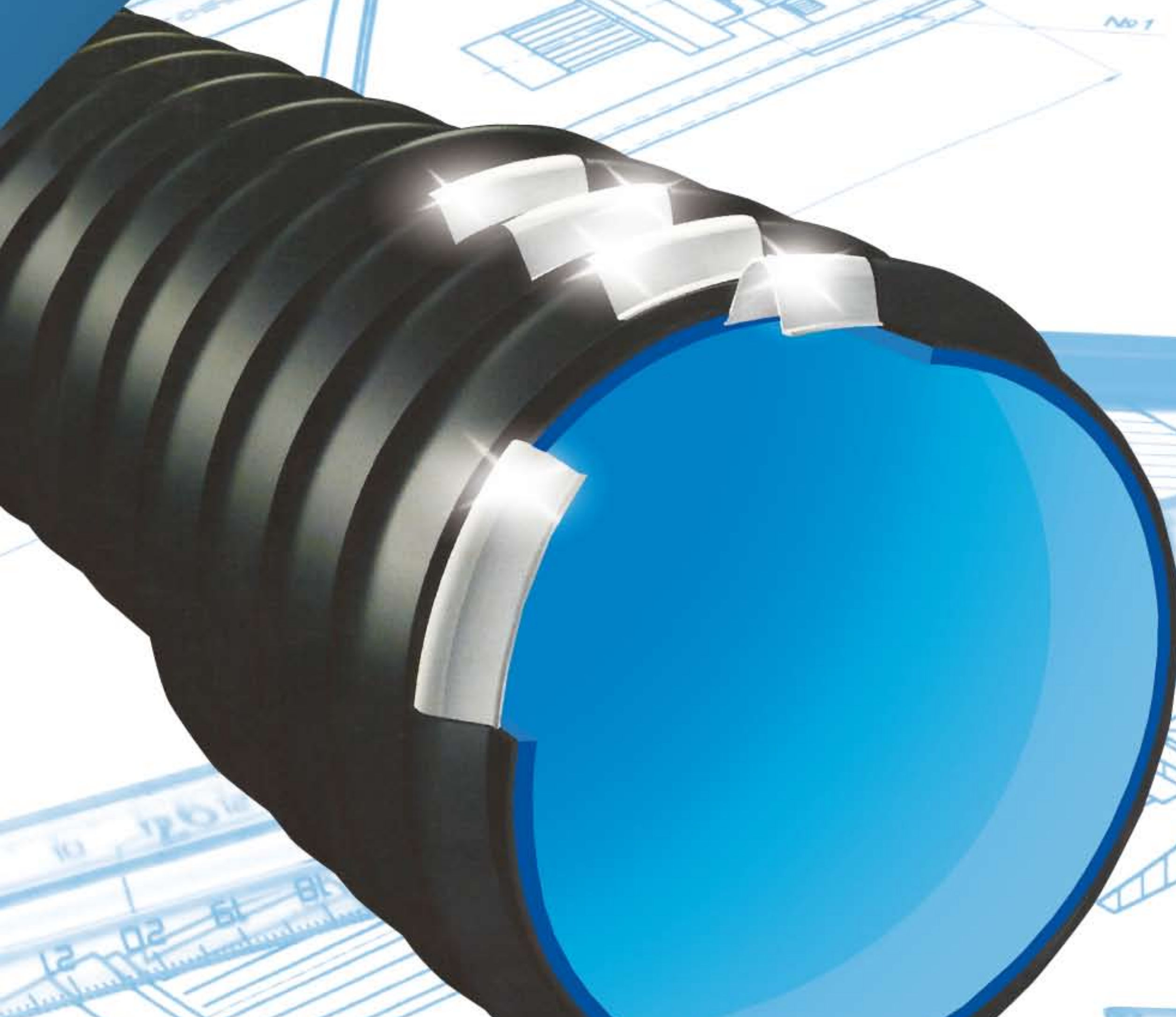
PALADERI



PALADEX

HDPE spiral pipes with galvanized steel reinforcements

compliant to UNI 11434

techinical guide
08 - 2014

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NOTE: Product dimensions here reported are for guidance only and are subject to standard dimensional tolerances.
Paladeri S.p.A. reserves the right to make, at any time and without notice, at its own sole discretion, all the changes that might be convenient to improve the manufacturing process or enhance product performance.

Introduction

Obsolete and inadequate sewer pipes, more and more intense rainfall, frequent landslides require innovative solutions for the disposal of larger quantities of stormwater and waste. Pipelines, today, have to bear all internal and external stresses that are potentially damaging to drainage systems.
In its factory in Villadose (Rovigo, Italy), the company **PALADERI S.p.A**. produces **PALADEX**, an HDPE (High Density Polyethylene) pipe reinforced with an inner galvanized steel profile designed for sewers and underground drain systems.

Its innovative technology, developed in Japan in the 1990s, allows to manufacture big size pipes featuring an extremely high mechanical strength and low weight. As a result, transport and laying are much easier.

The innovative design of **PALADEX** pipes combines the typical properties of polyethylene - resistance to abrasion, light weight, minimum frictional resistance, resistance to chemical agents, versatility and ease of installation - with the properties of steel, having an elastic modulus 200 times higher than the polyethylene.

PALADEX pipes are obtained thanks to a process of spiral winding of polyethylene and an omega - shaped steel profile. Therefore, pipes consist of an inner layer in polyethylene, an outer structured wall in polyethylene and a core of galvanized steel completely covered by a polyethylene-based primer, which ensures a perfect blending with the two walls.
The combination of the two materials, along with the use of an omega-shaped profile, ensures a performance that is by far better than other structured pipes in fiber glass, concrete, cast iron or clay available on the market.
The presence of the steel has several advantages: a higher resistance to pressure (up to 20 kN/m^2), unequalled by other pipes in thermoplastic material; a smaller outer diameter, requiring a reduced amount of raw materials and clear benefits in terms of environmental impact and ease of installation; a better long-term performance, with particular reference to deformation under constant load and a creep ratio lower than other pipes made exclusively in polyethylene.

PALADEX, whose product range goes from pipes with nominal diameter/inside diameter (DN/ID) from 400 to 2400 mm, represents the best solution to business and technical needs of designers, public bodies, and building companies.

Furthermore, the low cost of **PALADEX** pipes allows to reduce the expenses planned for transport, handling and laying, thus having a relevant impact on overall budgets.
PALADEX pipe, manufactured by an ISO 9001:2008 certified company, was awarded with the IIP (Istituto Italiano dei Plastici) marking in compliance with Italian standard UNI 11434 in June 2012.

Specifications

HDPE spiral pipe with galvanized steel reinforcement suitable for sewerage, non pressure underground drainage and ventilation ducts, application area code U, produced according to UNI 11434 standard, by ISO 9001 certified company and accompanied by compliance certificate issued by a third party certification body accredited in the EA as per UNI CEI ISO/IEC 17065:2012 standard.
Structured spiral pipes, smooth inside and corrugated outside, reinforced with an omega-like profile in galvanized steel (DX51D + ZF/Z class) complying with UNI EN 10346 requirements and entirely embedded into the pipe wall.
Junction is made thanks to a male-female connection consisting of a female weld socket and a male component equipped with an EPDM seal (complying with UNI EN 681 standard), housed in a preset slot assuring the water-tightness of the junction (up to 1 bar pressure/0.3 bar vacuum) according to UNI EN 1277 standard. Male and female components have the same properties as pipes, in order to ensure a constant inside diameter and increase product resistance.

Ring stiffness classes according to EN ISO 9969:2008:

Class A (= 8 kN/m^2) corresponding to SN 8
Class B (= 12 kN/m^2) corresponding to SN12
Class C (= 16 kN/m^2) corresponding to SN16

Norms - UNI 11434

In January 2012, UNI (Ente Nazionale Italiano di Unificazione; National Agency for Standardization) issued the UNI 11434 standard which applies to PE spiral tubes reinforced with a steel profile completely embedded between pipe walls; pipes have a smooth inner surface with a diameter (DN/ID) from 400 to 2500 mm and are used for sewage systems, to drain rainwater and as ventilation ducts (U marking).
Therefore, Italy is the first country in Europe to adopt a specific technical legislation concerning PE pipes reinforced with steel, which stands as reference for the institution of a technical team working on a EU document on behalf of CEN (European Committee for Standardization).
Taking into account the features of an innovative product, the working group SC8 (appointed by Uniplast to draft the new standard) used the following references: American standard ASTM (American Standard Testing Materials) F 2435-07; Israeli legislation IS 5302; Italian technical specification IIP (Istituto Italiano dei Plastici) RP 1.1/CO, 2008; French technical specification 17/07-190; German DIN 16961; European EN 13476 standard.
European norms already issued by CEN and used as EN standards or implemented by existing international standards (EN ISO standards) were used as testing methods.
Particular attention was paid to the calculation of ring stiffness, whose reference is EN ISO 9969 standard.

Marking

PALADEX pipes are permanently and visibly marked every 2 metres and feature at least one marking per pipe, in compliance with **UNI 11434** standard, par. 9.

Marking includes the following information:

N. of reference standard	UNI 11434
Area of application code	U
Manufacturer and/or brand name	**PALADERI**
Nominal dimension (inside)	Example: DN/ID 1200
Pipe class	Example: A (= SN8)
Material	PE/Fe
Date of production	day / month / year
Certifying authority	**IIP**

Marking is an essential element to enhance product traceability required by ISO 9001:2000 standard and applicable laws related to quality assessment and product certification.
Non-marked pipes are not compliant with any reference standard.

Certificates

The systematic monitoring of business management systems and strict compliance to applicable laws have made possible the achievement of ISO 9001:2008 certificate issued by the Swiss agency SQS.

PALADERI was the first Italian company to be allowed to use the IIP marking (Istituto Italiano dei Plastici) for the production of PE spiral pipes reinforced by steel and in compliance with UNI 11434.

PE pipes reinforced with steel have already been widely used for several purposes in the USA, Israel, Japan, China and France for over a decade.

PALADEX pipes are manufactured in conformity with the technical requirements contained in the following standards / specifications: ASTM F 2435-07 (USA), IS 5302 (Israel), CSTB 17/07-190 (France).


IIP
CERTIFICATO DI CONFORMITÀ
Certificate of conformity
n° 676 / 2012 — Rev. 1

Certificate IIP
n. 676/2012 - Rev.1


BUREAU VERITAS
Certification
Certificato di Conformità
PALADERI SPA

Certificate BUREAU VERITAS
n. 771/001

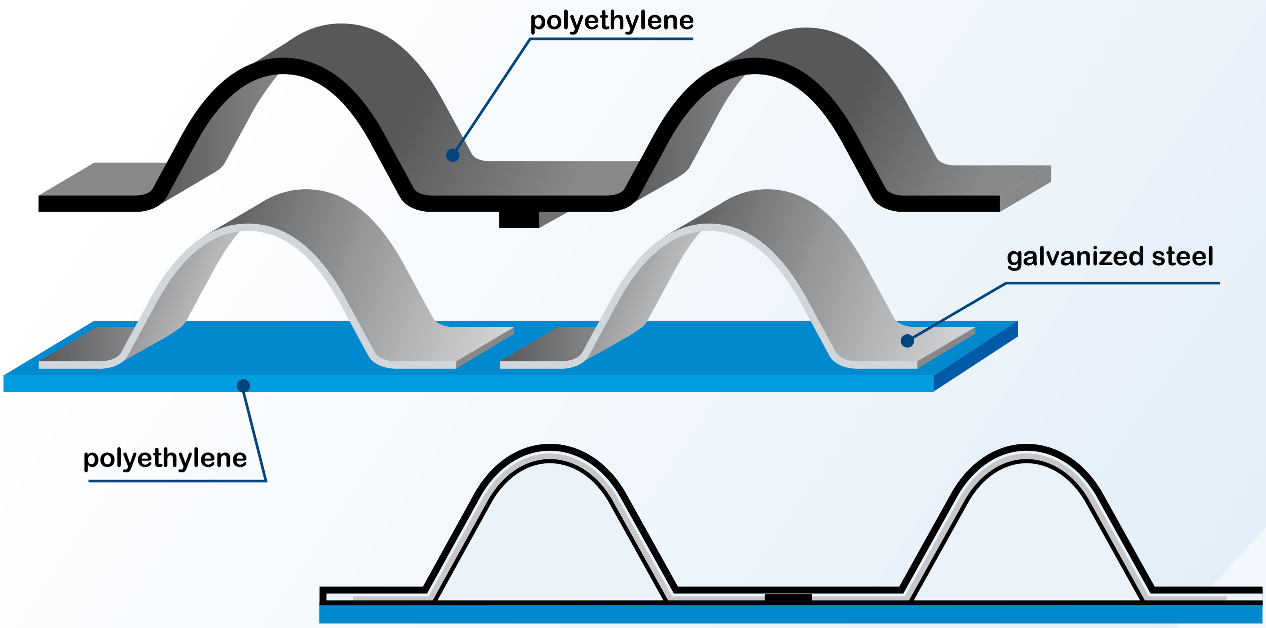

SQS
Certificato
Paladeri S.p.A.
Via S. Leonardo, 2
45010 Villadose (RO)
Italia
ISO 9001:2008 Sistema di gestione per la qualità

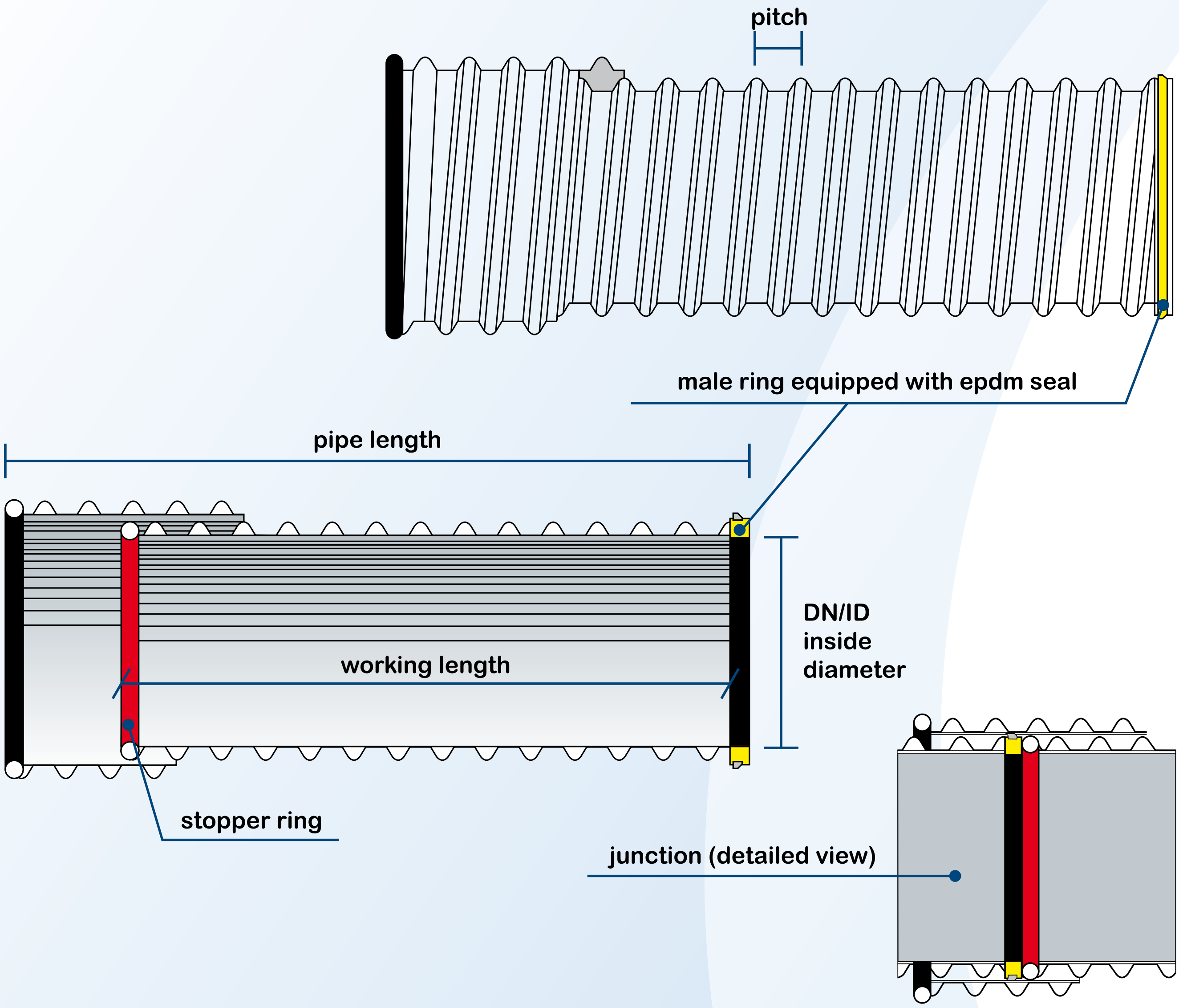

ICECON CERT
Certification body
CERTIFICAT DE CONFORMITATE
0419.1/21.02.2014
ŢEVI RAMFORSATE CU OŢEL, CU SUPRAFAŢĂ INTERIOARĂ NETEDĂ ŞI SUPRAFAŢĂ EXTERIOARĂ PROFILATĂ, TIP B

Certificate SQS ISO 9001:2008

Certificate ICECON n. 0419.1/2014

Cross-section of a pipe





Dimensional table

Inside nominal diameter DN/ID	Average Minimum Inside Diameter	Average Maximum Inside Diameter	Minimum Inside Wall Thickness S_1 min	Average Outside Diameter OD	Average Outside Diameter (Female component)
400	396	408	2,5	437	474
500	495	510	3,0	544	588
600	594	612	3,5	650	700
700	693	714	4,0	760	810
800	792	816	4,5	870	940
900	891	918	4,8	970	1045
1000	990	1020	5,0	1080	1160
1100	1090	1123	5,0	1180	1270
1200	1188	1224	5,0	1300	1400
1300	1287	1326	5,0	1411	1524
1400	1386	1428	5,0	1523	1661
1500	1485	1530	5,0	1633	1773
1640	1625	1671	5,5	1750	1880
1800*	1781	1835	6,0	1955	2111
2000*	1979	2039	7,0	2170	2344
2200*	2177	2243	7,0	2390	2582
2400*	2375	2447	7,0	2605	2813

Measures are in mm
Pipes from 1.0 to 13.40 m long are available upon customer's request and following positive assessment by **PALADERI** technical staff.

* under development

Pipe weight

The particular and innovative polyethylene structure of **PALADEX** pipes, reinforced with an omega-like profile in galvanized steel entirely embedded between two polyethylene layers, allows to manufacture an extremely lightweight pipe, in comparison with the available alternatives having the same ring stiffness.
The average weight of a spiral **PALADEX** pipe DN/DI 1200 SN 8 is 70 kg/m, while an equivalent traditional polyethylene spiral pipe weighs about 120 kg/m and a concrete pipe weighs more than 1900 kg/m.

The light weight of **PALADEX** pipes does not affect ring stiffness and ensures the following advantages:

- Cheap price of pipes
- Quick and cheap laying
- Possibility to manufacture bars up to 13.40 m length without welding
- Possibility to store pipes of smaller diameter within larger pipes, so as to reduce the cost of transport
- Not expensive equipment needed in work areas for handling operations

Ring stiffness

Ring stiffness, according to **EN 476 (1997),** standard, indicates pipe resistance to vertical deformation due to external loads.

$$S = \frac{E \cdot I}{D^3}$$

Where:

S pipe ring stiffness [kN/m^2];

E modulus of elasticity with transversal bending [kN/m^2];

I longitudinal inertial moment of the pipe wall, cross section for every unit [m^4/m]; the value is equivalent to the ratio I = s^3/12 where s is equivalent to pipe thickness;

D neutral pipe wall diameter [m].

Vertical deformation closely depends on the quality of surrounding filling soil which supports the pipe on its sides and prevents its ovalization.

Ring stiffness may be determined using the method reported in **EN ISO 9969 (2007)** standard (see ch. 5-6-7-8 about apparatus, sampling, testing and testing procedures).

The formula for calculating the ring stiffness of structured thermoplastic pipes using the compression test is:

$$S = \left(0{,}0186 + 0{,}025 \cdot \frac{y}{D_i}\right) \cdot \frac{F}{L \cdot y} 10^6$$

Where:

y pipe diameter deformation (mm) corresponding to 3.0% of the inside diameter y/D_i =0,03;

D_i inside diameter of the pipe (mm);

F force (kN) corresponding to 3.0% pipe deformation;

L length of tested sample (mm).

In order to allow a thorough analysis of **PALADEX** pipe's ring stiffness according to the new Italian standard UNI 11434, it is appropriate to highlight the relationships between the existing standards concerning structured thermoplastic pipes: the German DIN 16961 and the European legislation EN 13476.
These two standards classify the resistance to pressure by using different methodologies, so it is essential to establish an equivalence to perform a comparison.
Both standards measure ring stiffness through a test carried out on a pipe section.
The test performed in accordance with German DIN 16961 requires the application, according to specific parameters, of a constant load in order to measure the deformation after 24 hours. The value of ring stiffness, calculated on pipe radius, is defined $\mathbf{S_{R24}}$.
The standard EN 13476 measures ring stiffness by means of a constant strain rate test in accordance with **EN ISO 9969:** the value of ring stiffness, calculated on the pipe diameter, is defined **SN** (Nominal Stiffness).
The methods used in EN 13476 standard offer a number of advantages, both practical and technical.

Firstly, there is a total duration of a few minutes against the 24 hours required by DIN 16961.
Secondly, EN 13476 standard requires the instant application of a load that favours the measurement of the pipe elastic modulus (E), which, for a polyolefin (PE or PP), features an elastic behaviour, i.e. dependent on the speed of deformation and time.
The value of the instantaneous elastic modulus (E_0) is easily measured in the laboratory by ordinary means, through a simple tensile test of a few minutes and with a speed of deformation rate which is established according to the standard. On the contrary, it is not as easy to check out the value of the modulus of elasticity after 24 hours (E_{24}).
The laboratory tests carried out in accordance with these standards and the equivalence between the respective formulas shows the following relationship:

$$SN = \frac{S_{R24}}{4}$$

To sum up, according to DIN 16961, $\mathbf{S_{R24} = E \cdot I / r^3}$, while according to EN 13476, $\mathbf{SN = E \cdot I / D^3}$.
The relationship between the two variables - $\mathbf{S_{R24}}$ and **SN** - needs two correction coefficients concerning, respectively, a) the relationship between the values of radius and diameter and b) the different behaviour of the elastic modulus of the polyethylene as a function of the test duration.

The equivalence between **S_{R24}** and **SN** can then be obtained in the following way: $SN = k1 \cdot k2 \cdot S_{R24}$

Where:

k1 is the radius / diameter correction coefficient;

k2 is the elastic modulus / test duration correction coefficient.

If D = 2r, the first correction coefficient will be: **$k1 = 1^3/2^3 = 1/8$**
PE elastic modulus E_0 is equivalent to N/mm^2. Following the application of a force for the duration of 24 hours, the value of E_0 will be approximately halved.
As a result, E_0 = 800 N/mm^2, while E_{24} = 380 N/mm^2.
The second correction factor will be: **k2 = 800/380 = 2.**
Therefore, the equivalence is:

$$SN = \frac{1}{8} \cdot 2 \cdot S_{R24} = \frac{S_{R24}}{4}$$

PALADEX spiral pipe is manufactured in compliance with Italian standard UNI 11434, issued in January 2012. This standard, in its Appendix A, identifies the parameters for the calculation of ring stiffness. The use of the equipment, methods of sampling, treatment of specimens, and test procedure are specified in EN ISO 9969 standard, which also refers to the EN 13476:2007 standard.
Appendix A also specifies that, with a deformation of the inside diameter corresponding to 3%, **PS** (Pipe Stiffness in kPa) can be worked out by using the following equation:

$$PS = \frac{F \cdot 10^6}{L \cdot y}$$

Where:

F force (kN) corresponding to 3.0% pipe deformation;
L length of tested sample (mm);
y pipe diameter deformation (mm) corresponding to 3.0% of the inside diameter.

HDPE spiral pipes reinforced in steel are classified in three types (A, B, C) related to their respective ring stiffness. Document n. 4 of UNI 11434 standard recaps Pipe Stiffness **PS** values and deformation of the inside diameter (ID) = 3% for each class:

Class A	PS ≥ 415 kPa
Class B	PS ≥ 620 kPa
Class C	PS ≥ 830 kPa

In order to convert these quantities in the value **S** (Stiffness) that is normally used in static calculations, you need to consider that **S = 0,0186 • PS** so that:

CLASS	A	S8
CLASS	B	S12
CLASS	C	S16

The note to Document n. 4 of UNI 11434 clarifies that the value of ring stiffness **S** (Stiffness) for classes A - B - C (with a 3% of diameter deformation), corresponds to the stiffness of structured thermoplastic pipes having a ring stiffness SN (Nominal Stiffness) of 8 - 12 - 16 according to EN ISO 9969. Therefore, it is possible to create the following table of equivalence between the values of ring stiffness defined by the parameters:

UNI 11434	EN 13476	DIN 16961
CLASS (S)	**SN**	**SERIES (S_{R24})**
	SN 2 (= 2 kN/m^2)	**SERIES 3** S_{R24} 8 (= 8 kN/m^2/ 4)
	SN 4 (= 4 kN/m^2)	**SERIES 4** S_{R24} 16 (= 16 kN/m^2/ 4)
CLASS A S8 (= 8 kN/m^2)	**SN 8** (= 8 kN/m^2)	**SERIES 5** S_{R24} 31,5 (= 31,5 kN/m^2 4)
CLASS B S12 (= 12 kN/m^2)		
CLASS C S16 (= 16 kN/m^2)	**SN 16** (= 16 kN/m^2)	**SERIES 6** S_{R24} 63 (= 63 kN/m^2/ 4)

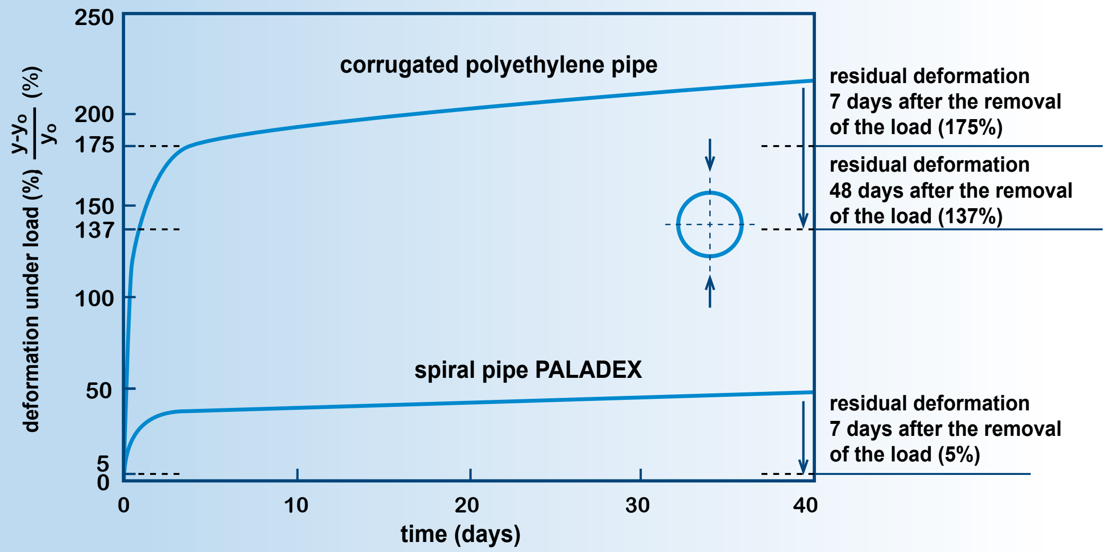
For example, a spiral polyethylene pipe reinforced with steel **CLASS A (= 8 kN/m^2)** complying with UNI 11434 will have a ring stiffness equivalent to a structured **SN8** pipe entirely in polyethylene complying with EN 13476:2007 and a structured pipe entirely in polyethylene **SERIES 5 S_{R24} 32** complying with DIN 16961 standard.

The product range of **PALADEX** pipes also includes pipes with a higher ring stiffness than what specified in UNI 11434 standard.

CREEP test

The effect of progressive deformation that can take place in piping systems is due to a constant load applied in radial direction. This effect is defined **CREEP**.
The calculation of the minimum ring stiffness is only the first requirement when choosing a pipe. It is also important to determine the incidence of **CREEP** in order to evaluate the long-term performance of the pipe.
The steel profile embedded between the two layers of polyethylene ensures a greater stiffness to **PALADEX** pipes.
The blend of different types of material - HDPE and steel - determines a reinforcing effect of polymeric materials and alters the mechanical characteristics and working conditions.
Steel, in particular, reduces the **CREEP** effect.
The following table shows data related to deformation - under - load tests, carried out on pipes having the same diameter (DN / ID 800 mm) and ring stiffness (class A = SN8).
During these tests, the applied load caused an initial deformation Y_0 equivalent to 3% of the nominal diameter.
As a further example, a **PALADEX** pipe complying with UNI 11434 and a corrugated pipe in polyethylene complying with EN 13476 have been examined and compared.

% VARIATION OF DEFORMATION, DUE TO THE PRESSURE OF A CONSTANT LOAD; PIPE RESTORATION AFTER REMOVAL OF LOAD



It has been observed that the **CREEP** effect takes place in both cases. However, the deformation value after 40 days of load application is about 4 times lower in **PALADEX** pipes.
Both pipes recover part of the deformation once the load is removed: the corrugated pipe recovers approximately one third of the total deformation after 48 days, while **PALADEX** completely recovers its initial shape after 7 days.
PALADEX pipe, therefore, in spite of its deformable structure, which means less rigid than the surrounding soil, is extremely more resistant to ovalisation in comparison with an ordinary structured thermoplastic pipe.
This shape-keeping property is a clear advantage during transport, storage and installation operations.

Junction system

One of the most relevant factors to determine the quality of a pipeline is the ability to convey fluids and prevent potentially damaging leaks in the junction system.

Therefore, the junction between pipes is a crucial issue, especially in those projects involving the use of pipes with high internal diameter (e.g. DN > 1000 mm) and where groundwater flows affect the working environment.

Although they are mainly non-pressure sewerage systems and drains, it is necessary that the junction system proposed by the manufacturer ensures efficiency and long-term performance.

Junction is made thanks to a male-female connection consisting of a female weld socket and a male component equipped with an EPDM seal (complying with UNI EN 681 standard), housed in a preset slot, ***assuring the water-tightness of the junction system (up to 1 bar pressure/0.3 bar in vacuum) according to UNI EN 1277 standard.***

“Male” and “female” components feature a structured spiral wall profile, smooth inside and corrugated outside, reinforced with an omega-like profile in galvanized steel (DX51D + ZF/Z class) complying with UNI EN 10346 requirements and entirely embedded into the pipe wall.
These manufacturing properties ensure a higher ring stiffness and increase product resistance in the most critical sections of the pipeline - connections - thus reducing the deformation of the inside diameter as much as possible.

PALADEX junction system ensures an easy and cheap laying and greater safety.
The "male" and "female" components are manufactured in such a way as to make easy pipe alignment and their assembling by using ordinary equipment and tools.
Laying costs are quite low, since assembling does not require any preliminary / completion steps.
The rigidity of the components compensates for any inaccuracies during the laying phase, thus limiting the risk of damage to the pipeline.

The male-female connection is very easy to accomplish, thanks to a free-of -charge lubricant supplied by our company and a stopper that guides the connection.
The male element, when requested by customers, can be equipped with a double seal to increase the safety of the hydraulic seal.

It is possible, upon request, to connect **PALADEX** pipes through a plastic thermoshrinking film positioned on the outer layer of pipes, after which the pipe inner surfaces can be welded together by a common hand extruder.

Hydraulic tightness

Junction system of **PALADEX** pipes (described in the previous section) ensures the water-tightness **of the system (up to 1 bar pressure/0.3 bar in vacuum) according to the testing methods specified in UNI EN 1277 standard.**

These performances are possible thanks to essential features, such as the rigidity of “male” and “female” components (both manufactured in the same way as pipes) and the use of special EPDM gaskets.

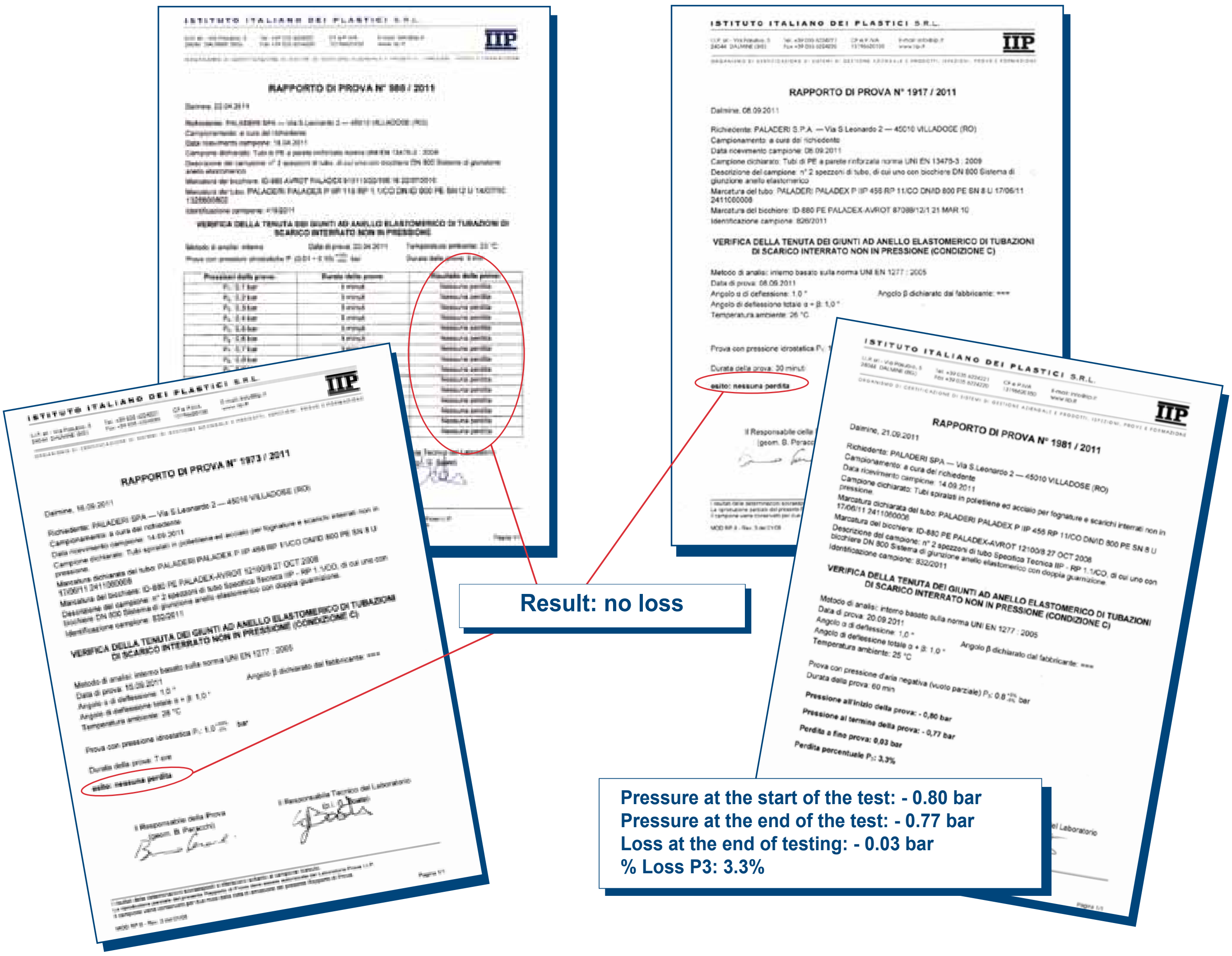
As a further evidence, some test results on hydraulic tightness are provided below; the tests were entirely performed in IIP laboratories on samples of **PALADEX** pipes, according to UNI EN 1277:2005 standard.

N. 986/2011 certifies the tightness of the junction system of **PALADEX** pipes at an incremental pressure up to 1.5 bar.

N. 1917/2011 certifies the tightness of the junction system of **PALADEX** pipes at a pressure of 1 bar for 30 minutes with angular deflection of 1°.

N. 1973/2011 certifies the tightness of the junction system of **PALADEX** pipes with double EPDM gasket at a pressure of 1 bar for 7 hours with angular deflection of 1°.

N. 1981/2011 certifies a pressure loss of only 0.03 bar, corresponding to a percentage P_3 = 3,3% due to the application of negative air pressure (partial vacuum) for the duration of 60 minutes, where P_3 = 0.8 bar + / - 5% with angular deflection of 1°.



Physical/mechanical characteristics of materials

PALADEX pipes combine the typical properties of polyethylene - resistance to abrasion, light weight, minimum frictional resistance, resistance to chemical agents, versatility and ease of installation - with the properties of steel, featuring an elastic modulus 200 times higher than the polyethylene.

Material	Properties	Standard	Testing criteria	Values
Polyethylene	Density	EN ISO 1183-1 EN ISO 1183-2		> 0,930 g/cm^3
Polyethylene	MFR = Melt Mass-Flow Rate (Melt Flow Index)	EN ISO 1133	Temperature 190°C Load mass 5 kg	≤ 1,6 g/10 min
Polyethylene	Yield strength, σ y			22 MPa
Polyethylene	Ultimate elongation	ISO 6259-3		≥ 500 %
Polyethylene	Elastic modulus		Short term E_s Long term E_l	900 MPa 150 MPa
Polyethylene	Thermal stability OIT = Oxidation Induction Time	UNI EN 728:1998	Temperature 200°C	≥ 20 minutes
Polyethylene	Internal pressure resistance	UNI EN ISO 1167	80°C; 4MPa	
Polyethylene	Coefficient of thermal linear expansion,α	UNI EN ISO 1167		0,22 mm/m • °C
Polyethylene	Thermal conductivity			0,4 W/m • °C
Polyethylene	Carbon Black	ISO 6964		2 - 2,5 %
Steel	Tensile strength	UNI EN 10346		≥ 270 MPa
Steel	Elastic modulus			2,1 x 10^6 MPa

Resistance to chemical agents

As far as chemical resistance is concerned, **PALADEX** pipes ensure the same resistance properties as traditional polyethylene pipes, in compliance with ISO TR 10358.

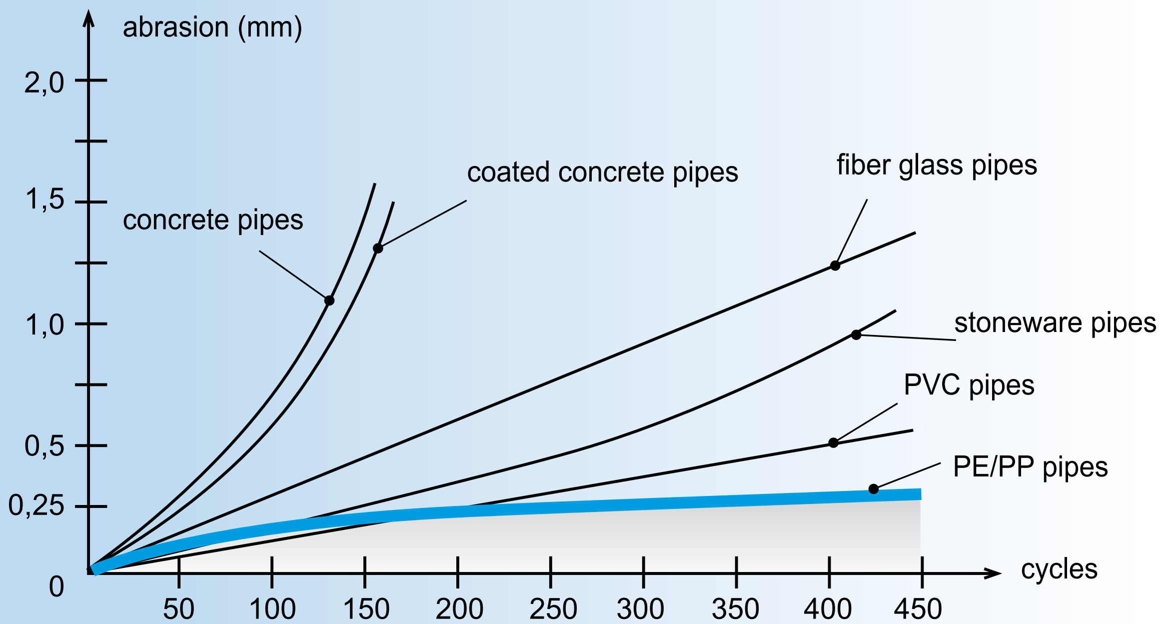
Material	Concentration	Temperature at 20°C	Temperature 60°C
Acetone		=	-
Chloric Acid	10%	+	+
Chloric Acid	35%	+	+
Chloric Acid	75%	+	=
Fluoric Acid	40%	+	+
Formic Acid	30%	+	+
Nitric Acid	10%	+	+
Nitric Acid	95%	-	-
Sulfuric Acid	10%	+	+
Aniline		+	-
Benzene		-	-
Gasoline		=	-
Calcium Chloride		+	+
Glycerol		+	+
Ammonium Hydroxide		+	+
Sodium Hypochlorite		+	+
Methanol		+	=
Hydrogen Peroxide	30%	+	+
Sodium Hydroxide	30%	+	+
Carbon Tetrachloride		-	-

+ Resistant   = slightly corroded, pre-treatment is required   - Non Resistant
NOTE: If the fluid contains small quantities of corrosive chemical substances, please consult our technical staff for further information

Abrasion

PALADEX, pipe inner surface is made of polyethylene and this ensures a high resistance to abrasion.
As a result, pipelines may be also used for high flow speed and slope (max speed up to 10 m/s) without producing relevant abrasion effects on the inner surface.
The diagram shows how polyethylene pipes are more resistant to abrasion than other pipes manufactured with other materials (concrete, coated concrete, fiber glass, clay, PVC etc.)

AVERAGE ABRASION VALUES FOR PIPES MANUFACTURED WITH DIFFERENT MATERIALS (UNIVERSITY OF DARMSTADT)



Resistance to UV rays

The outside black PE wall of **PALADEX** pipe is resistant to damages due to environmental factors and UV radiation, thanks to carbon black added to the fiber-reinforced polymer.
Therefore, **PALADEX** pipes can be kept and stocked outdoor.

Corrosion

Polymeric materials do not require any protection against electrochemical corrosion or galvanic coupling, since they are not conductive.
Steel may be subject to such phenomena should it come into direct contact with the fluids transported or flowing outside the pipe.

The steel profile (class **DX51D + ZF/Z** complying with **UNI EN 10346**, requirements) that reinforces **PALADEX** pipes is entirely coated with a polyethylene primer that ensures a perfect fusion with the two polyethylene walls.

Every single batch of steel, used for the production of **PALADEX** pipes, is firstly checked by using a peeling test, which measures the strength of adhesiveness of the polyethylene primer to the steel, so as to guarantee its isolation from internal / external agents.

The particular construction technology used for **PALADEX** pipes ensures a perfect union between steel and polyethylene, thus avoiding the contact with water and preventing any corrosion process.

PALADERI S.p.A. commissioned to C.T.R. (Centro Triveneto per la Ricerca e prove sui materiali, Limena, PD) a test of accelerated corrosion in neutral salt spray, in order to study the impact of corrosion on spiral **PALADEX** pipes in a sea environment.

The **PALADEX**, samples used for this test were immersed in a basic saline solution containing concentrations of NaCl e Na_2SO_4 higher than the quantity specified in UNI 11130 standard; the samples were immersed for 8 hours a day and left exposed to the air for the remaining 16 hours.

At the end of the 30-day test, the samples were visually inspected and revealed the absence of delamination of the polyethylene from the steel and the absence of any infiltration beneath the polyethylene coating.
When the pipe is cut (generally at the entry of a manhole) or if steel is not covered with protective layers, the open cut must be treated as any other metal surface by using the materials supplied by the manufacturer and protecting it from corrosion.
The protection of the steel profile can be restored by using highly resistant epoxy resins and thanks to the specific experience acquired in the field of PE pipelines reinforced by steel and conveying oil products.

Accessories

Upon request, **PALADERI** SpA is able to supply a complete range of special components for every required diameter and stiffness class, such as: **bends, tees, clarinets, manholes etc.**
All special **PALADEX** components are equipped with male/female connections in order to be connected to other similar pipes or can be arranged to be connected with different pipes (corrugated HDPE pipes, smooth HDPE pipes, PVC pipes, etc.).


Manholes


Clarinets


Tees


Bends


Accessories
Push-fits

Transport and handling

Pipes must be handled according to the requirements generally observed with traditional pipes.
PALADEX pipes can be stacked up without any problems, thanks to their light weight and high ring stiffness.

Loading, transport, downloading and all related operations must be carried out with great care, by using means and devices appropriate to the type of pipes and taking all the safety measures in order to avoid breaks, cracks, or damages.

In building sites, **PALADEX** pipes have to be properly handled by using suitable lifting trolleys to be positioned at the centre of the pipe and at the same distance from pipe ends.

Pipes will be stored in a flat and safe area.
The first row of pipes that is placed on the ground must be arranged so as to avoid possible damages to the outer surface, bending and deformation.
Stacked pipes must be protected with appropriate wedges in order to prevent sudden falls.
Pipes will be stored in areas where they are not subject to deformation and where there is enough room to handle and move them. **PALADEX** pipes will be stacked up by alternating "male" and "female" ends and placing the connecting component outside the pile.

Laying

Besides its performance, the proper functioning of a pipeline and its reliability depend on the attention paid during the installation process.
Mechanical and hydraulic properties can be altered if laying is carried out by unskilled personnel or by using low-quality and not mechanically compacted filling materials.

The remarks in this paragraph are simply meant to inform customers on the main points to consider for a proper laying. However, they have to be necessarily integrated with all the recommendations contained in the specifications or based on experience.

The main references used for this paragraph are the following:

- Technical specifications on the pipeline systems, Decreto del Ministero dei LL.PP., 12 December 1985;
- Official note issued by Ministero dei LL.PP., n° 27291, 20 March 1986;
- UNI EN 1610 (Construction and testing of drains and sewers), November 1999.

PALADEX, thanks to its constructive features, allows an easier and cheaper laying, capable of balancing possible negligences during the installation process.
The combination of light weight and high resistance, the small size of the outer diameter, a simple and safe junction system ensure a quick and easy laying.

Burying and trench width

European standards legislation specifies that trenches designed to house sewers must comply with precise requirements. UNI EN 1610 standard, in particular, says that narrow trenches must have a width which is 2-3 times bigger than the outer diameter of the pipeline.
The width of the trench must be the same for an area whose height is never less than one meter above the crown of the pipe. In this area, walls should be as much vertical as possible and stabilized with a shoring system for the protection of personnel working in the trench. Shoring will be removed immediately after the partial backfilling and before compaction.
In case of a large trench, however, there should be an area protected against backfilling material such as to comply as much as possible with the working conditions prescribed in the case of a narrow trench. As far as dimensions are concerned, UNI EN 1610 standard states that the minimum width should be no less than the upper value among those specified in the tables below, where OD represents the outer diameter of the pipe (in metres).

Table n. 1 - Trench minimum width in relation to pipe nominal dimensions

DN	Trench minimum width (OD + x) in m		
	Supported trench	Non - supported trench	
		ß > 60°	ß ≤ 60°
400 ≤ DN ≤ 700	OD + 0,70	OD + 0,70	OD + 0,40
700 < DN ≤ 1200	OD + 0,85	OD + 0,85	OD + 0,40
DN > 1200	OD + 1,00	OD + 1,00	OD + 0,40

Table n. 2 - Trench minimum width in relation to its depth

Trench depth (m)	Trench minimum width (m)
< 1,00	Not required
1,00 ≤ p ≤ 1,75	0,80
1,75 < p ≤ 4,00	0,90
> 4,00	1,00

If two or more than two pipelines are required, the standard prescribes a minimum horizontal distance between the pipelines:
- 0.35 m for pipes having a DN of 700 mm (included);
- 0.50 m for pipes having a DN of more than 700 mm.

Laying bed

Setting up the laying bed is one of the most difficult operations, since the pipeline is to be installed with the right slope that ensures a proper flowing of the conveyed fluid.
It is necessary to clear and level the laying bed as much as possible, by eliminating the bumps that could damage the pipes.
It is recommended to use sand and avoid the use of materials with sharp edges that can damage pipes. The laying surface, in any case, will work as a permanent and stable support to the pipeline.
In case of damages during laying operations, pipes will be repaired, if possible, or better replaced with new pipes.
The UNI EN 1610 prescribes that the thickness of the laying bed is not below:

- 1100 mm in normal soil conditions;
- 150 mm in hard ground conditions (rocks/stones).

Once verified the evenness of the laying bed, measurements will have to be very precise, so as to ensure the correct setup of the pipeline slope.
In presence of groundwater, appropriate pumping systems will allow to work in dry conditions.
Backfilling will be carried out in order to avoid the floating or the collapse of the pipe wall.
The possible migration of the sand can be prevented by adopting suitable geo-textiles materials.

Pipeline laying

The pipeline has to be positioned in the centre of the trench, after setting up the laying bed and checking soil level.
Junctions will be carried out by testing pipe alignment, the correct position of seals and examining the inside of the pipe for extraneous materials/debris.
Also the connection to manholes or tanks will follow the correct alignment of pipes, avoiding anomalous stresses on pipes and junctions.
Once tested the correct altimetric and planimetric positioning of the pipeline, sockets and pipes will be kept firm and steady by using sand; wedges should be avoided.

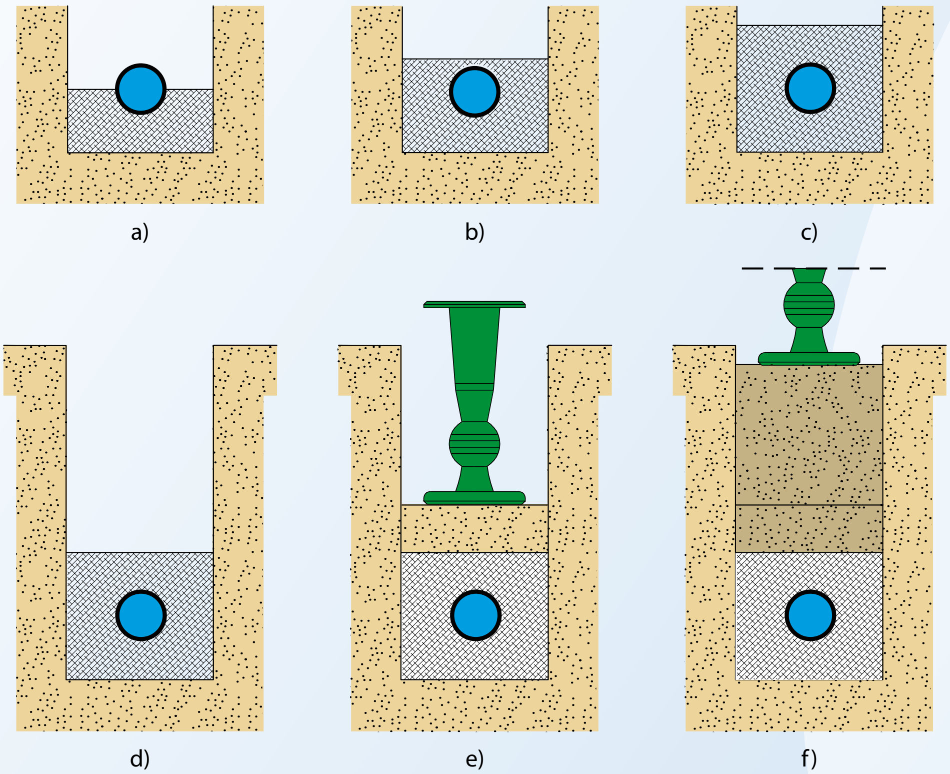
Backfilling and soil compaction

Backfilling and soil compaction are operations to accomplish in an accurate way, since they can affect the duration and the whole performance of the pipeline.
Firstly, it is necessary to select the correct filling material, preferably sand, and in any case a material with low granulometry, free of debris and stones. Filling material will be used all over the area surrounding the pipes and at least 20 cm over their upper side.
It is recommended to use a type of soil which is compatible with the static behaviour of the whole trench and the backfilling of its remaining part.
After completing the backfilling, it is necessary to carry out a very careful soil compaction, with particular attention to the filling material along the sides of the pipes. The process of compaction should be performed in more steps, by positioning layers (about 30 cm thick) in order to get a 90% Proctor degree.
The tools used for soil compaction will be different, so as to compact the soil in a homogeneous and regular way and prevent any misalignments and abnormal stresses on the connections.
Manual compaction methods will work better on the sides of the pipeline; in particular, the first sideways layers must exceed the pipe diameter in order to prevent its raising up.
Compaction will be carried out by using light tools up to a meter above the upper side of the pipe, after which normal means of compaction can be employed.
The table that follows, included in UNI EN 1046 standard, summarizes the recommended thickness for every soil layer and the number of steps required to obtain the different classes of compaction, depending on the type of equipment and the filling materials.
The following table also reports the minimum thickness for every layer of backfilling material before carrying out soil compaction.

Table n. 1 - Compaction method (according to UNI EN 1046)

Compaction method	Number of passages for every compaction class			Thickness after compacting for every soil class (m)				Minimum thickness before compaction (m)
	B (good)	M (medium)	N (without)	group 1	group 2	group 3	group 4	group 1-4
On foot or hand mallet								
15 kg minimum	3	1	0	0.15	0.10	0.10	0.10	0.20
Vibrating mallet								
70 kg minimum	3	1	0	0.30	0.25	0.20	0.15	0.35
Flat vibrator								
50 kg minimum	4	1	0	0.10	-	-	-	0.15
100 kg minimum	4	1	0	0.15	0.10	-	-	0.20
200 kg minimum	4	1	0	0.20	0.15	0.10	-	0.25
400 kg minimum	4	1	0	0.30	0.20	0.15	0.10	0.35
600 kg minimum	4	1	0	0.40	0.30	0.20	0.15	0.50
Vibrating roller								
15 kW/m minimum	6	2	0	0.35	0.25	0.20	-	0.60
30 kW/m minimum	6	2	0	0.60	0.50	0.30	-	1.20
45 kW/m minimum	6	2	0	1.00	0.75	0.40	-	1.80
65 kW/m minimum	6	2	0	1.50	1.10	0.60	-	2.40
Double vibrating roller								
5 kW/m minimum	6	2	0	0.15	0.10	-	-	0.20
10 kW/m minimum	6	2	0	0.25	0.20	0.15	-	0.45
20 kW/m minimum	6	2	0	0.35	0.30	0.20	-	0.60
30 kW/m minimum	6	2	0	0.50	0.40	0.30	-	0.85
Triple heavy roller without vibrations								
50 kW/m minimum	6	2	0	0.25	0.20	0.20	-	1.00

Table n. 2 - Backfilling and compaction process



a) Manually compacted sand on pipe sides.
b) Manually compacted sand until the upper surface of the pipe.
c) Backfilling with sand up to 20 cm at least above the upper surface of the pipe.

d) Mechanical compaction by vibrating plate.
e) Backfilling by using uniform material arranged in layers of 30 cm; mechanical compaction.
f) Further mechanical compaction after the consolidation of the backfilling.

Expansion

The thermal expansion of **PALADEX** pipe is not significant if compared to other polyethylene pipes, but has to be considered when involving temperature changes.

During ordinary operations (pipes are underground), the interaction with the surrounding soil and its insulating properties will prevent any expansion, making the calculation useless.

Nonetheless, it is advisable to calculate the length variation due to expansion every time it is necessary to cut a pipe section.

Hereinafter the formula for calculating the thermal expansions: $\Delta L = \alpha \cdot \Delta T \cdot L_0$ [mm]

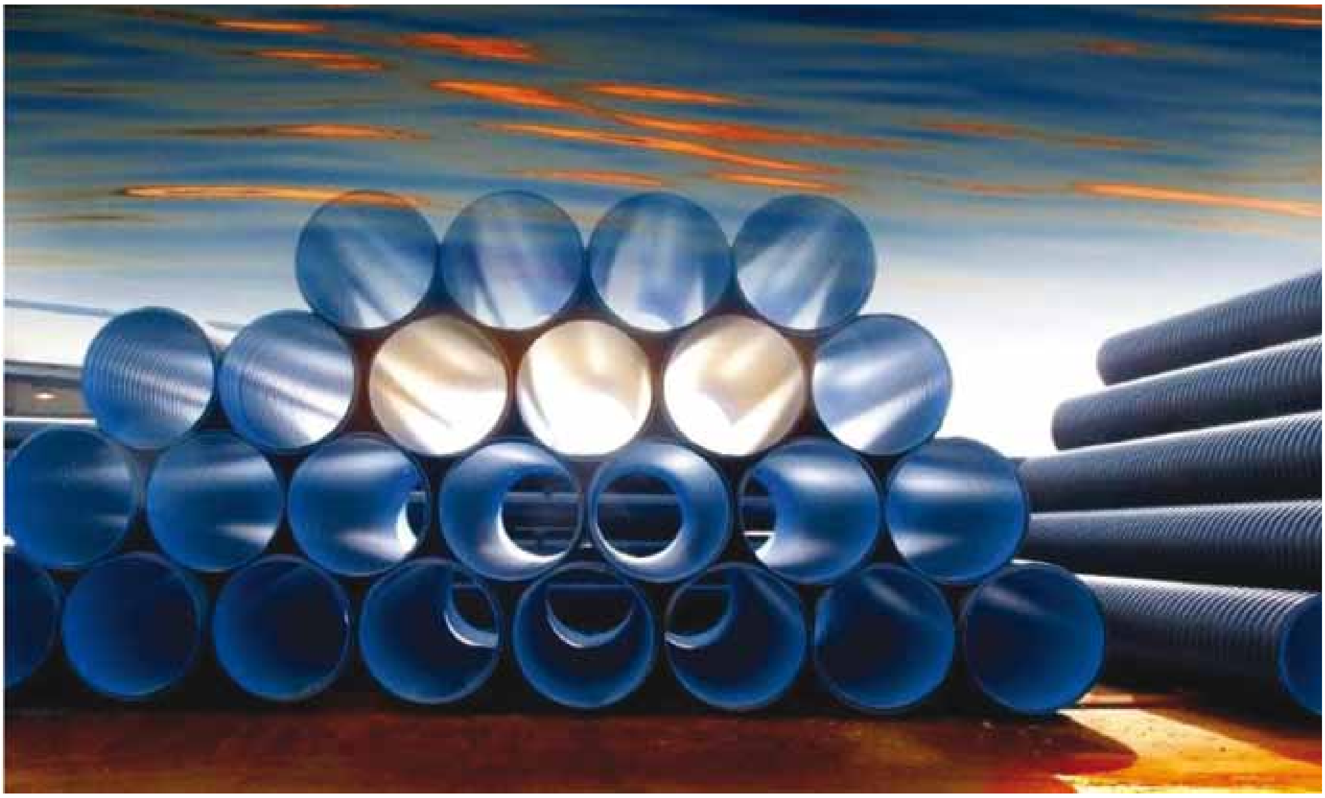
Where:

ΔL change of length;

α coefficient of linear expansion, that is $1{,}7\ 10^{-4}$ [1/°C];

ΔT change of temperature [°C];

L_0 length of a given pipe section [mm].



Hydraulic characteristics

Thanks to the smooth surface of their polyethylene inner walls, **PALADEX** pipes have an excellent water conductivity if compared to all other drainage pipes on the market (concrete, cast iron, steel, clay, fiber glass).
The excellent surface smoothness allows the design of draining lines that reach high flow rates at very low longitudinal slopes.
The low hydraulic resistance prevents the presence of debris inside the pipelines, thus avoiding periodical cleaning.
The nominal diameter of **PALADEX** pipes is based on their inner diameter, thus improving hydraulic dimensioning.
The calculation of flow rate, given the values of slope and fill level, is based on the Gauckler-Strickler formula:

$$Q = K_S \cdot R_H^{\frac{2}{3}} \cdot i^{\frac{1}{2}} \cdot A$$

Where:

Q flow rate [m^3/s];

A cross sectional area of the flow [m^2];

R_H hydraulic radius (m), defined as the ratio of the cross-sectional area of a flow channel to the wetted perimeter of the flow;

i longitudinal slope of the conduit;

K_S roughness index according to Gauckler-Strickler which, for sewages in polyethylene, has a value of 80 $m^{1/3}\ s^{-1}$.

Flow speed can be calculated in the following way: $v = Q/A$

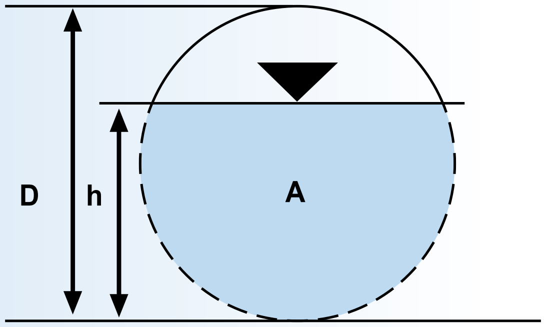
Where:

v flow rate within the pipe [m/s];

Q flow rate [m^3/s];

A cross sectional area of the flow [m^2].

The parameters **A** and **R_H** can be calculated if the fill level **h/D** is known (**h** = filling height; D = pipe inner diameter), as we can see from the chart:



The table below recaps the values for the cross section of the conduit **A** and hydraulic radius R_H calculated according to the fill level **h/D**

h/D	A/D^2	R_H/D
0,30	0,1982	0,1709
0,40	0,2934	0,2142
0,50	0,3927	0,2500
0,60	0,4920	0,2776
0,70	0,5872	0,2962
0,75	0,6319	0,3017
0,80	0,6736	0,3042
0,90	0,7115	0,2980
1,00	0,7854	0,2500

Example: for a pipeline with fill level **h/D** = 0,50 the cross-sectional area of the flow **A** will be 0,3927 • D^2 and the hydraulic radius R_H will be 0,25 • **D**

When dimensioning sewer pipelines, it is also important to test if tangential stress (measured in Pa), which the flow generates on the pipeline bottom, can prevent sediment deposition.
Usually, this is the formula that is used:

$$\tau = \gamma R_H \cdot i \geq 2Pa$$

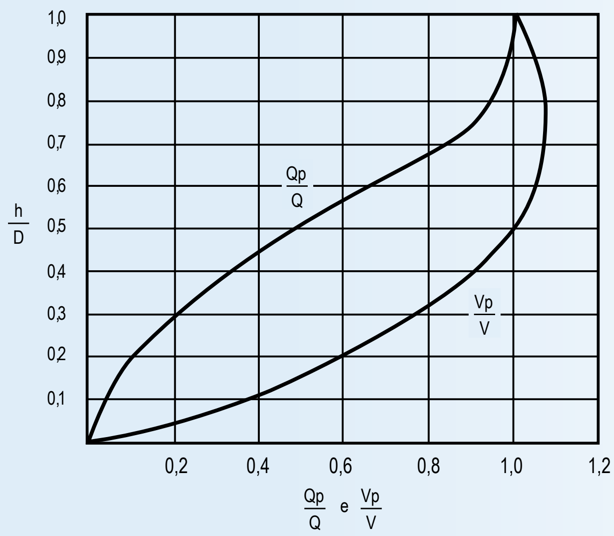
Where:

γ specific weight of water [N/m³];

R_H hydraulic radius [m];

i longitudinal slope of the conduit.

The following chart allows to calculate the hydraulic section that is required for a specific project:



Where:

Vp flow speed / partial filling [m/s]

V flow speed / total filling [m/s]

Qp flow rate / partial filling [m³/s]

Q flow rate / total filling [m³/s]

h/D fill level of the conduit

Table of flow rate values (m^3/s) at different slopes for Paladex pipes

D (mm)	300		400		500		600		700		800	
A (m²)	0,071		0,126		0,196		0,283		0,385		0,503	
i (%)	flow speed (m/s)	flow rate (m³/s)	flow speed (m/s)	flow rate (m³/s)	flow speed (m/s)	flow rate (m³/s)	flow speed (m/s)	flow rate (m³/s)	flow speed (m/s)	flow rate (m³/s)	flow speed (m/s)	flow rate (m³/s)
0,1	0,450	0,032	0,545	0,068	0,632	0,124	0,714	0,202	0,791	0,305	0,865	0,435
0,2	0,636	0,045	0,771	0,097	0,894	0,176	1,010	0,286	1,119	0,431	1,224	0,615
0,3	0,779	0,055	0,944	0,119	1,095	0,215	1,237	0,350	1,371	0,528	1,499	0,753
0,4	0,900	0,064	1,090	0,137	1,265	0,248	1,428	0,404	1,583	0,609	1,730	0,870
0,5	1,006	0,071	1,219	0,153	1,414	0,278	1,597	0,452	1,770	0,681	1,935	0,972
0,6	1,102	0,078	1,335	0,168	1,549	0,304	1,749	0,495	1,939	0,746	2,119	1,065
0,7	1,190	0,084	1,442	0,181	1,673	0,329	1,890	0,534	2,094	0,806	2,289	1,151
0,8	1,273	0,090	1,542	0,194	1,789	0,351	2,020	0,571	2,239	0,862	2,447	1,230
0,9	1,350	0,095	1,635	0,205	1,897	0,373	2,143	0,606	2,374	0,914	2,596	1,305
1	1,423	0,101	1,724	0,217	2,000	0,393	2,258	0,639	2,503	0,963	2,736	1,375
1,5	1,743	0,123	2,111	0,265	2,449	0,481	2,766	0,782	3,065	1,180	3,351	1,684
2	2,012	0,142	2,437	0,306	2,828	0,555	3,194	0,903	3,540	1,362	3,869	1,945
2,5	2,250	0,159	2,725	0,342	3,162	0,621	3,571	1,010	3,957	1,523	4,326	2,174
3	2,464	0,174	2,985	0,375	3,464	0,680	3,912	1,106	4,335	1,668	4,739	2,382
3,5	2,662	0,188	3,224	0,405	3,742	0,735	4,225	1,195	4,683	1,802	5,119	2,573

D (mm)	900		1000		1100		1200		1300		1400	
A (m²)	0,636		0,785		0,950		1,131		1,327		1,539	
	flow speed (m/s)	flow rate (m³/s)	flow speed (m/s)	flow rate (m³/s)	flow speed (m/s)	flow rate (m³/s)	flow speed (m/s)	flow rate (m³/s)	flow speed (m/s)	flow rate (m³/s)	flow speed (m/s)	flow rate (m³/s)
0,1	0,936	0,595	1,004	0,789	1,070	1,017	1,134	1,282	1,196	1,587	1,256	1,934
0,2	1,324	0,842	1,420	1,115	1,513	1,438	1,603	1,813	1,691	2,245	1,777	2,735
0,3	1,621	1,031	1,739	1,366	1,853	1,761	1,964	2,221	2,071	2,749	2,176	3,350
0,4	1,872	1,191	2,008	1,577	2,140	2,033	2,267	2,564	2,392	3,175	2,513	3,868
0,5	2,093	1,331	2,245	1,763	2,392	2,273	2,535	2,867	2,674	3,549	2,809	4,325
0,6	2,292	1,458	2,459	1,931	2,621	2,490	2,777	3,141	2,929	3,888	3,078	4,738
0,7	2,476	1,575	2,656	2,086	2,830	2,690	3,000	3,392	3,164	4,200	3,324	5,117
0,8	2,647	1,684	2,840	2,230	3,026	2,876	3,207	3,627	3,382	4,490	3,554	5,470
0,9	2,808	1,786	3,012	2,366	3,209	3,050	3,401	3,847	3,588	4,762	3,769	5,802
1	2,959	1,883	3,175	2,493	3,383	3,215	3,585	4,055	3,782	5,019	3,973	6,116
1,5	3,625	2,306	3,888	3,054	4,143	3,938	4,391	4,966	4,632	6,148	4,866	7,491
2	4,185	2,663	4,490	3,526	4,784	4,547	5,070	5,734	5,348	7,099	5,619	8,650
2,5	4,679	2,977	5,020	3,943	5,349	5,083	5,669	6,411	5,979	7,936	6,282	9,671
3	5,126	3,261	5,499	4,319	5,860	5,569	6,210	7,023	6,550	8,694	6,882	10,594
3,5	5,537	3,522	5,940	4,665	6,329	6,015	6,707	7,586	7,075	9,391	7,433	11,442

Table of flow rate values (m^3/s) at different slopes for Paladex pipes

D (mm)	1500		1600		1700		1800		1900	
A (m^2)	1,767		2,011		2,270		2,545		2,835	
i (%)	flow speed (m/s)	flow rate (m^3/s)	flow speed (m/s)	flow rate (m^3/s)	flow speed (m/s)	flow rate (m^3/s)	flow speed (m/s)	flow rate (m^3/s)	flow speed (m/s)	flow rate (m^3/s)
0,1	1,316	2,325	1,373	2,761	1,430	3,246	1,486	3,780	1,540	4,367
0,2	1,860	3,288	1,942	3,905	2,022	4,590	2,101	5,346	2,178	6,175
0,3	2,279	4,027	2,379	4,783	2,477	5,622	2,573	6,548	2,668	7,563
0,4	2,631	4,650	2,747	5,523	2,860	6,492	2,971	7,561	3,080	8,733
0,5	2,942	5,198	3,071	6,175	3,198	7,258	3,322	8,453	3,444	9,764
0,6	3,222	5,695	3,364	6,764	3,503	7,951	3,639	9,260	3,772	10,696
0,7	3,481	6,151	3,634	7,306	3,784	8,588	3,930	10,002	4,075	11,553
0,8	3,721	6,575	3,885	7,810	4,045	9,181	4,202	10,692	4,356	12,351
0,9	3,947	6,974	4,120	8,284	4,290	9,738	4,457	11,341	4,620	13,100
1	4,160	7,352	4,343	8,732	4,522	10,264	4,698	11,955	4,870	13,809
1,5	5,095	9,004	5,319	10,695	5,539	12,571	5,754	14,641	5,965	16,912
2	5,883	10,397	6,142	12,349	6,395	14,516	6,644	16,906	6,888	19,528
2,5	6,578	11,624	6,867	13,807	7,150	16,230	7,428	18,902	7,701	21,833
3	7,206	12,733	7,522	15,125	7,833	17,779	8,137	20,706	8,436	23,917
3,5	7,783	13,754	8,125	16,337	8,460	19,203	8,789	22,365	9,111	25,834

D (mm)	2000		2100		2200		2300		2400	
A (m^2)	3,142		3,464		3,801		4,155		4,524	
	flow speed (m/s)	flow rate (m^3/s)	flow speed (m/s)	flow rate (m^3/s)	flow speed (m/s)	flow rate (m^3/s)	flow speed (m/s)	flow rate (m^3/s)	flow speed (m/s)	flow rate (m^3/s)
0,1	1,594	5,007	1,646	5,702	1,698	6,456	1,749	7,268	1,800	8,141
0,2	2,254	7,081	2,328	8,064	2,402	9,130	2,474	10,278	2,545	11,514
0,3	2,760	8,672	2,852	9,877	2,941	11,181	3,030	12,589	3,117	14,101
0,4	3,187	10,013	3,293	11,405	3,396	12,911	3,499	14,536	3,599	16,283
0,5	3,564	11,195	3,681	12,751	3,797	14,435	3,912	16,252	4,024	18,205
0,6	3,904	12,264	4,033	13,968	4,160	15,813	4,285	17,803	4,408	19,942
0,7	4,217	13,247	4,356	15,087	4,493	17,080	4,628	19,229	4,761	21,540
0,8	4,508	14,161	4,657	16,129	4,803	18,259	4,948	20,557	5,090	23,028
0,9	4,781	15,020	4,939	17,107	5,095	19,367	5,248	21,804	5,399	24,424
1	5,040	15,833	5,206	18,033	5,370	20,414	5,532	22,983	5,691	25,746
1,5	6,172	19,391	6,376	22,085	6,577	25,002	6,775	28,149	6,970	31,532
2	7,127	22,391	7,363	25,502	7,595	28,870	7,823	32,503	8,048	36,410
2,5	7,968	25,034	8,232	28,512	8,491	32,278	8,747	36,340	8,998	40,707
3	8,729	27,423	9,018	31,233	9,302	35,359	9,581	39,808	9,857	44,593
3,5	9,428	29,620	9,740	33,736	10,047	38,192	10,349	42,998	10,647	48,166

Loads design

Maximum allowable deformation

PALADEX pipe is included in the category of the so called “flexible” pipes, unlike the pipes defined “rigid” (concrete, cast-iron, clay etc.), which means that vertical deformation closely depends on the quality of surrounding filling soil which supports the pipe on its sides and prevents its ovalization.
According to international standards related to laying and testing polyethylene pipes, the methods for calculating loads and deformations of flexible pipes are based on the maximum allowable perpendicular deformation as a result of outside loads, caused by soil pressure, road vehicles and groundwater.
In order to ensure a proper loads design, it is necessary to establish the granule-metric and compaction characteristics of the filling soil used during the laying.

The methodology of analysis used herein is the one developed by Spangler and modified by Barnard, as we can see in the following formula:

$$\Delta_v = \frac{[(d_1 \cdot q_t) + q_m + q_f] \cdot K_x}{8 \cdot SN + 0{,}061 \cdot E} \quad [m]$$

Where:

- **Δ_v** deformation [m];
- **d_1** auto-compaction factor;
- **q_t** load due to filling soil [N/m];
- **q_m** vertical loads due to pressure from a surface road (weight of asphalt, vehicles etc.) [N/m];
- **q_f** loads due to groundwater [N/m];
- **K_x** coefficient related to support angle;
- **SN** ring stiffness [N/m2];
- **E** soil modulus of resistance [N/m2].

The auto-compaction factor **d_1** is 1.5 in case of low compaction and 2 in case of medium compaction.

The values for **K_X,** related to the support angle, are recapped in the table below:

Support angle	0°	90°	120°	180°
K_x	0,110	0,096	0,090	0,083

By increasing the support angle, the values for **K_X** and deformation will be lower and lower.
If you use flexible pipes, it is recommended to create a laying bed that allows a support angle between 90°and 120°.

The calculation of soil modulus of resistance (E) can be obtained in the following way:

E = E$_S$ (soil elastic reaction modulus) • **r** (pipe radius)

The value of **E$_S$** is related to soil compaction and granulometry, according to the values (10^6 N/m^2) recapped in the table below.

Filling materials

<table>
<tr><th>SOIL COMPACTION (PROCTOR DENSITY)</th><th>Fine-grained soil: group 4 with less than 25% of coarse - grained particles</th><th>Fine-grained soil: group 4 with more than 25% of coarse - grained particles</th><th>Coarse-grained soil: group 3 with more than 12% of particles</th><th>Coarse-grained soil: group 2 with less than 12% of finegrained particles</th><th>Coarse-grained soil: group 1 with less than 12% of finegrained particles</th><th>Smashed up rock: group 1</th></tr>
<tr><td></td><td>0.34</td><td>0.69</td><td rowspan="2">0.69</td><td rowspan="4">1.4</td><td rowspan="7">1.4</td><td rowspan="7">6.9</td></tr>
<tr><td>75% - 78%</td><td rowspan="2">1.40</td><td rowspan="2">2.80</td></tr>
<tr><td>79% - 80%</td><td rowspan="3">2.80</td></tr>
<tr><td>81% - 83%</td><td rowspan="2">1.40</td><td rowspan="2">2.80</td></tr>
<tr><td>84%</td><td>6.90</td></tr>
<tr><td>85%</td><td rowspan="2">2.80</td><td rowspan="2">6.90</td><td>6.90</td><td rowspan="2">13.80</td></tr>
<tr><td>86% - 89%</td><td rowspan="2">6.90</td></tr>
<tr><td>90% - 92%</td><td rowspan="3">2.80</td><td rowspan="3">6.90</td><td rowspan="3">13.80</td><td rowspan="2">13.80</td><td rowspan="2">20.70</td></tr>
<tr><td>93% - 94%</td><td>6.90</td></tr>
<tr><td>95%</td><td rowspan="2">13.80</td><td rowspan="3">20.70</td><td rowspan="3">20.70</td></tr>
<tr><td>96%</td><td></td><td></td><td rowspan="3">20.70</td></tr>
<tr><td>97%</td><td></td><td></td><td></td></tr>
<tr><td>96% -100%</td><td></td><td></td><td></td><td>20.70</td><td>20.70</td></tr>
</table>

- Randomly discharged and without proctor density check
- Class N: No compaction, but including proctor density check
- Class M: Medium compaction
- Class B: Good compaction

According to Spangler equation:
Max deformation = load exerted onto the pipe / pipe stiffness + soil stiffness.

Calculation of soil loads

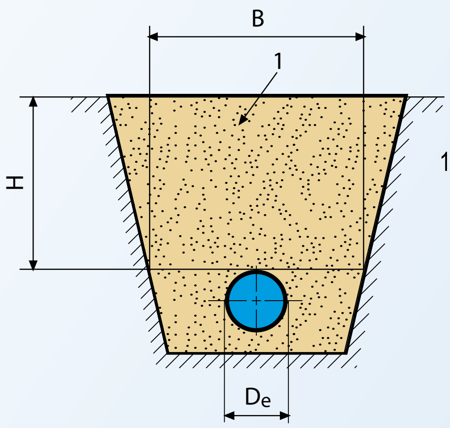
The load exerted by the covering soil onto the pipe depends on several factors: the type of trench, the typology of materials used for the covering, the possible presence of groundwater and the overall height of the covering soil on the upper surface of the pipe.

Types of trench

The ratio between the geometrical dimensions of the trench (width B and height H) and the outer diameter (D_e) of the pipeline can single out three types of trench.
The size of **PALADEX** pipes, on equal hydraulic section and ring stiffness values, is lower than traditional corrugated pipes, which allows a reduction of the trench width

Narrow trench:

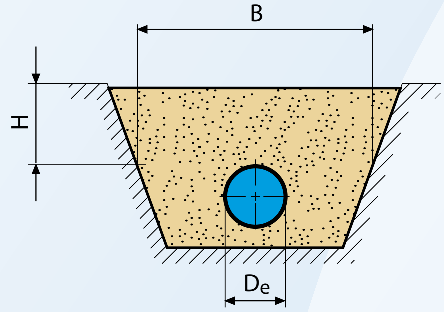
$B \leq 3D_e \quad H \geq 2B$



A trench is considered 'narrow' if its width is lower than/equivalent to the triple of the pipe outside diameter and its height is equivalent/more than the double of its width

Large trench:

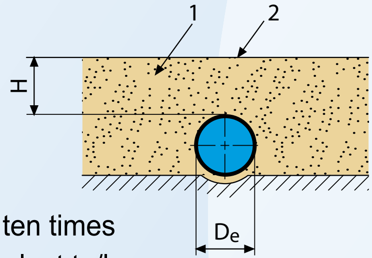
$3D_e < B < 10D_e \quad H \leq 2B$



A trench is considered 'large' if its width is between three/ten times the pipe outside diameter and its height is equivalent to/lower than the double of its width.

Endless trench or bank

$B \geq 10D_e \quad H \leq 2B$



A trench is considered 'endless' if its more than ten times the pipe outside diameter and its height is equivalent to/lower than the double of its width.

Calculation of soil load (q_t) for a narrow trench

In case of a narrow trench, pipes do not support the full weight of the filling soil, which is partially withstood by the friction between soil and side walls.
Therefore, the formula to calculate soil load q_t is:

$$q_t = C \cdot \gamma_t \cdot D_e \cdot B \qquad [N/m]$$

Where:

- q_t soil load [N/m];
- **C** soil loading rate;
- γ_t specific weight of the filling soil [N/m³] as specified in Table n. 1;
- D_e pipe outside diameter [m];
- **B** trench width [m].

Soil loading rate can be calculated in the following way:

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

Where:

- θ friction angle between the filling material and the side walls of the trench (see Table n. 2);
- **H** covering height of the pipe measured from the upper surface [m];
- **B** trench width [m].
- **K** Rankine's dimension-less coefficient, calculated as: $K = \frac{1 - \sin ø}{1 + \sin ø}$

Where:

- **ø** inner friction angle of filling material, as specified in Table n. 3.

Table n. 1 - Specific weight of the filling material

Type of soil	Specific weight [n/m³]
Granular soil, without cohesion	17.000
Sand and gravel	19.000
Saturated rural soil, clayey	20.000
Normal solid clay	21.000
Saturated clay	22.000

Table n. 2 - Friction angle between the filling material and the side walls of the trench

	Filling material	
Original soil	Sand	Gravel
Smooth rocks	25°	30°
Marl	30°	35°
Schistose rocks	35°	40°

Table n. 3 - Inner friction angle of the filling material

Filling material	Angle Ø
Plastic Clay	11° - 12°
Morbid soil	12°
Normal clay	14°
Clayey loess	18°
Sandy marl	20°
White marl	22°
Very solid marl	24°
Green marl	26°
Wet sand	30°
Non-pressed fine sand	31°
Sand and gravel	33°
Gravel and stones	37°
Big stones	44°

Calculation of soil load (q_t) for large/endless trenches

In case of a large or endless trench, pipes will withstand the overall weight of the filling soil.
Therefore, q_t will be equivalent to:

$$q_t = \gamma_t \cdot D_e \cdot H \qquad [N/m]$$

Where:

q_t soil load [N/m];

γ_t specific weight of the filling soil [N/m³] as specified in Table n. 1;

H covering height of the pipe measured from the upper surface [m];

D_e pipe outside diameter [m].

Calculation of surface vertical overloads (q_m)

Vertical overloads are due to surface stresses, movable or fixed ones, acting onto the filling soil. Overloads can be sharp-type (the pressure of a motor vehicle tyre) or spread-type (the weight of an asphalt road).

This issue is here simplified by considering the stress coming from a load placed vertically above the pipeline in an endless trench.

The pertinent formula is:

$$q_m = \frac{3}{2 \cdot \pi} \cdot \frac{P}{\left(H + \frac{D_e}{2000} \right)} \cdot \varphi \qquad [N/m]$$

Where:

q_m vertical loads due to pressure from a surface road [N/m];

P surface load [N];

H covering height of the pipe measured from the upper surface [m];

D_e pipe outside diameter [m];

φ corrective coefficient for loads typology.

In particular for:

$\varphi = 1$ static loads

$\varphi = 1 + \frac{0,3}{H}$ dynamic road loads

$\varphi = 1 + \frac{0,6}{H}$ dynamic railway loads

Stresses due to road traffic are summarized in the following table:

Table n. 4 - Road loads according to traffic type

Traffic type	Total load (N)	Max load per wheel
Heavy	600.000	100.000
Medium	450.000 300.000	75.000 50.000
Light	120.000 60.000	20.000 front. 40.000 back. 20.000
Car	30.000	10.000

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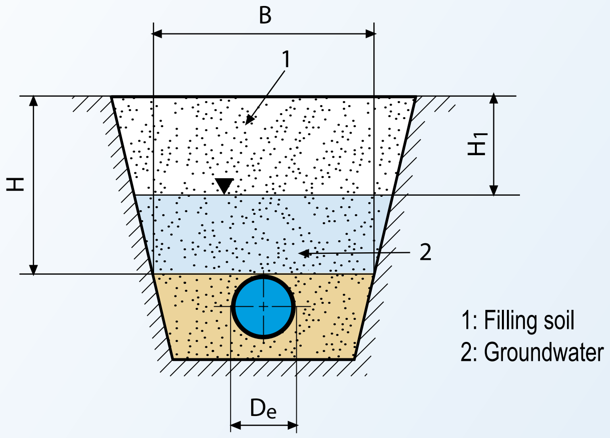
Calculation of loads due to groundwater (q_f)

The load due to groundwater can affect the pipeline and cause a further stress q_f according to the formula:

$$q_f = \gamma_w \cdot \left(H - H_1 + \frac{D_e}{2000} \right) \quad [N/m]$$



Where:

q_f groundwater load [N/m];

γ_w water specific weight;

H height of the covering filling measured from the upper surface [m];

H_1 height of the covering filling measured above the groundwater [m];

D_e pipe outside diameter.

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