the damaged ones have been replaced, the pipes can be put in place. To lift and lay the pipes in the excavation, on a relief or supports, follow the same procedures as for the previous operations and make sure the pipe surfaces are not damaged. To do so, use suitable means according to the pipe diameters. When laying the pipes, make sure no foreign matter or debris enter inside the pipes and that the inner surface is not damaged.

First check that the bed is flat and levelled and remove any projection that may damage the pipes. If you need to prepare a bedding or use for the first embankment materials other than those coming from the excavation, remove the materials that may damage the pipe during laying. Never adjust the pipe position inside the trench using stones or bricks or other unstable supports. The bedding surface must be stable and in those parts where ground settling is expected, use suitable joints or treat the trench bottom.

If the excavation bottom is made of soft material, without stones or hard debris, the EUROFLO® pipe can be installed directly on the excavation bottom, provided the gradient is correct. Best practice, a sand bed or small size gravel (AP5) or a well rounded gravel (AP10) bed should be prepared.

Section 5.4 of AS/NZS 2566.2 covers the requirements of the embedment zone.

Pipes damaged during laying should be repaired or replaced if damaged.

6.4.6 INSTALLATION

EUROFLO® is generally connected to couplers after it has been laid on the excavation bottom. Because of its lightness, it can also be connected outside the excavation and then laid on the bottom. In all cases, the ends of pipes and special components to be connected, and also the seals, must be cleaned before jointing. Moreover, every time a pipe is laid and connected, its slope and alignment must be checked.

All installation guidelines and requirements of the AS/NZS 2566.2 are laid out comprehensively in section 5 of the standard.

During laying, special attention should be paid to expansion though the EUROFLO® pipe has a remarkably lower expansion (around 50%) than polyethylene solid wall pipes. In theory, when couplers are connected, pipe displacement could occur; to avoid it, block the pipe with partial filling every 30-40m and complete filling, after you have controlled any possible movement, in the early hours of the day.

If filling is correct, there will be no longitudinal movement as the compacted ground around the ribs prevents pipe expansion.

6.4.7 FILLING THE EXCAVATION

This is a very delicate operation for the installation of piping. Filling without correct compaction has negative effects on both stiff and flexible pipes.

Compaction made without taking the necessary measures may result in burst; during television inspections made after installation, cement, stoneware and PVC manifolds were completely destroyed even before their use.

Regardless of the type of pipe to be installed, for a long-lasting and correct installation follow the instructions below:

1) choose the correct backfilling: the material must be dry, with low grading, without sharp edges, stones or debris at least in the part which comes in contact with the pipe and at least up to 30cm over the pipe.

2) careful compaction: compaction must be carried out in 30cm thick successive layers using suitable equipment at least up to one metre over the upper top of the pipe. A good compaction should have a Proctor index equal to 90-92%. The first sidefill layer must be higher than the pipe semidiameter to prevent the pipe from raising or it may be required to block the pipe temporarily during compaction.

3) regular compaction: avoid discontinuous compaction to prevent pipe misalignment and excessive strain on the joints or abnormal bending of the pipe body.

4) compacting means: up to one metre above the top of the pipe, compaction must be carried out with light-duty means while normal means may be used over 1 metre. Be careful when using heavy-duty vehicles for compaction if the effects of the dynamic load on the underlying pipe have not been calculated.

Table 6.3, taken from UNI ENV 1046 standard, shows the maximum thickness values recommended for the layers and the number of passages required to obtain the compaction classes according to the equipment used and the backfilling around the pipe. It also shows the minimum thickness values recommended for covering the pipe before the suitable equipment is used on the pipe.

General compaction requirements are laid out in section 5.6 of AS/NZS 2566.2 which details direct methods as related to soil types, whether cohesionless, cohesive or stabilized. Emphasis is placed on compaction control, which requires direct tests except where indirect tests are permitted. All methods are detailed in Appendix H of the standard.

Compaction method	Number of passages for different compaction classes			Thickness after compaction for different ground classes, m				
	W (good)	M (medium)	N (without)	Group 1	Group 2	Group 3	Group 4	Groups 1-4
Manual sledge								
15 kg	3	1	0	0.15	0.10	0.10	0.10	0.20
Vibrating tube								
70 kg	3	1	0	0.30	0.25	0.20	0.15	0.35
Flat vibrator								
50 kg	4	1	0	0.10	--	--	--	0.15
100 kg	4	1	0	0.15	0.10	--	--	0.20
200 kg	4	1	0	0.20	0.15	0.10	--	0.25
400 kg	4	1	0	0.30	0.25	0.15	0.10	0.35
600 kg	4	1	0	0.40	0.30	0.20	0.15	0.50
Vibrating roll								
15 kN/m	6	2	0	0.35	0.25	0.20	--	0.60
30 kN/m	6	2	0	0.60	0.50	0.30	--	1.20
45 kN/m	6	2	0	1.00	0.75	0.40	--	1.80
65 kN/m	6	2	0	1.50	1.10	0.60	--	2.40
Vibrat. double roll								
5 kN/m	6	2	0	0.15	0.10	--	--	0.20
10 kN/m	6	2	0	0.25	0.20	0.15	--	0.45
20 kN/m	6	2	0	0.35	0.30	0.20	--	0.60
30 kN/m	6	2	0	0.50	0.40	0.30	--	0.85
Heavy triple roll, without vibration								
50 kN/m	6	2	0	0.25	0.20	0.20	--	1.00

Table 6.3: Recommended thickness for layers and number of passages for compaction

6.4.8 LAYING PIPES WITH GROUNDWATER

The corrugated pipe is for non-pressure drainage systems and therefore the jointing system is tested to withstand temporary pressure and negative pressure phenomena. When there is constantly groundwater around the pipe, it is recommended to use smooth polyethylene pipes with compact walls working under pressure, jointed by butt welding or electro-welded couplers.

When groundwater fluctuates throughout the year, structured plastic pipes may be used, while following further instructions: they must be laid with the excavation bottom dry, to guarantee the creation of bedding and correct sloping. Well-point systems should be used to remove extra water in order to perform laying in the above-mentioned conditions.

As you may guess, EUROFLO® like other types of plastic structured wall pipes, has a floatation thrust when plunged into the water. Filling must prevent floatation or failure of walls. The grading of backfilling must be such as to prevent the particle migration to the surrounding ground or vice versa. Migration may be avoided by applying a suitable fabric filter (geotextile membrane).

6.5 HYDRAULIC TESTING

As explained previously, the EUROFLO® pipe-coupler system resists to 0.5 bar pressure and - 0.3 bar pressure at 23°C for 15 minutes. These conditions are also guaranteed in the case of a diametrical deflection (10% of the pipe and 5% of coupler) or an angular deflection of the system (which varies from 2° to 1° according to diameter).

In any case, it is necessary to make sure that no initial considerable deflections occur during filling and compaction. It is always advisable to make a hydraulic test on the installed pipe.

The test must be carried out according to Appendix H of AS/NZS 2566.2.The standard provides two methods for hydraulic tests: the Constant Pressure Test (Water Loss Method) and the Pressure Decay Test - choice of method must be indicated by the engineer and checked to meet requirements of guidelines set out in AS/NZS 2566.2. Two additional tests (the 'Air test' and 'Water test') as recommended by European standards are described in the following and may provide useful supplement tests for an installation.

For the air test, the test equipment is composed of a number of rubber balloons which must stick to internal wall of the pipe, one compressor, one pressure gauge connected to a detector with a diagram. The test consists in placing two watertightness balloons for closing the downflow section upstream and downstream the section which is being tested.

One balloon is equipped with a through valve for air filling into the pipe, which is connected to an external recording and detection device. The standard provides for four test methods (LA, LB, LC and LD) each characterised by an increase in test pressures and a decrease in test times. Table 7.4. indicates test pressure, pressure drop and test times for air testing for impregnated concrete pipes and for all other materials.

For testing, follow the instructions below:

- for about 5 minutes, keep an initial pressure 10% higher than the test pressure required;
- adjust pressure to test pressure as shown in table 6.4;
- check whether the drop measured after the test time is lower than Δp indicated in table 7.4.

The pressure levels according to time are recorded and displayed on a screen and printed or saved on a "time-pressure" diagram.

For the water test, the test pressure to be taken into consideration is the pressure which corresponds or results from filling the test section up to ground level near the manholes installed upstream or downstream with a maximum pressure of 50 kPa (0.5 bar) and a minimum pressure of 10 kPA measured on the upper pipe top.

For testing, follow the instructions below:

- fill the pipe until the test pressure required is reached;
- wait for about 1 hour until the pipe is impregnated;
- keep pressure within 1 Kpa of test pressure by adding water;
- measure and record the total amount of water added to keep the water level corresponding to the test pressure required;
- check that the amount of water added in 30 minutes is not higher than
  0.15 l/m² for pipes
  0.20 l/m² for pipes including manholes
  0.40 l/m² for manholes and inspection chambers
  where m² refer to the wet internal surface.

	po mbar	Δp mbar	Test time (min)						
			DN 100	DN 200	DN 300	DN 400	DN 600	DN 800	DN 1000
LA	10	2.5	5	5	7	10	14	19	24
LB	50	10	4	4	6	7	11	15	19
LC	100	15	3	3	4	5	8	11	14
LD	200	15	1.5	1.5	2	2.5	4	5	7

Table 6.4: Data concerning air testing

APPENDIX

SN8 EUROFLO® PIPE AS/NZS 5065

- All sizes stocked in New Zealand
- 5.8M lengths overall including socket
- Rubber ring joints available if needed, all sizes stocked in New Zealand

PRODUCT CODE	DESCRIPTION	SN RATING	CRATE QTY	NOMINAL BORE (MM)	OUTSIDE DIAMETER (MM)
560-250-5.8M	250mm Heavy Wall EUROFLO® pipe	SN8	11	220	250
560-315-5.8M	315mm Heavy Wall EUROFLO® pipe	SN8	6	280	315
560-400-5.8M	400mm Heavy Wall EUROFLO® pipe	SN8	3	350	400
560-500-5.8M	500mm Heavy Wall EUROFLO® pipe	SN8	2	430	500
560-630-5.8M	630mm Heavy Wall EUROFLO® pipe	SN8	1	530	630
560-800-5.8M	800mm Heavy Wall EUROFLO® pipe	SN8	1	691	800
560-1000-5.8M	1000mm Heavy Wall EUROFLO® pipe	SN8	1	850	1000
560-1200-5.8M	1200mm Heavy Wall EUROFLO® pipe	SN8	1	1030	1200