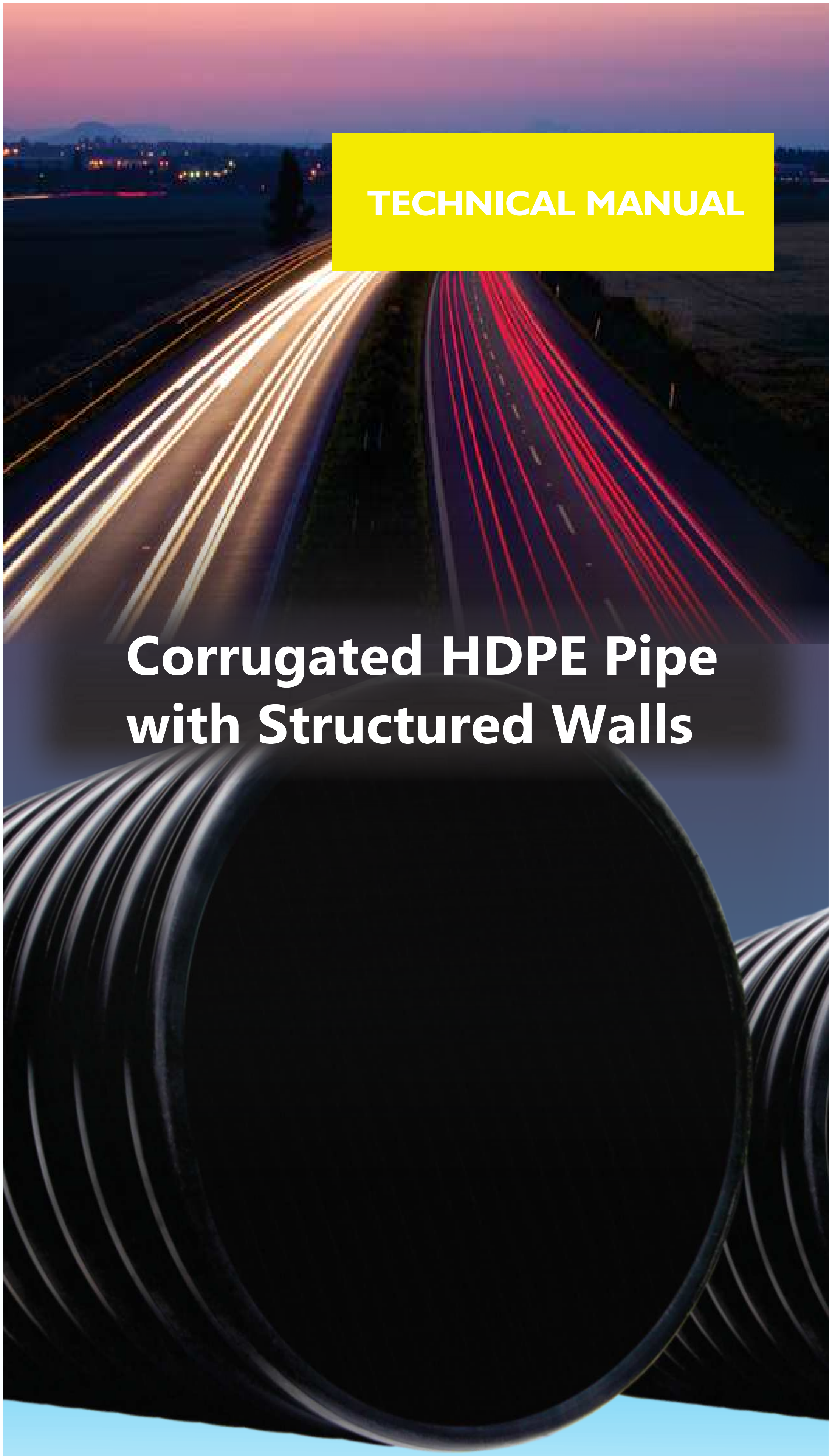
KNTS Drain

TECHNICAL MANUAL

Corrugated HDPE Pipe with Structured Walls



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1. Introduction

KNTS Drain is a corrugated pipe with structured walls, double-walled with a smooth inner wall and a ring corrugated outer wall, made from HDPE (High Density Polyethylene), designed to conduct liquids by gravity in underground infrastructure networks.

This manual provides technical support for designers and installers and does not replace engineering criteria, safety regulations or any other local laws and provisions, as well as the specifications and instructions of the designer, the final authority at all stages of engineering work.

Item 2 presents the technical and dimensional characteristics of KNTS Drain pipes and fittings.

Item 3 presents the parameters and formulas that allow the calculation of vertical deflections and hydraulic performance of pipes.

KNTS Drain pipes must be installed taking into account the laying and backfill support of the pipe in accordance with the guidelines contained in item 4, since the success of the construction of networks with non-rigid pipes depends mainly on the type of execution (trench or landfill) and the behavior of the surrounding and covering soil. The pipe and the enclosing/covering material form a pipe-soil system, since buried non-rigid pipes are structures that interact strongly with the surrounding soil. To provide information for those unfamiliar with the field of geotechnics, this item covers some concepts of soil mechanics, so as to provide the basic foundation needed to understand correct installation, involving materials, precautions and methods that add safety to the execution of the pipeline system in the field.

Installation must be carried out carefully and properly to maximize the results of the countless advantages that KNTS Drain pipes provide.

2. Technical and Dimensional Characteristics - Pipe and fittings

KNTS Drain is a double-walled corrugated pipe with a smooth inner wall and a ring corrugated outer wall made from HDPE (High Density Polyethylene). Designed to be used in underground installations, it is used for rainwater drainage and groundwater conveyance. When compared to most pipes made from other materials, KNTS Drain provides higher flow velocities and flow rates in the pipeline system.

It is manufactured as a 6-meter bar with an integrated bell and a supplied sealing ring positioned at the end of the bell. The joint between pipes, of the elastic joint type, is easy and quick to assemble. It allows expansions and angular deflections in the network, facilitating the adaptation of the pipe according to the design layout and reducing the need for connections.

Figure 1 - KNTS Drain Pipe Manufacture

Available in stiffness rating SN4 (4KN/m^2) according to ISO 9969 in nominal diameters from 250 to 1200 (Table 2); the KNTS Drain has high mechanical performance, enabling safe installation when the design parameters and installation guidelines contained in this manual are respected.

KNTS Drain is manufactured in accordance with the highest standards and meets the standard DNIT 094/2014-EM: Glass fiber reinforced polyester (GRP) and polyolefin (PE and PP) pipes for road drainage - Material specification**.**

KNTS Drain characteristics:

- **Lightness:** significantly reduces the risk of accidents to personnel and the need for heavy machinery in the transportation, handling and trench laying stages;
- **6-meter bar:** allows a faster installation when compared to other pipes with the same application, providing significant productivity gains on site;
- **High chemical resistance:** allows installation in soils with high salinity; immunity to accidental passage of aggressive fluids or industrial effluents;
- **Low roughness:** its Manning coefficient of 0.010 allows the reduction of the installation slope and/or, in many cases, reduces the inner diameter of galleries previously designed for pipes with greater roughness, without sacrificing the design flow rate;
- **High impact resistance:** reduces to zero the loss of material due to breakages resulting from falls and any mechanical shocks during the handling / transportation / installation stages on site;

- Spigot-bell-sealing ring joint: the profile of the KNTS Drain pipe, which is regular over the entire section, allows the spigot-bell-sealing ring to fit together perfectly, providing the network with a high degree of watertightness;

KNTS Drain is also manufactured in the perforated type, intended to be used in drainage devices to capture groundwater on roads, railroads, airports, sports fields and other infrastructure works where there is a need to control infiltrated water or water rising from the water table. In this case, **Perforated KNTS Drain Pipe** must be specified (for this option, the sealing ring is not provided with the bar).

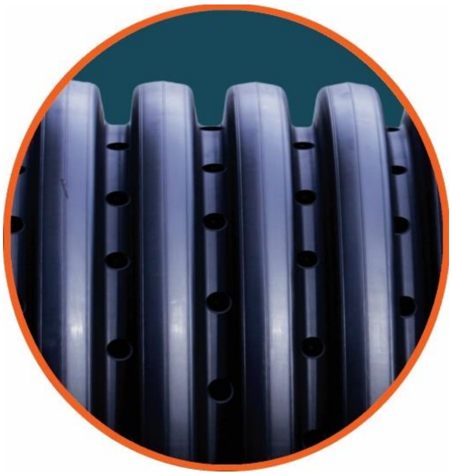


Figure 2 - Perforated KNTS Drain Pipe

2.1 Raw material

2.1.1. Polyethylene

Polyethylene (PE) is a plastic obtained by joining countless ethylene molecules (monomers) through the polymerization reaction, generating a large macromolecule, which in turn gives this material the characteristics of a polymer.

Polymers that consist solely of carbon and hydrogen (hydrocarbons) are classified as polyolefins. PE is the polyolefin with the simplest molecular structure and is the most widely used plastic in the world today.

The advantages of PE include:

- lightness;
- high chemical resistance;
- excellent elasticity;
- high abrasion resistance;
- high impact resistance, even at low temperatures.

2.1.2. Types of PE According to Density

PE is remarkable for its wide density range and, according to this property, can be divided into:

High Density Polyethylene	**HDPE**
Medium Density Polyethylene	**MDPE**
Low Density Polyethylene	**LDPE**

The PE used to manufacture the KNTS Drain pipe has a typical density value of approximately 0.95 g/cm³, which classifies it as HDPE pipe. Due to this characteristic, combined with the corrugated structure of the pipe, the end product is very light compared to pipes made from other materials and used in the same application.

2.1.3. Chemical Resistance of PE

PE has an apolar structure similar to that of paraffinic hydrocarbons and that is why this polymer has excellent resistance to chemical substances.

PE is resistant to aqueous solutions of salts, dilute acids and alkalis. Only strongly oxidizing agents such as highly concentrated peroxides and acids or halogens attack PE after a prolonged period of exposure.

However, such resistance does not exclude the possibility that, under certain conditions, the mechanical properties of PE may be influenced by the action of chemical compounds. For more specific and detailed information, we recommend consulting ISO/TR 10358 “Plastics pipes and fittings - Combined chemical - resistance classification table”.
Some information on the Chemical Resistance of PE is shown in Table 1.

Product	Temperature		Product	Temperature	
	20°C	60°C		20°C	60°C
Lead acetate	E	E	Sodium chloride	E	E
Acetone 100%	E	E,D	Zinc chloride	E	E
Glacial acetic acid	E	G,D,c,f	Chlorine (gas and liquid)	F	N
Hydrobromic acid 100%	E	E	Chlorobenzene	G	F,D,d,c
Carbonic acid	E	E	Chloroform	G	F,D,d,c
Carboxylic acid	E	E	Detergents	E	E,c
Hydrocyanic acid	E	E	Dichlorobenzene	F	F
Hydrochloric acid	E	E,d	Dioctyl phthalate	E	G,c
Chlorosulfonic acid	F	N	Liquid sulfur dioxide	F	N
Chromic acid 80%	E	F,D	Sulfur	E	E
Hydrofluoric acid 1-75%	E	E	Turpentine	G	G
Phosphoric acid 30-90%	E	G,D	Aliphatic esters	E	G
Glycolic acid 55-70%	E	E	Ether	G	F
Nitric acid 50%	G,D	F,D,f	Petroleum ether	G,d,i	F,d
Nitric acid 95%	N,F,f	N,c	Fluorine gas 100%	N	N
Perchloric acid 70%	E	F,D	Gasoline	E	G,c
Salicylic acid	E	E	Ammonium hydroxide 30%	E	E
Sulfuric-chromic acid	F	F,f	Conc. potassium hydroxide	E	E,c
Sulfuric acid 50%	E	E	Conc. sodium hydroxide	E	E,c
Sulfuric acid 98%	G,D	F,D,f	Sat. calcium hypochlorite	E	E
Sulfurous acid	E	E	Sodium hypochlorite 15%	E	E,D,d
Tartaric acid	E	E	Iso-octane	G	G
Trichloroacetic acid 50%	E	E	Methyl ethyl ketone	E	F
Trichloroacetic acid100%	E	F	Naphtha	E	G
Acrylonitrile	E	E	Saturated ammonium nitrate	E	E
Seawater	E	E	Silver nitrate	E	E
Benzyl alcohol	E	E	Sodium nitrate	E	E
Butyl alcohol	E	E	Nitrobenzene	F	N,c
Ethyl alcohol 96%	E	E	Edible oil	E	E
Methyl alcohol	E	E	Diesel oil	E	G
Ammonia	E,D,d	E,D,d	Phosphorus pentoxide	E	E
Anhydrous acetic	E	G,D	Potassium permanganate	D,E	E
Aniline	E	G	Hydrogen peroxide 30%	E	E,d
Benzene	G,d	G,d,i	Petroleum	E	G
Sodium benzoate	E	E	Kerosene	G	G,c
Potassium bichromate 40%	E	E,D	Nickel salts	E	E
Sodium borate	E	E	Metal sulfates	E	E
Bleaches	E	G,c	Sodium sulfide	E	G
Liquid bromine	F	N	Carbon tetrachloride	G,d,i	F,d,c
Sodium carbonate	E	E	Trichloroethylene	F,D	N,D
Ammonium chloride	E	E	Xylene (xylol)	G,d,i	F,c,d

Table 1 - Chemical Resistance of PE

CAPTION:

D - Discoloration.

E - 30-day exposure without losing characteristics and able to tolerate contact for many years.

F - Some signs of attack after 7 days in contact with the product.

G - Slight absorption after 30 days of exposure, without compromising mechanical properties.

N - Not recommended. Signs of attack detected between minutes and hours since the beginning of exposure.

c - Cracking.

d - Deformation.

f - Fragilization.

i - Swelling.

2.1.4. HDPE Abrasion Resistance

HDPE has excellent abrasion resistance compared to other materials used in the manufacture of pipes for infrastructure applications.

A test method was developed to evaluate this property, which became known as the *Darmstadt Abrasion Test*, standardized in DIN 19534.

Pipe samples of different materials were subjected to the same abrasion test and the results are shown in Figure 3.

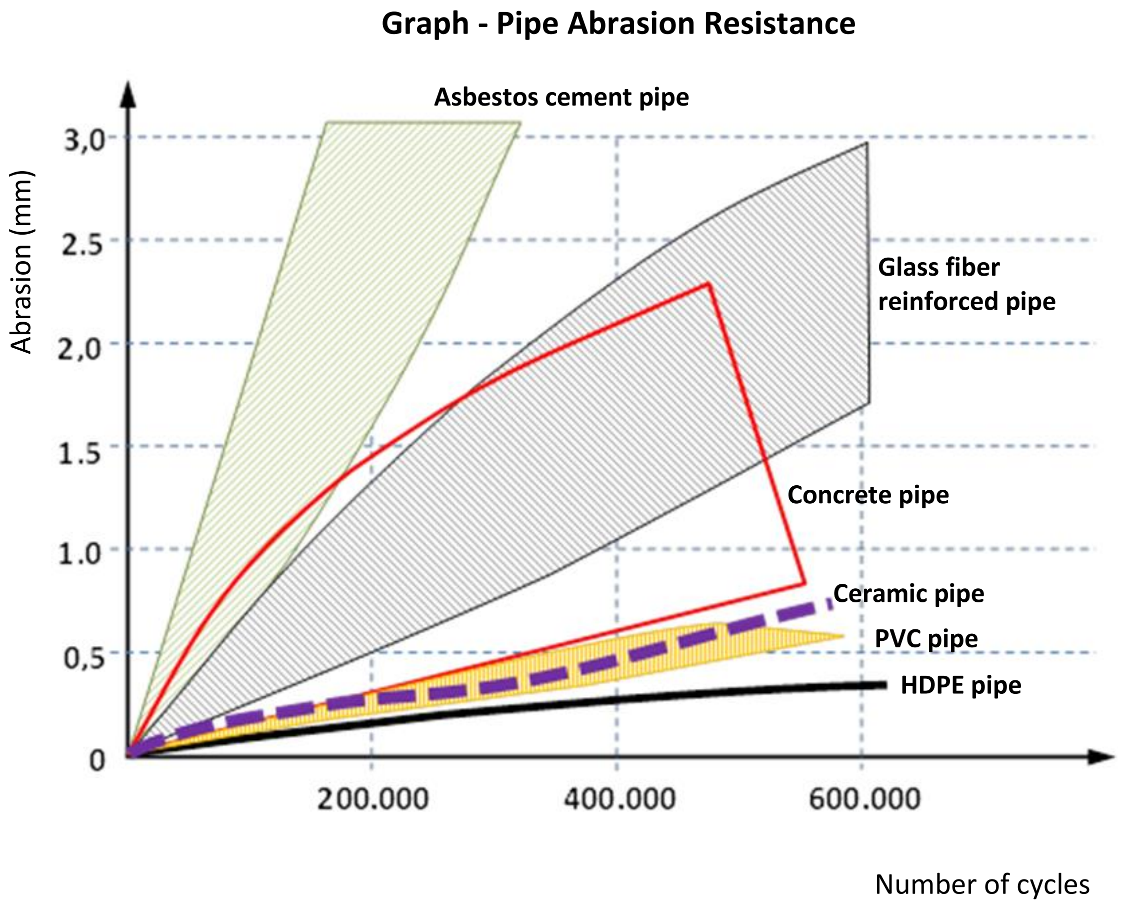


Figure 3 - Abrasion graph (DIN 19534) - University of Darmstadt

2.1.5. Other characteristics

HDPE is a ductile material with excellent resistance to elongation in the break, which allows the deformation of pipes made from this material due to eventual movement/accommodation of the ground, without breaking or cracking.

The HDPE used in the manufacture of KNTS Drain pipe has typical values of elongation in the break of over 350% and a modulus of elasticity of around 800 MPa.

2.1.6 Operating temperature

The KNTS Drain pipe was designed and dimensioned to work underground and not pressurized. Due to these conditions and the low thermal conductivity of HDPE, the pipe's outer surface is expected to be at a lower temperature than the maximum temperature of the fluid inside.

The operating temperature limits can vary between 0 and 40°C, and work at a maximum temperature of up to 60°C is allowed on a sporadic basis. The temperature reference must always be considered for the fluid and not for the pipe.

Within this context, it is vitally important to consider the chemical resistance properties of HDPE and also of the material used to make the sealing ring; therefore, the conditions and limits defined for each of the materials that make up the pipeline system must be observed. Therefore, it may be necessary to reduce the maximum temperature limit due to the chemical compatibility between the fluid and the pipeline materials in cases that the liquid being conveyed is different from rainwater or groundwater.

Like all plastics, HDPE's properties are also affected by temperature. Increased temperature reduces the rigidity of the material and decreased temperature increases its rigidity. Even so, no implications are expected regarding the handling and installation of corrugated pipes since, as the pipe cools to the ambient temperature of the ground, the original stiffness characteristics return.

During installation, when extreme conditions are observed between the temperature on the surface of the pipe and the temperature in the trench environment, it is recommended, after the joints have been made, to cover the executed section to prevent the joints from shifting due to the linear thermal expansion coefficient of HDPE.

2.2 KNTS Drain Pipe

KNTS Drain is manufactured in the dimensions and stiffness rating shown in Figure 4 and Table 2 below:

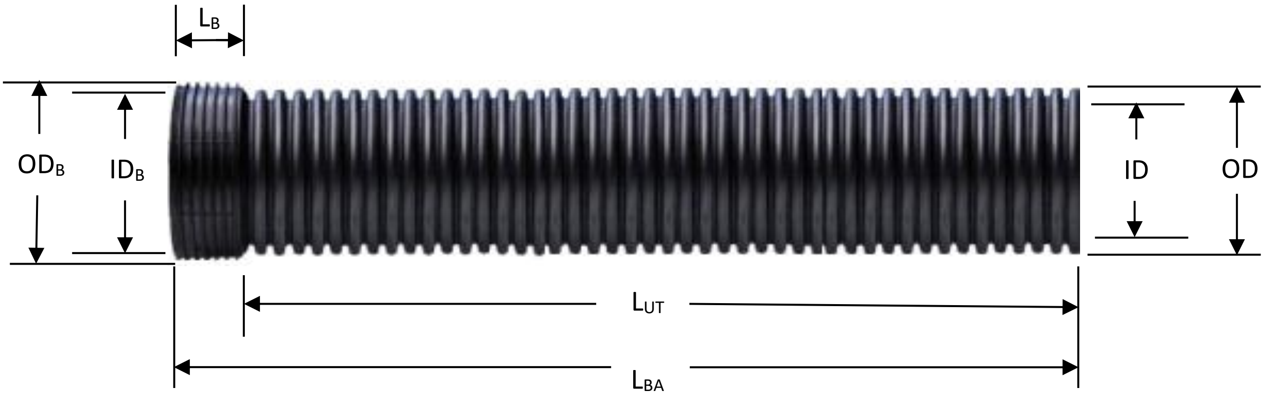


Figure 4 - KNTS Drain Pipe

Table of reference measures							
ID series (mm)	**Stiffness Rating**	**Pipe Dimensions**	**Bell Dimensions**			**Total bar length**	**Bar service length**
	SN (kN/m^2 or kPa)	**OD (mm)**	**OD_B (mm)**	**ID_B (mm)**	**L_B (mm)**	**L_{BA} (m)**	**L_{UT} (m)**
250	4	296	315	298	140	6.03	5.89
300	4	371	395	372	160	6.04	5.88
400	4	465	495	469	170	6.07	5.90
500	4	586	621	592	200	6.07	5.87
600	4	704	740	711	240	6.07	5.83
800	4	903	965	905	350	6.08	5.73
1000	4	1141	1230	1150	480	6.10	5.62
1200	4	1387	1495	1400	400	6.11	5.71
ID series. Nominal Diameter corresponds to Inner Diameter							

Table 2- KNTS Drain Pipe Size Chart

2.3 Fittings

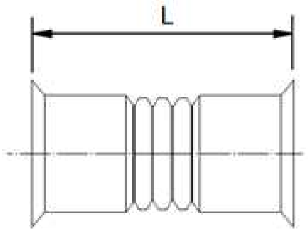
Kanaflex offers a wide range of fittings for the KNTS Drain line to provide flexibility and versatility for specific connection needs in pipeline systems.

The fittings are manufactured from sections of the pipe itself, by welding, guaranteeing watertightness and high resistance at the joints.

Upon request, Kanaflex can manufacture/supply other types of fittings for KNTS Drain Pipes through a segmentation process, guaranteeing the same watertightness as the joints between pipes.

2.3.1 Bell-Bell Connection

HDPE part, with a circular internal section, designed to join KNTS Drain pipes having the same nominal diameter. Watertightness is secured by the sealing ring which is housed in the first corrugation valley at the end of the pipe.

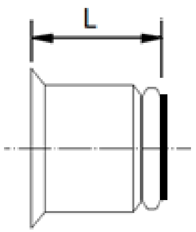


DN	SN (kN/m²)	Dimensions L (mm)
250	4	383
300	4	456
400	4	490
500	4	583
600	4	714
800	4	945
1000	4	1339
1200	4	1223

Figure 5 - KNTS Drain Bell-Bell Connection

2.3.2 Plug

HDPE part, with a circular internal section, intended for plugging KNTS Drain pipes to prevent foreign elements from entering them at the beginning or end of the line.

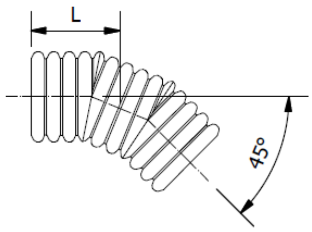


DN	SN (kN/m²)	Dimensions L (mm)
250	4	178
300	4	204
400	4	217
500	4	258
600	4	315
800	4	473
1000	4	670
1200	4	611

Figure 6 - KNTS Drain Plug

2.3.3 Spigot-Spigot 45° Bend

HDPE part with a circular internal section in Spigot-Spigot format, designed to join KNTS Drain pipes with the same nominal diameter, forming an angle of 45° between the longitudinal axes of the pipes.

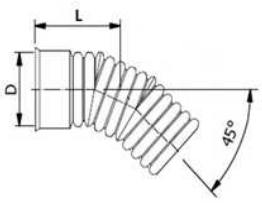


ND	SN (kN/m²)	Dimensions L (mm)
250	4	299
300	4	341
400	4	391
500	4	462
600	4	584
800	4	
1000	4	On request
1200	4	

Figure 7 - KNTS Drain Spigot 45° Bend

2.3.4 Spigot-Bell 45° Bend

HDPE part with a circular internal section in Spigot-Bell format, designed to join KNTS Drain pipes with the same nominal diameter, forming an angle of 45° between the longitudinal axes of the pipes.

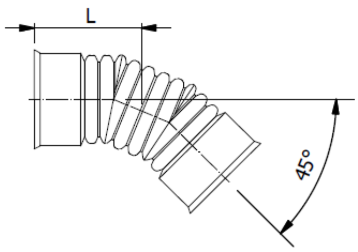


ND	SN (kN/m²)	Dimensions L (mm)
250	4	322
300	4	399
400	4	438
500	4	517
600	4	645
800	4	820
1000	4	1181
1200	4	1258

Figure 8 - KNTS Drain Spigot-Bell 45° Bend

2.3.5 Bell-Bell 45° Bend

HDPE part with a circular internal section in Bell-Bell format, designed to join KNTS Drain pipes with the same nominal diameter, forming an angle of 45° between the longitudinal axes of the pipes.

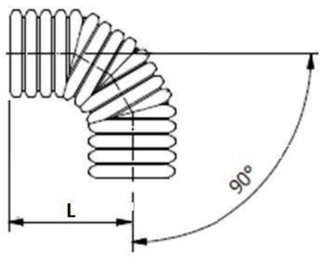


ND	SN (kN/m²)	Dimensions L (mm)
250	4	322
300	4	399
400	4	438
500	4	517
600	4	645
800	4	
1000	4	On request
1200	4	

Figure 9 - KNTS Drain Bell-Bell 45° Bend

2.3.6 Spigot-Spigot 90° Bend

HDPE part with a circular internal section in Spigot-Spigot format, designed to join KNTS Drain pipes with the same nominal diameter, forming an angle of 90° between the longitudinal axes of the pipes.

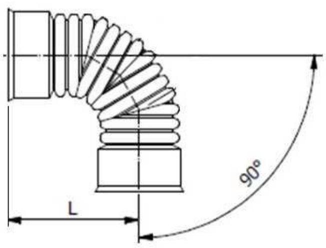


ND	SN (kN/m²)	Dimensions L (mm)
250	4	491
300	4	526
400	4	597
500	4	701
600	4	890
800	4	On request
1000	4	
1200	4	

Figure 10 - KNTS Drain Spigot 90° Bend

2.3.7 Bell-Bell 90° Bend

HDPE part with a circular internal section in Bell-Bell format, designed to join KNTS Drain pipes with the same nominal diameter, forming an angle of 90° between the longitudinal axes of the pipes.

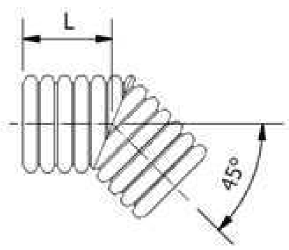


ND	SN (kN/m²)	Dimensions L (mm)
250	4	514
300	4	584
400	4	644
500	4	756
600	4	951
800	4	On request
1000	4	
1200	4	

Figure 11 - KNTS Drain Bell-Bell 90° Bend

2.3.8 Spigot-Spigot 45° Elbow

HDPE part with a circular internal section in Spigot-Spigot format, designed to join KNTS Drain pipes with the same nominal diameter, forming an angle of 45° between the longitudinal axes of the pipes.

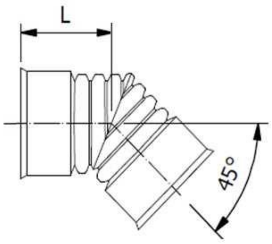


ND	SN (kN/m²)	Dimensions L (mm)
250	4	246
300	4	326
400	4	369
500	4	436
600	4	552
800	4	On request
1000	4	
1200	4	

Figure 12 - KNTS Drain Spigot-Spigot 45° Elbow

2.3.9 Bell-Bell 45° Elbow

HDPE part with a circular internal section in Bell-Bell format, designed to join KNTS Drain pipes with the same nominal diameter, forming an angle of 45° between the longitudinal axes of the pipes.

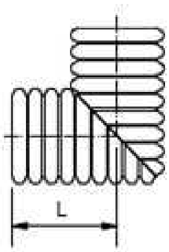


ND	SN (kN/m²)	Dimensions L (mm)
250	4	306
300	4	379
400	4	414
500	4	488
600	4	609
800	4	On request
1000	4	
1200	4	

Figure 13 - KNTS Drain Bell-Bell 45° Elbow

2.3.10 Spigot-Spigot 90° Elbow

HDPE part with a circular internal section in Spigot-Spigot format, designed to join KNTS Drain pipes with the same nominal diameter, forming an angle of 90° between the longitudinal axes of the pipes.

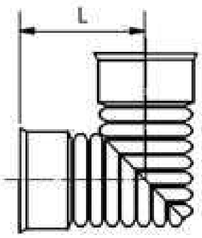


ND	SN (kN/m²)	Dimensions L (mm)
250	4	358
300	4	419
400	4	530
500	4	620
600	4	789
800	4	On request
1000	4	
1200	4	

Figure 14 - KNTS Drain Spigot-Spigot 90° Elbow

2.3.11 Bell-Bell 90° Elbow

HDPE part with a circular internal section in Bell-Bell format, designed to join KNTS Drain pipes with the same nominal diameter, forming an angle of 90° between the longitudinal axes of the pipes.

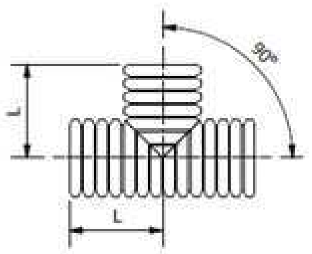


ND	SN (kN/m²)	Dimensions L (mm)
250	4	380
300	4	477
400	4	577
500	4	675
600	4	850
800	4	On request
1000	4	
1200	4	

Figure 15 - KNTS Drain Bell-Bell 90° Elbow

2.3.12 Spigot-Spigot-Spigot T-Joint

HDPE part with a circular internal section in Spigot-Spigot-Spigot format, designed to join KNTS Drain pipes with the same nominal diameter, forming an angle of 90° between the longitudinal axes of the pipes.

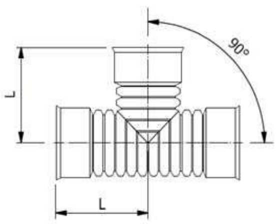


ND	SN (kN/m²)	Dimensions L (mm)
250	4	338
300	4	437
400	4	509
500	4	608
600	4	761
800	4	On request
1000	4	
1200	4	

Figure 16 - KNTS Drain Spigot-Spigot-Spigot T-Joint

2.3.13 Bell-Bell-Bell T-Joint

HDPE part with a circular internal section in Bell-Bell-Bell format, designed to join KNTS Drain pipes with the same nominal diameter, forming an angle of 90° between the longitudinal axes of the pipes.

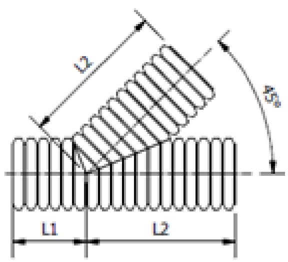


ND	SN (kN/m²)	Dimensions L (mm)
250	4	398
300	4	495
400	4	556
500	4	663
600	4	822
800	4	On request
1000	4	
1200	4	

Figure 17 - KNTS Drain Bell-Bell-Bell T-Joint

2.3.14 Spigot-Spigot-Spigot Y-Joint

HDPE part with a circular internal section in Spigot-Spigot-Spigot format, designed to join KNTS Drain pipes with the same nominal diameter, forming an angle of 45° between the longitudinal axes of the pipes.

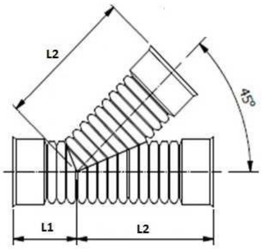


ND	SN (kN/m²)	Dimensions (mm) L_1	Dimensions (mm) L_2
250	4	263	563
300	4	291	679
400	4	339	791
500	4	405	1013
600	4	507	1268

Figure 18 - KNTS Drain Spigot-Spigot-Spigot Y-Joint

2.3.15 Bell-Bell-Bell Y-Joint

HDPE part with a circular internal section in Bell-Bell-Bell format, designed to join KNTS Drain pipes with the same nominal diameter, forming an angle of 45° between the longitudinal axes of the pipes.

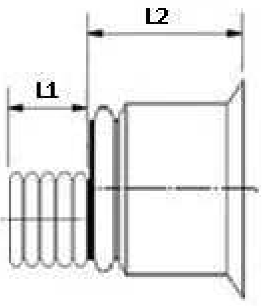


ND	SN (kN/m²)	Dimensions (mm)	
		L_1	L_2
250	4	285	585
300	4	349	737
400	4	386	895
500	4	460	1068
600	4	568	1329

Figure 19 - KNTS Drain Bell-Bell-Bell Y-Joint

2.3.16 Spigot-Bell Eccentric Reduction

HDPE part with a circular internal section in Spigot-Bell format, designed to join KNTS Drain pipes of different nominal diameters.

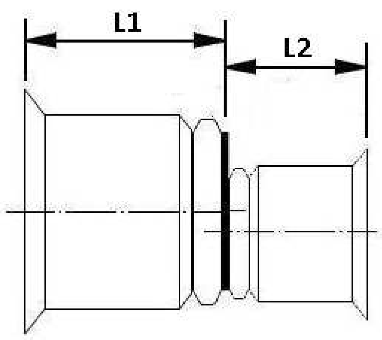


ND	SN (kN/m²)	Dimensions (mm)	
		L_1	L_2
300x250	4	188	204
400x250	4	188	217
400x300	4	194	217
500x250	4	188	258
500x300	4	194	258
500x400	4	226	258
600x250	4	188	315
600x300	4	194	315
600x400	4	226	315
600x500	4	270	315

Figure 20 - KNTS Drain Spigot-Bell Eccentric Reduction

2.3.17 Bell-Bell Eccentric Reduction

HDPE part with a circular internal section in Bell-Bell format, designed to join KNTS Drain pipes of different nominal diameters.

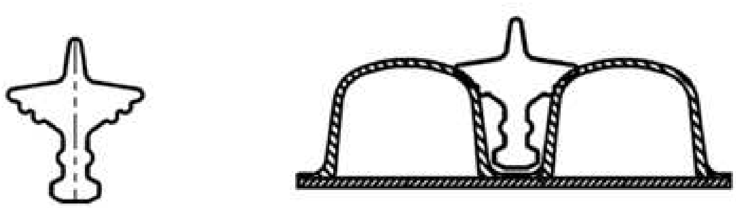


ND	SN (kN/m²)	Dimensions (mm)	
		L_1	L_2
300x250	4	204	173
400x250	4	217	173
400x300	4	217	204
500x250	4	258	173
500x300	4	258	204
500x400	4	258	217
600x250	4	315	173
600x300	4	315	204
600x400	4	315	217
600x500	4	315	258

Figure 21 - KNTS Drain Bell-Bell Eccentric Reduction

2.3.18 Sealing Ring

Non-toroidal circular part, made of rubber, to be installed in the valley of the corrugation at the end of the pipe, designed to seal and provide watertightness to KNTS Drain pipes at the joints, as shown in Figure 21.



Ring section **Ring mounted in the first valley of the corrugation**

Figure 22 - KNTS Drain Sealing Ring

2.3.19 Kanalub Lubricating Paste

Kanalub is a saponified fatty acids-based neutral paste with great lubricating power, to be applied to the inside of the bell and the sealing ring to facilitate the sliding of the ring on the bell during the joining process. Petroleum-based greases or oils should never be used to avoid damaging the rubber of the sealing rings and/or endangering the environment.

Figure 23 - Kanalub Lubricating Paste

The packaging of Kanalub Lubricating Paste, of the jar type, contains 900 grams and Table 3 should be taken into account when quantifying its use on site.

Pipe ND	Number of joints per Kanalub jar
250	24
300	22
400	20
500	18
600	15
800	12
1000	8
1200	6

Table 3 - Quantification of Kanalub Paste for use in the installation.

3 Dimensioning

The dimensioning information contained in this item is guidance based on current technical standards and academic technical literature.

The information and formulas presented in section 3.1 are aimed at understanding the parameters taken into consideration for the mechanical dimensioning of the KNTS Drain pipe, as well as the conditions in which it interacts with the soil so that its vertical deflection during and after installation remains within the limits established at the design stage.

The information and formulas presented in item 3.2 allow the calculation of hydraulic performance of KNTS Drain pipes.

3.1 Mechanical Dimensioning and the Influence of External Loads

The study of external loads acting on underground pipes was developed theoretically and experimentally by A. Marston. The basic concept of the study is that the load due to the weight of the landfill column on the pipe installed underground in the trench is modified by the arch effect through which part of this weight is transferred to the adjacent lateral prisms, with the result that the load on the pipe may be less than the weight of the landfill column acting on it. To develop the study, some essential definitions had to be established, such as Pipe Stiffness and Installation Conditions.

3.1.1. Pipe Stiffness Rating

Regarding the degree of stiffness, pipes can be classified as rigid, semi-rigid or non-rigid according to the horizontal or vertical deformations that the cross-sections can reach without suffering permanent damage, as shown in Table 4.

Pipe rating	% Deflection without structural damage	Examples
Rigid	Deflection < 0.1 %	Concrete, ceramic
Semi-rigid	0.1 % ≤ Deflection ≤ 3.0 %	Cast iron
Non-rigid	Deflection > 3.0%	HDPE, steel, ductile iron

Table 4 - Rating of pipes according to their deflection

This rating was later modified by Dr. Spangler (University of Iowa), who reduced the types of pipes to rigid and non-rigid.

According to this mechanical concept, the KNTS Drain pipe is rated as a non-rigid pipe. The concept of a non-rigid pipe does not refer to the longitudinal direction of the bar, but to its cross-section.

3.1.2. Installation Conditions and Pipe-Ground Interaction

In terms of installation conditions, buried pipes can be laid in a trench or on land that will serve as a base for an landfill. Figure 24 illustrates the three basic installation conditions. Non-rigid pipes are designed for installation in firm ground and are therefore ideal for installation in open trenches in stable natural terrain.

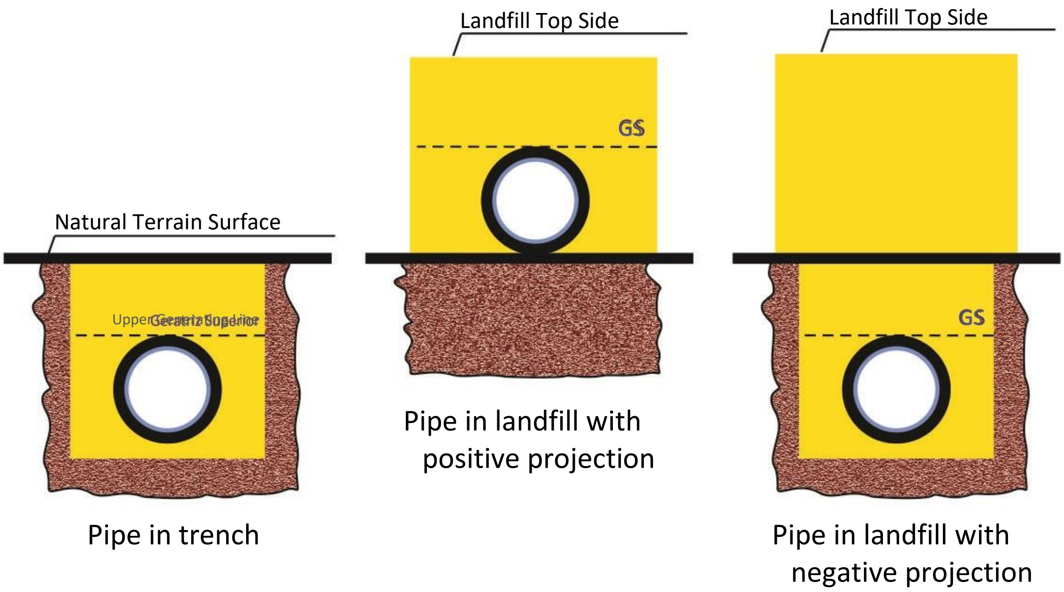


Figure 24 - Conditions for installing pipes in a trench or landfill

Installing pipes in trenches involves laying the pipe in a relatively narrow trench excavated in passive, undisturbed soil, which is then backfilled.

The concept of a relatively narrow trench can be established by the proportion of the trench width ranging from 1.5 to 2.0 times the outer diameter of the pipe (ideally the width = DE + 2x400mm). When the trench width exceeds these limits, there is basically a condition of landfill and special care must be taken when installing a non-rigid pipe.

The installation of a pipe on land that serves as a base for an landfill has two subdivisions:

- The laying of the pipe on the natural ground that receives the landfill, but which has its upper generating line located above the ground level, as illustrated for “pipe in landfill with positive projection”. If a non-rigid pipe is to be installed in an landfill on natural ground, the landfill must first be properly compacted and then the trench dug and the pipe laid.
- The laying of the pipe on the ground that receives the landfill, but which has its upper generating line located below the natural ground level, as illustrated for “pipe in landfill with negative projection”.

Spangler's studies resulted in the following proposition: “Underground pipe networks derive their load-bearing capacity from the inherent resistance of each pipe to external vertical loads and from the lateral backfill pressure (enveloping) on the sides of the pipe, which causes stresses in the pipe rings in the direction opposite to that produced by the vertical load.”

For non-rigid pipes, the trench width limit of 2 x DE has been tried and used, which offers good conditions for construction/settlement, and there are no known problems with using the valuation mentioned above when the pipe is installed in accordance with the other recommendations in this manual.

Road culverts can be mentioned as an illustrative example of application. They are basically divided into two types: grate culverts and gully culverts.

Grate culvert is a classic application of “pipe in trench” or “pipe in landfill with negative projection”. It is intended for conveying occasional water (gutters and gullies) where the water inlet is normally made through collection boxes and is used to allow the transposition of water flow collected by surface drainage devices, notably gutters. It can also collect flows from natural thalwegs or gullies intercepted by the road in cut segments.

Gully culvert is a classic application of a “pipe in landfill with positive projection”. It is installed at the bottom of thalwegs and is intended for permanent waters. In the case of larger works, this corresponds to permanent watercourses in existing streams and canals, and consequently involves a great deal of responsibility.

****Ravine*** – a large concentration of water flowing down the slopes. It is a depression in the ground produced by the erosive work of these run-off waters. Ravines are usually classified as smaller in scale than gullies, valleys and canyons.

****Thalweg*** - the path through which spring water flows. A sinuous line in the valley floor, resulting from the intersection of the planes of two slopes and where the water that descends from them is concentrated.

KNTS Drain pipe benefits from its ability to deform or change under load without structural damage, as illustrated in Figure 25.

This deformation is known as deflection, which allows the pipe to adapt to the shape of the outer enclosure, transferring most of the vertical load received to the enclosure.

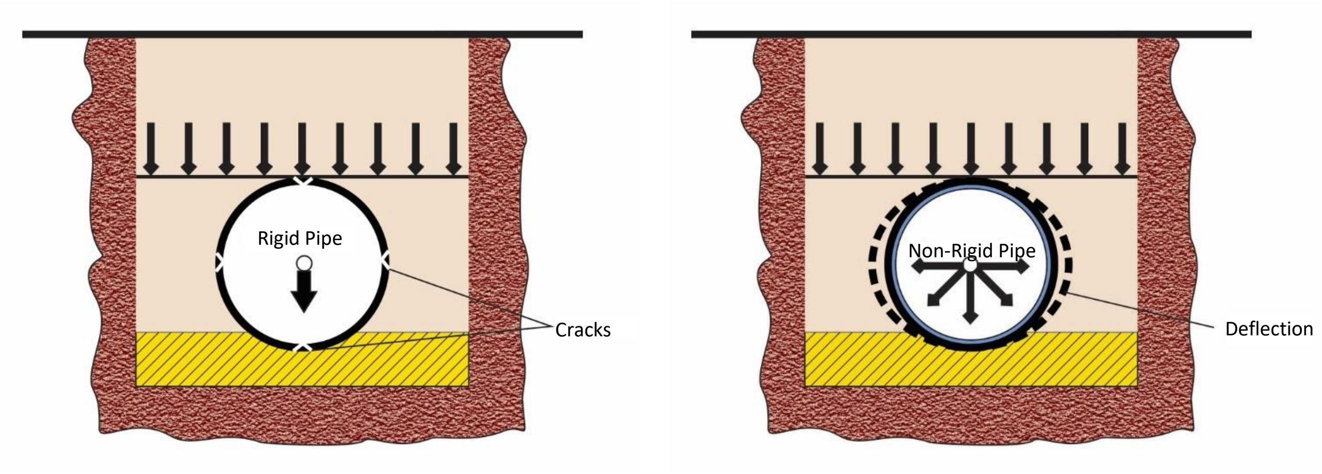


Figure 25 - Pipe behavior under vertical load

Both rigid and non-rigid pipes require an appropriate soil, although the soil-pipe interaction is different in each case.

In the case of rigid pipes, the top load is transferred to the bottom of the trench (laying base or cradle). In a non-rigid pipe, the load is distributed over the surrounding soil, which is why it is said that the pipe interacts with the soil.

Figure 26 illustrates the soil-pipe interaction and load transfer in the two types of pipe:

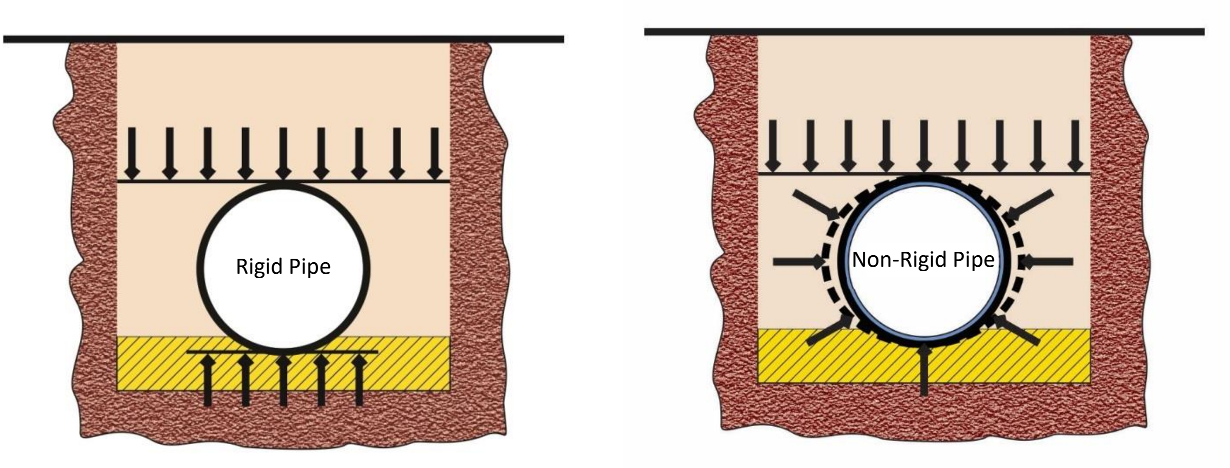


Figure 26 - Soil-Pipe Interaction (pipe with surrounding soil)

A rigid pipe is almost always many times stiffer than the surrounding soil, leading to the need to support soil loads much greater than the prism load over the pipe.

On the other hand, a non-rigid pipe is not as rigid as the backfill soil, thus forcing a mobilization of the lateral surrounding soil to support the weight of the traffic and soil loads.

3.1.3. Structural Pipe Design

To define the stiffness rating applicable to an underground non-rigid pipe system, designers first need to establish the permissible deflections for the pipes, based on their experience and/or regulatory references.

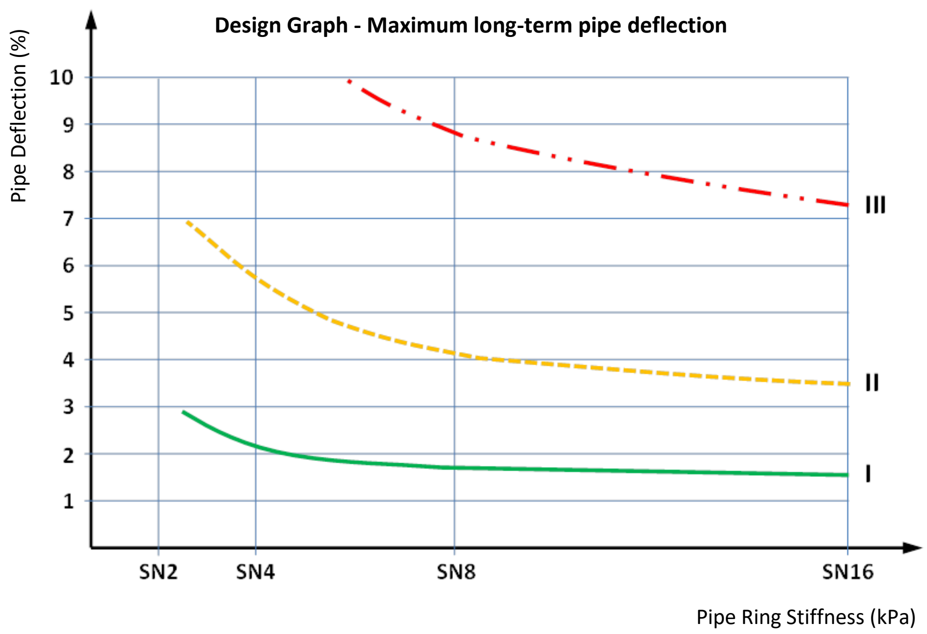
The practice in the Brazilian market is to adopt a maximum initial vertical deflection of 5%, but international standards recommend deflection limits as shown in Table 5. The calculated values of vertical deflection should not exceed such limits, mainly for the purpose of preserving the watertightness of the joints.

Stiffness Class	Initial Average Vertical Deflection	Long-Term Average Vertical Deflection
SN 4	8%	10%

Table 5 - Recommended design deflection limits

An intensive study of vertical deflection recordings/observations of non-rigid pipes installed in different conditions over more than 25 years resulted in the experience as shown in the Design Graph in Figure 27.

For the three enclosure compaction conditions during installation, the order of magnitude of the vertical deflection can be estimated and the stiffness rating of the pipe to be used can be chosen. The validation conditions for the estimate are detailed in Table 6.



Caption:
I - Good Compaction / II - Moderate Compaction / III - No Compaction (not recommended)

Figure 27 - Project Graph

The Design Graph is only for informative reference to the designer and is not intended to replace the structural calculation, nor to limit the conditions to which the pipes can be subjected.

Parameter	Validation conditions
Backfill height (*)	0.8 to 6.0 m measured from the upper generating line of the pipe.
Traffic loads	Considered existing.
Installation quality **"Good", "Moderate", "No" installation category - should reflect workmanship that the designer can trust.** **(the trench filling layers are detailed in Figure 26).**	**"Good" Compaction (I)** In the trench, the granular fill soil around the pipe is carefully placed in layers of no more than 30 cm, and each layer must be compacted before receiving the next layer. Starting from the upper generating line, the pipe must be covered with a layer of at least 15 cm and also compacted, which is considered an integral part of the pipe enclosure. The final backfill layer, on top of the pipe enclosure, is filled with enclosure material or native soil and then compacted. Typical Proctor density values should be above 94%.
	"Moderate" Compaction (II) In the trench, the granular fill soil around the pipe is carefully placed in layers of no more than 50 cm, and each layer must be compacted before receiving the next layer. Starting from the upper generating line, the pipe must be covered with a layer of at least 15 cm and also compacted, which is also considered an integral part of the pipe enclosure. The final backfill layer, on top of the pipe enclosure layer, is filled with enclosure material or native soil and then compacted. Typical Proctor density values should remain in the 87% to 94% range.
	No Compaction (III) The piles/slabs of the lateral shoring must be removed before compaction, in accordance with the recommendations of Standard EN 1610:1997. However, if the piles/slabs are removed after compaction, the "Good" or "Moderate" level of compaction should be considered to be reduced to the **No Compaction (III)** level.

Table 6 - Project Chart validation conditions

(*) Note: The backfill height can be less than 0.8m in installations where the traffic load involves light vehicles, as well as where there is no high water table that could generate thrust in the underground pipe line.

Similarly, backfill heights can be greater than 6.0m, taking care to calculate vertical deflection.

Figure 28 shows a cross-section of the main parts/stages of a typical underground pipe installation for trenching with vertical walls in native soil (or compacted backfill). The terminology of the parts indicated on the drawing is that used in the text of this manual.

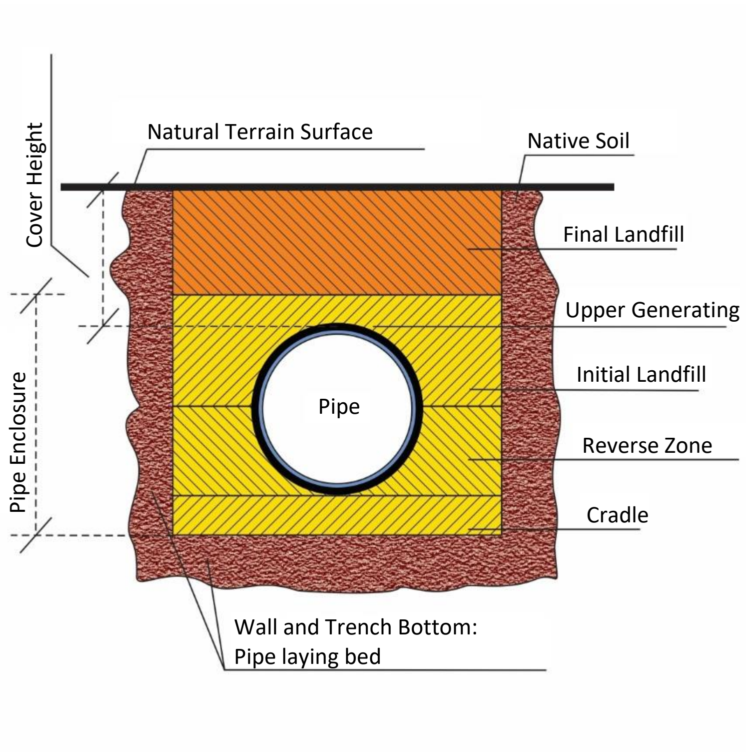


Figure 28 - Underground pipe - definition of the integral parts of a typical installation

Native soil is the area of soil made up of material that is firm, compact, consistent, without flaws, where the trench will be opened to install the pipe. The pipe laying bed comprises the trench walls and bottom. Regarding the pipe installation in landfill over native soil, first, the landfill must be properly compacted and then a trench must be dug to install the pipe.

Enclosure is the name given to the compacted material adjacent to the pipe, which includes the reverse zone, the initial landfill and the layer immediately above the upper generating line. In non-rigid pipe installations, the enclosure performs a very important structural function, where its ability to support the imposed loads depends on adequate lateral support.

Cradle is the support layer of the pipe. In the case of non-rigid pipes, the cradle layer should be made with granular material, preferably uncompacted sand, to lay the corrugation. You can use zero or one gravel (DN>400), or clay soil as long as there is no water/groundwater rising from the bottom of the trench. In case of water at the bottom of the trench, the use of clay is not recommended due to the risk of loss on soil consistency and the corresponding pipe-soil interaction.

The reverse zone, initial landfill and compacted layer immediately above the upper generating line are areas of the enclosure that require very careful execution so the buried non-rigid tubular system will have the desired performance.

Cover height is the total thickness of the compacted layers of cover soil, from the top generating line of the pipe in the trench to the surface of the natural terrain, or to the surface of the landfill if landfilling occurs above the level of the surface of the natural terrain.

3.1.4. Ground / Pipe Structure (Marston-Spangler)

Dr. Spangler and Dr. Marston, from the University of Iowa - USA, analyzed the performance of a non-rigid soil/pipe structure to mathematically predict the vertical deflection of the pipe in response to the load (traffic and soil), the embankment (compaction and soil type) and the pipe (manufacturing material and geometry).

The equation resulting from this study became known as the ***Spangler*** equation or the Iowa formula:

Deflection = Load(s) on pipe / (Pipe stiffness + Soil stiffness)

After installation, the settlement of the surrounding soil (pipe enclosure) develops over time due to external loading and the way the pipe is laid.

Experience shows that the maximum vertical deflection tends to be reached between 1 and 3 years after installation, depending on the materials used for the enclosure and final landfill, the quality of the soil compaction work and the external loads. For this reason, the vertical deflection calculation presented in this manual only considers the short-term (initial) properties of the product.

Figure 29 illustrates the behavior of the pipe's vertical deflection at installation and after installation, taking into account the influence of traffic load.

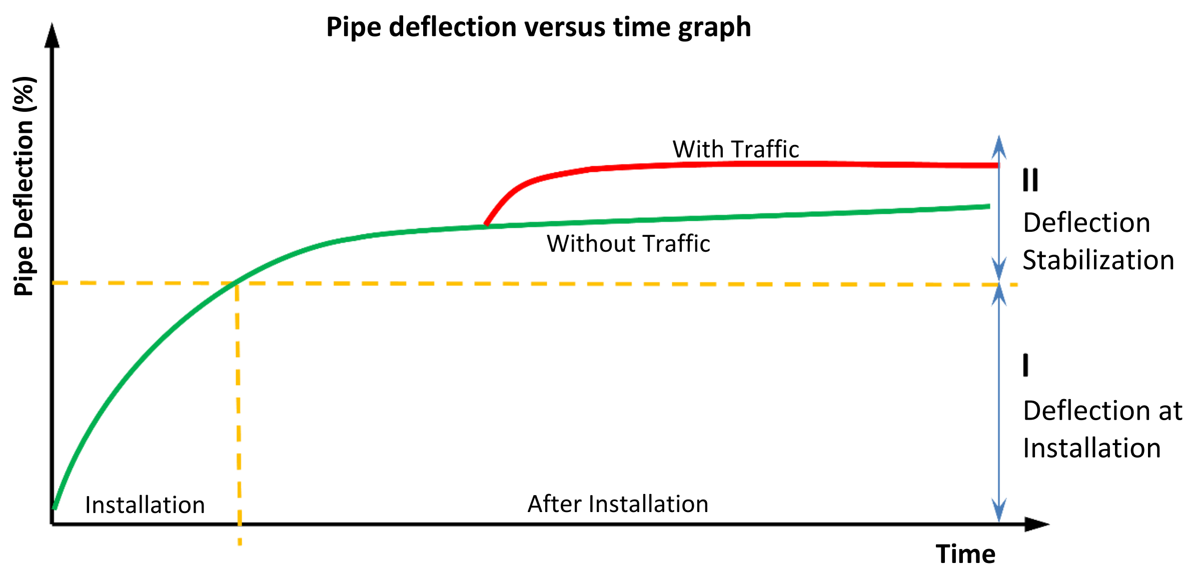


Figure 29 - Pipe deflection graph at the time of installation and after installation

Research indicates that the additional deflection, until the system becomes stable, can vary from 1.5 to 2 times the deflection resulting from the installation. This variation establishes the self-compaction factor to be considered when calculating vertical deflection, and is detailed in section 3.1.5.5.

3.1.5. Calculating Vertical Deflection of the Pipe - ΔD_V

The Spangler equation was modified based on studies conducted by several researchers, including Dr. Barnard and Dr. Watkins, who simplified the original equation and established the modified Iowa formula:

$$\Delta D_v = b_1.(C.P_s+P_t) / (8.SN+0.061.E_R)$$

ΔD_v = vertical deflection, [%]
b_1 = load distribution factor
C = self-compaction factor
P_s = soil load, [kN]
P_t = traffic load, [kN]
SN = pipe ring stiffness, [kN/m²]
E_R = soil modulus of rigidity, [kN/m²]

Studies show that the vertical load acting on a non-rigid pipe placed in a trench is lower than the weight of the covering material. The following formulas allow the calculation of the variables that make up the modified Iowa formula, based on the German standard ATV-DVWK-A127, considering a pipe installed in a trench with vertical walls.

3.1.5.1. Ground Load (Static Load) - P_S

The soil load acting on the pipe can be calculated according to the Silo theory, which takes into account a soil load correction factor caused by the self-support of the ground.

$$PS = SC \cdot \gamma \cdot H$$

Ps = vertical soil load, [kN/m²].
γ = specific weight of the filling material, [kN/m³].
H = depth of the trench to the upper generating line of the pipe (m)
SC = soil load correction coefficient (-)

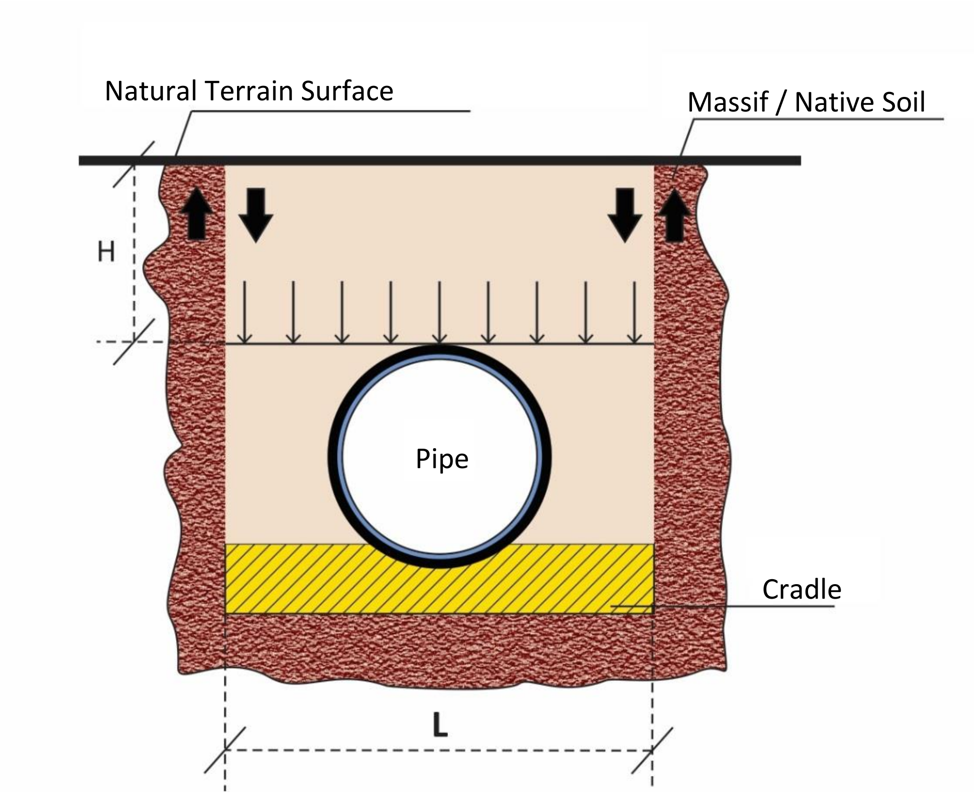


Figure 30 - Acting soil load

3.1.5.2. Ground Load Correction Coefficient - SC

The soil load correction coefficient for trenches with vertical or approximately vertical walls is calculated according to the following formula:

$$SC = (1 - e^{-2.K_1.tg(\delta).H/L}) / (2.K_1.tg(\delta).H/L)$$

SC = soil load correction coefficient.
δ = effective angle of friction between the backfill soil and the trench wall (degrees).
K_1 = ratio between the horizontal and vertical forces in the trench backfill material.
H = depth of the trench to the upper generating line of the pipe (m)
L = trench width (m).

Note: When $\delta = 0$, consider SC = 1.

The conditions under which the enclosure is made, specifically the degree of compaction and the properties of the enclosure material, are essential for the good performance of the pipe in relation to the loads it will be subjected to.

The “δ” and “K_1” parameters, depending on the quality of the enclosure, are shown in Table 7.

Coating conditions		K_1	δ
C1	Enclosure and final landfill compacted by layers against the trench wall in natural soil, with verification of the Proctor density (Dp).	0.5	$\delta = \Psi$
C2	Enclosure and final landfill compacted by layers against the trench wall in natural soil, without verification of the Proctor density (Dp).	0.5	$\delta = 2/3\Psi$
C3	Enclosure and final landfill in vertically shored trenches and without compaction.	0.5	$\delta = 1/3\Psi$
C4	Ditches built vertically, supported by wooden boards or other types of containment equipment.	0.5	$\delta = 0$

Note: Ψ - angle of internal friction of the enclosure material

Table 7 – "δ" and "K_1" parameters for coating conditions

Table 8 shows some of the soil types that can be used in enclosures and their respective values for specific weight and angle of internal friction.

Soil Types	γ specific weight (KN/m³)	Ψ Angle of internal friction (°)
NON-COHESIVE SOILS		
Gravel + pebbles	21	35.0
Gravel + sand	21	35.0
Dense sand	20	35.0
Semi-dense sand	20	32.5
Loose sand	19	30.0
COHESIVE SOILS		
Stiff sandy clay	22	22.5
Soft sandy clay	21	22.5
Semi-solid clay	21	15.0
Stiff clay	20	15.0

Table 8 - Types of soils that can be used for enclosures - Specific weight and angle of friction

The most suitable types of soil for use in non-rigid pipe enclosures are sand, fine-grained gravel or a mixture of gravel/pebbles/sand and non-cohesive soils. Special care should be taken when using non-cohesive soils for pipes with a low cover height, no impermeable floor finish layer on the surface and the risk of rising groundwater or the entry / infiltration of rainwater or other surface water into the trench, which could cause thrust. Cohesive soils, mainly clays, can be used in trenches where there is no risk of excessive presence of water, which can lead to loss of plasticity of the surrounding/covering material, with consequent loss of the soil's lateral bearing capacity.

3.1.5.3. Stiffness Modulus of the Enclosure Material and Final Landfill - E_R

The measure of the soil's compaction quality is given by the "Proctor Density" (Dp), which represents the ratio between the density of the pipe enclosing material and that of the natural soil.

The minimum Proctor compaction level of 95% is recommended for both cohesive and non-cohesive soils.

Another composition of soil groups, classified according to DIN 18196, is shown in Table 9.

Group	Soil Type
1	Non-cohesive soils
2	Slightly cohesive soils
3	Cohesive soils with mixtures (cohesive sand and gravel)
4	Cohesive soils

Table 9 - Composition of Soil Groups

The modulus of rigidity of the backfill material (ER), as a function of its degree of compaction (Proctor Density - PD), for the various groups of soils classified according to Table 9, are shown in Table 10.

Soil Group	E_R - Modulus of rigidity of the enclosing material and final landfill (KN/m² or KPa)					
	PD = 85%	PD = 90%	PD = 92%	PD = 95%	PD = 97%	PD = 100%
1	2,000	6,000	9,000	16,000	23,000	40,000
2	1,200	3,000	4,000	8,000	11,000	20,000
3	800	2,000	3,000	5,000	8,000	13,000
4	600	1,500	2,000	4,000	6,000	10,000

Table 10 - Modulus of rigidity of the enclosing material and final landfill, as a function of Proctor density

3.1.5.4. Traffic Load (Dynamic Load) - P_t

The traffic loads produced on the ground surface are transmitted to the subsoil. The increase in vertical stress, relative to the traffic load, acting in the plane tangential to the upper generating line of the pipe can be determined using the following equation.

The shallower the trench, the greater the traffic load. The equation is not applicable for values of H < 0.5 m.

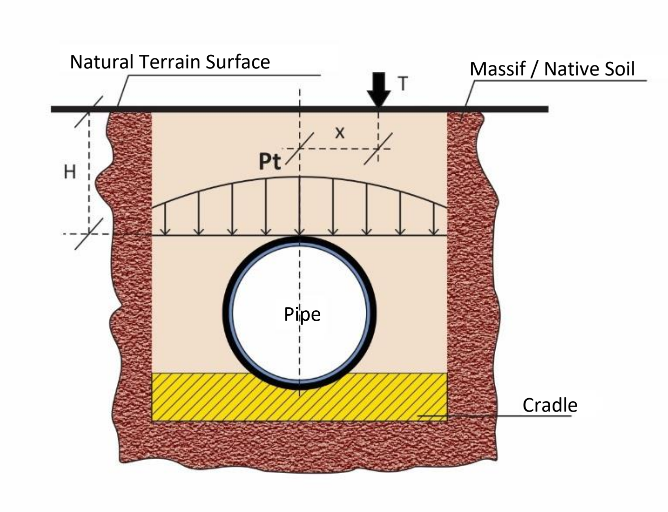


Figure 31 - Traffic load

$$P_t = (3.T) / \{2 . \pi . H^2 . [1 + (x^2/H^2)]^{5/2}\}$$

Pt = traffic load [kN/m²].
T = expected traffic load [kN].
H = depth of the trench to the upper generating line of the pipe [m].
x = distance relative to the pipe axis, where the traffic load will occur [m].

Expected traffic load values (T) can be considered according to Table 11.

Traffic Type	Total Expected Traffic Load (kN)	Expected Traffic Load per Wheel (kN)
Heavy	600	100
Medium	300	50
Light	120	40 on the rear wheels 20 on the front wheels

Table 11 - Expected traffic load (T)

3.1.5.5. Self-compaction and Load Distribution Factors in the Cradle

The self-compaction factor (C) is used to correct the vertical deflection of the pipe until the soil reaches the stabilization condition of accommodation over time. A value of 1.5 should be adopted for moderate compaction and a value of 2.0 for moderate compaction with low cover height.

The way the cradle is made directly influences the vertical deflection that the pipe undergoes after installation. The cradle load distribution factor (b1) is a pipe support coefficient, applicable to the calculation of vertical deflection (see equation in section 3.1.5.) and is related to the angle “a” formed by the accommodation of the pipe in the cradle layer as shown in Figure 32.

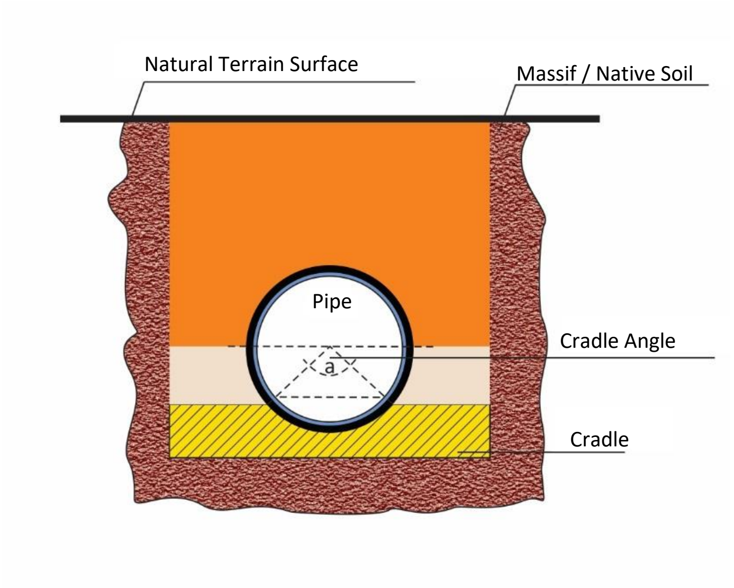


Figure 32 - Cradle Angle

Cradle Angle (a)	Load Distribution Factor (b1)
0^{O}	0.110
30^{O}	0.108
45^{O}	0.105
60^{O}	0.102
90^{O}	0.096
120^{O}	0.090
180^{O}	0.083

3.1.5.6. Stiffness Rating or Nominal Ring Stiffness

Corrugated pipes are classified by their ring stiffness, which is determined according to ISO Standard 9969.

The term "SN" indicates the nominal ring stiffness of the pipe, i.e. the minimum stiffness presented by the pipe, with "SN" values stated in kN/m² (or KPa).

The KNTS Drain pipe is manufactured in stiffness rating of SN4 and has a minimum annular stiffness of 4 kN/m² (or KPa), compatible with the deflection levels under the validation conditions, both discussed in item 3.1.3.

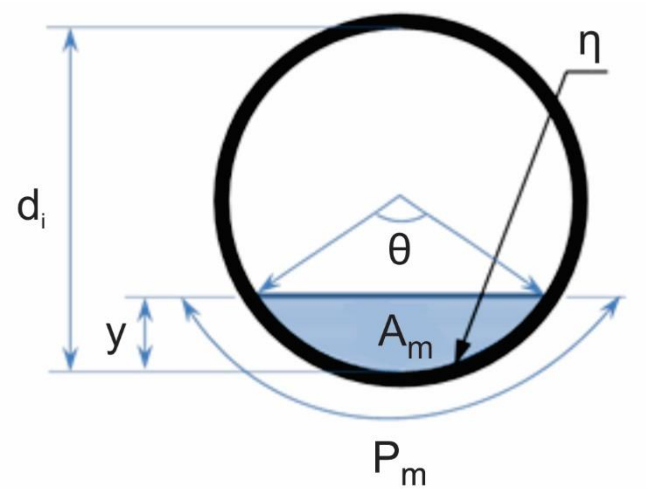
3.2 Hydraulic Dimensioning

3.2.1 Free Conduits - Water Table and Flow Velocity

Pipes and channels function as free conduits when atmospheric pressure reigns on the surface of the liquid being drained. Channels are considered open free conduits, and pipes for drainage or sewage applications, in this pressure condition, are considered closed free conduits.

In a piping system for drainage or gravity sewage, the liquid flow is generally non-uniform (varied). However, the hypothesis of a uniform flow is postulated order to simplify the hydraulic analysis of the system.

For hydraulic calculations, the variables in Figure 33 must be taken into account.



d_i = pipe internal diameter, [m]
y = water table height, [m]
A_m = wet area, [m²]
P_m = wet perimeter, [m]
θ = angle of the water table, [°]
η = Manning's coefficient, [-]

Figure 33 - Hydraulic dimensioning variables

The main parameters of interest when dimensioning closed free conduits are the flow velocity inside and the flow rate (volume of liquid flowing per unit time). These parameters are calculated, for each inner diameter of the pipe, based on the height of the water table inside, the roughness coefficient of the pipe, the inner diameter and the slope established for the pipe in its longitudinal direction, according to the equations presented later in this manual.

The maximum flow velocity inside a closed free conduit occurs when the height of the water table is around 81.3% of the inner diameter (y/di = 0.813). The maximum flow rate occurs when the height of the water table is around 93.8% of the inner diameter (y/di = 0.938).

The diameter of the pipe is usually selected based on the desired flow rate, taking into account the design limitations with regard to slope.

When a pipe is selected based on this criterion, it is important to ensure that there is a minimum flow velocity inside the pipe to avoid the deposition of solid matter on the inside bottom of the pipe, which could slow down or impair normal flow transportation.

In addition to the minimum flow rate for any section of the network, it is important to consider the minimum and maximum flow velocity allowed for the network.

The minimum flow rate to be considered in the design, as established in ABNT Standard NBR 9690, is 1.5 l/s. The values considered in practice for the minimum flow velocity are usually 0.60 m/s for sanitary sewage and 0.75 m/s for rainwater. The maximum flow velocity in sewage and rainwater collection network designs is around 5 m/s for concrete pipes and 8 m/s for corrugated wall metal pipes. For HDPE pipes, which are more resistant to abrasion (see figure 3), a flow velocity of around 8m/s or more is not a limitation. Higher velocities can be considered at the designer's discretion, in which case it should be pointed out that a decanting box/solids retention device should be provided upstream (and/or in the middle of the route), and that a suitable energy dissipation structure should be detailed and built at the outfall so that there is no erosion in the receiving body.

In some designs, the concept of considering the minimum velocity has been replaced by the criterion of calculating the tensile or drag stress, which can be defined as the tangential component of the weight of the liquid on the portion of area corresponding to the hydraulic radius, which acts on the material settled there, promoting its drag. The formula for calculating the tensile stress is shown in item 3.2.1.1.7. of this Manual.

For plastic pipes with a smooth inner wall, the minimum tensile stress value generally used is 0.60 Pa in sewage systems and 1.00 Pa in rainwater systems.

3.2.1.1. Hydraulic Dimensioning of Free Conduits

3.2.1.1.1 Water Table Angle

The angle of the water table (θ) is calculated for a pipe with an inner diameter of di and a water table height of y, using the formula:

$$\theta = 2 \,.\, \arccos[1 - (2 \,.\, y/d_i)]$$

θ = water table angle (rad)
y = water table height (m)
d_i = pipe inner diameter (m)

3.2.1.1.2 Wet Area (Am)

Once the angle of the water table has been obtained, the wet area (Am) is calculated using the formula:

$$A_m = (\theta - \text{sen}\theta) \,.\, d_i^2/8$$

A_m = wet area (m^2)
θ = water table angle (rad)
d_i = pipe inner diameter (m)

3.2.1.1.3. Hydraulic Radius (Rh)

The hydraulic radius (RH) is also calculated from the angle of the water table using the formula:

$$R_h = (1 - \text{sen}\theta / \theta) \,.\, d_i/4$$

R_h = hydraulic radius (m)
θ = water table angle (rad)
d_i = pipe inner diameter (m)

3.2.1.1.4. Slope (i)

The slope of the installation should follow the topography of the terrain or be defined by the pipe network designer. Minimizing the slope adopted reduces trench depths and excavation costs.

3.2.1.1.5. Flow Velocity (V)

The equation most often used to calculate the flow velocity in free conduits is Manning's formula.

$$V = (1/\eta) \,.\, R_h^{2/3} \,.\, i^{1/2}$$

V = flow velocity (m/s)
R_h = hydraulic radius (m)
i = pipe slope (m/m)
η = Manning's coefficient (-)

One of the most important parameters in this equation is Manning's coefficient (η). The lower its value, the higher the flow velocity inside the pipe for a given slope.

Manning's coefficient varies according to the type of pipe and the material used in its manufacture. For practical purposes and calculation purposes, smooth-walled PE pipes have a value of η=0.010.

3.2.1.1.6. Flow Rate (Q)

The flow rate in a pipe functioning as a free conduit, for non-viscous liquids, is calculated by multiplying the wet area by the flow velocity, according to the formula:

$$Q = A_m \cdot (1/\eta) \cdot R_h^{2/3} \cdot i^{1/2}$$

Q = flow rate (m^3/s)
A_m = wet area (m^2)
R_h = hydraulic radius (m)
i = pipe slope (m/m)
η = Manning's coefficient (-)

3.2.1.1.7. Tensile Stress

The tensile stress **(**σ_t**)** is calculated using the formula:

$$\sigma_t = \gamma_l \cdot R_h \cdot i$$

σ_t = tensile stress (Pa)
γ_l = specific weight of the fluid (N/m^3)
R_h = hydraulic radius (m)
i = pipe slope (m/m)

3.2.1.1.8. General Considerations for Hydraulic Dimensioning

When dimensioning pipes for networks in which the initial and final design flow rates are defined, they must be sized for the final flow rate, and the maximum and minimum flow velocity values as well as the tensile stress must be checked to ensure that they are within the limits established for both the final condition and the initial flow rate condition defined for the network. It is recommended that, whenever possible, the pipe be checked for final flow at a water table height equal to 81.3% of its inner diameter, a condition which allows the maximum flow velocity to be assessed inside and outside the system.

Kanaflex offers designers and interested parties a KNTS Drain Spreadsheet to support the dimensioning and evaluation of all the parameters of interest in the design, as well as simulations of slope variation or the water table height/inner diameter ratio (y/di) for the design of networks using KNTS Drain pipes.

3.2.1.1.9. Flow Rate and Velocity Table

DN	y	θ	n	Am	i (m/m)	0.10%		0.20%		0.30%		0.40%		0.50%	
					Rh	V	Q	V	Q	V	Q	V	Q	V	Q
mm	-	º	-	m2	m	m/s	l/s	m/s	l/s	m/s	l/s	m/s	l/s	m/s	l/s
250	0.938	302.327	0.010	0.0494	0.074	0.56	27.43	0.79	38.80	0.96	47.52	1.11	54.87	1.24	61.35
300				0.0774	0.092	0.65	49.95	0.91	70.64	1.12	86.52	1.29	99.90	1.44	111.70
400				0.1224	0.116	0.75	92.10	1.06	130.24	1.30	159.51	1.50	184.19	1.68	205.93
500				0.1936	0.146	0.88	169.66	1.24	239.94	1.52	293.87	1.75	339.33	1.96	379.38
600				0.2810	0.176	0.99	278.83	1.40	394.32	1.72	482.95	1.98	557.66	2.22	623.48
800				0.4848	0.231	1.19	577.00	1.68	816.01	2.06	999.40	2.38	1,154.01	2.66	1,290.22
1000				0.7485	0.287	1.38	1,029.44	1.95	1,455.85	2.38	1,783.04	2.75	2,058.88	3.08	2,301.89
1200				1.0872	0.346	1.56	1,693.61	2.20	2,395.13	2.70	2,933.42	3.12	3,387.22	3.48	3,787.03

Table 12 a - Flow Velocity and Maximum Flow for Different Slopes (Part 1/2)

DN	y	θ	n	Am	i (m/m)	0.10%		0.20%		0.30%		0.40%		0.50%	
					Rh	V	Q	V	Q	V	Q	V	Q	V	Q
mm	-	º	-	m2	m	m/s	l/s	m/s	l/s	m/s	l/s	m/s	l/s	m/s	l/s
250	0.938	302.327	0.010	0.0494	0.074	1.76	86.76	2.49	122.69	3.04	150.27	3.51	173.51	3.93	193.99
300				0.0774	0.092	2.04	157.96	2.89	223.39	3.54	273.60	4.08	315.92	4.56	353.21
400				0.1224	0.116	2.38	291.23	3.36	411.86	4.12	504.43	4.76	582.46	5.32	651.21
500				0.1936	0.146	2.77	536.53	3.92	758.76	4.80	929.29	5.54	1,073.05	6.20	1,199.71
600				0.2810	0.176	3.14	881.73	4.44	1,246.96	5.43	1,527.21	6.28	1,763.47	7.02	1,971.61
800				0.4848	0.231	3.76	1,824.64	5.32	2,580.44	6.52	3,160.38	7.53	3,649.29	8.42	4,080.03
1000				0.7485	0.287	4.35	3,255.37	6.15	4,603.79	7.53	5,638.46	8.70	6,510.74	9.73	7,279.23
1200				1.0872	0.346	4.93	5,355.67	6.97	7,574.05	8.53	9,276.28	9.85	10,711.33	11.01	11,975.63

Table 12 b - Flow Velocity and Maximum Flow for Different Slopes (Part 2/2)

Note: Maximum Flow occurs when y/di = 0.938 and Maximum Velocity occurs when y/di = 0.813.

4. Installation

Considering that non-rigid pipes for underground installations are designed taking into account the bed (native soil or compacted backfill) and enclosure, the pipe and the laying material together form a pipe-soil system suitable for providing support for the installation. It is therefore important that the construction process of the underground pipe network, defined at the design stage of the pipeline system, includes a geotechnical foundation or design.

The structural calculation recommendations in this manual are based on the installation of the non-rigid pipe in trenches with open vertical walls in stable natural terrain. For landfill applications, the pipe must be installed after the earthwork soil has been compacted and the trench opened, as discussed above.

4.1. General Considerations on Soil and Geotechnical Properties

Knowledge of the geotechnical properties of the native soil, in the bed, in the surrounding areas and in the final landfill, is very important in relation to the location and conditions of the excavation, as well as the possibility of using the local soil in the surrounding area of the pipe. Native soil analysis, when carried out at the design stage, also makes it possible to identify seasonal changes in the soil, such as the presence of water.

4.1.1. Trench Opening and Filling Soil

The native material or compacted backfill where the trench will be opened must adequately confine the pipe's enclosing and covering layers (cradle, reverse zone, initial landfill and final landfill) to provide it with the necessary support for an installation that will perform adequately throughout its service life.

In cases where the native soils do not provide suitable materials for making the cradle and enclosing the pipe, it is necessary to import the material.

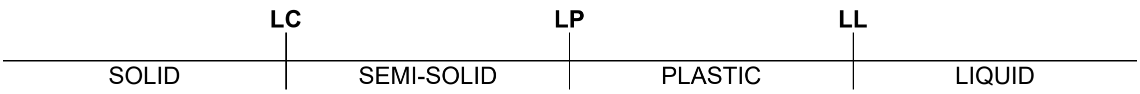
Soil characterization basically involves knowledge of three factors:

a) **The aspects of its three-phase structure**, i.e. the proportions of solid particles, water and air present in the pores. In its most general state, soil is an element made up of solid particles which, when organized, form a porous matrix whose voids can be filled with water and/or air. When all the voids are filled with water, the soil is called “saturated”; when they are filled only with air, it is called “dry soil”. In the intermediate condition, the soil is called “unsaturated”.

b) The aspects of the particle size curve, which is obtained by separating the soil into various fractions according to the size of the particles. The classification of soils according to particle size is divided into Rubble (gravel and pebble/crushed rock), Sand, Silt and Clay, taking ABNT NBR 6502 as a reference.

   The Rubble and Sand ratings form the coarse soils, also known as non-cohesive soils. Silty and clayey soils have very small diameter particles that are invisible to the naked eye and are also called cohesive soils.

c) **Consistency indices** establish consistency limits, which are the moisture levels at which the soil material passes from one physical state to another. In the case of clays, the particles, due to their geometric shape and chemical constitution, have a great avidity for water, which greatly influences the consistency of the soil. The consistency limits, or Atterberg limits, vary from solid to liquid, passing through the state of plasticity, depending on the moisture content. The determination of the liquidity limit is standardized by ABNT NBR 6459 and the plasticity limit by ABNT NBR 7180.



Atterberg limits or consistency of a soil.

When excavating trenches, the soils must have a certain content of fine material with good plasticity to avoid the use of shoring. Materials free of fines and clayey soils of lesser consistency almost always require some form of wall containment.

Geotechnical studies aimed at installing underground structures usually involve investigating the subsoil order to gain an adequate understanding of the composition of the terrain, as well as the water table. There are several ways of investigating the subsoil, the most common for underground pipe projects being auger borings and simple reconnaissance borings.

The simple reconnaissance survey (SPT - Standard Penetration Test) is an activity that not only allows you to determine the stratigraphy of the terrain, together with the position of the water level, but also makes it possible to obtain the penetration resistance index of the soil. Soil strength or blow count (SPT test) is a benchmark indicator for assessing the firmness and consistency of native soil.

4.1.2. Soils for use in Pipe Enclosure

Backfill soils that are essentially granular provide relatively high stiffness with minimal compaction effort; compacted granular soils have little tendency to shift or consolidate over time. Non-cohesive soils are less sensitive to moisture, both when they are laid and during long-term use.

If the particles are mostly clay, the soils are more sensitive to moisture, reducing rigidity and causing the soil to shift over time. In this case, greater compaction effort is required to achieve the required density. Considering soils at a maximum liquidity limit (LL) of 40%, highly moisture-sensitive and plastic soils should be eliminated from application for enclosure.

Granular soils such as pebbles, crushed rock, gravel and sand are easy to use as enclosure and backfill and are very reliable. They have a low sensitivity to moisture and the backfill can be easily compacted using a vibratory plate compactor, in layers of 20 to 30 cm. In trenches with the presence of water where a combination with gravelly soils is used, a geotextile with a filtering/separating function should be used to prevent particle migration and subsequent loss of pipe support.

Silty sand type soils are acceptable as enclosing/backfill material for pipe installation. In the case of trenches opened in silty sand soil, it can be directly reused as backfill material in the pipe area. Precaution should be taken with these soils, as they can be sensitive to moisture. Moisture control may be required when compacting the soil to achieve the desired density with reasonable compaction energy.

Soils of the silty/clayey sand and sandy/clayey silt types are acceptable materials for enclosures/backfill, however, their relatively low stiffness hinders their use in deeper installations which can become saturated, preventing proper compaction in places where stagnant water is present. Extra care must be taken when placing and compacting the backfill under the pipe.

Cohesive soil can be used in the pipe enclosure area with the following precautions:

- The moisture content must be controlled during placement and compaction. The clay soil should not be wetted during compaction of the layers when applying it to the enclosure and/or backfill. The densification process should be applied when using materials such as sand or crushed rock dust;
- It should not be used in installations with unstable foundations or where water is present in the trench;
- Extra effort will be needed to place and compact the backfill in the reverse zone;
- Compaction tests should be carried out periodically during installation to ensure that the appropriate relative compaction has been achieved;
- Care must be taken not to cause an increase in the vertical diameter of the pipe due to excessive lateral compaction effort.

4.1.3. Soil Compaction for use in Enclosures and Final Landfills

In general, the minimum degree of compaction specified for the layers is 94% in relation to the normal Proctor energy.

In soils with a higher fraction of fines, the enclosure should be compacted with portable sockets (manual or mechanical). In granular soils, compaction is more efficient if carried out by vibratory plate equipment.

4. 2. Installation Procedure

4.2.1. Trench Opening and Preparation

When installing underground pipes, the trench walls should preferably be vertical and their width can be determined by the diameter of the KNTS Drain pipe to be installed, the quality of the local soil, backfill materials, loading and compaction levels. The height of the enclosing layer above the upper generating line of the pipe (Figure 27) is recommended to be at least 30 cm and, above this, the height of the final backfill layer should not be less than 30 cm to the surface level of the natural terrain, or the top level of the asphalt floor/covering layer. In situations where there is constant vehicle traffic and/or landfill above the top of the trench, the height of the backfill layers may vary and is calculated according to the vertical deflection limit allowed in the design for the pipes, as discussed in items 3.1.4 and 3.1.5.

4.2.2. Trench Digging

The trench must be dug in accordance with the construction specifications. If all or part of the excavation is to be mechanized, the type of equipment to be used at this stage must be defined in advance, taking into account the type and volume of material to be excavated, the depth and width of the excavation, the need to shore up the walls, the way the pipe is supported, the space available between the installed pipe and the trench walls for adequate compaction, the type of shoring and its removal, among other factors.

The use of backhoes or trenchers is very advantageous, except when rocks or other interferences prevent their use.

At the beginning of the trench excavation, the debris resulting from breaking up the paving should be moved away from the edge of the trench, to prevent it from being misused during the subsequent pipe enveloping stage. During excavation, material free of stones or debris must be placed outside the limits of the trench to avoid possible collapse into the trench.

4.2.3. Trench Width

The width of the trench must be calculated to allow for the pipe installation services and the compaction of the adjacent soil. The space between the pipe and the side walls of the trench must be greater than the width of the necessary compaction equipment (vibratory plates, manual or mechanical sockets).

The suggested trench width for installing KNTS Drain pipes, unless specified otherwise in the design, is shown below:
Trench width = Pipe outer diameter + 2 x 400 mm.

4.2.4. Trench Depth

The excavation of the trench must exceed the depth of the project by at least 15 cm to allow the placement of regularizing cradle layer on which the pipe is laid.

The bottom of the trench on which the cradle layer will be laid must be uniform, free of stones or other objects that could cause stress or damage to the pipes to be installed, always complying with the slope stipulated in the design.

In some situations, it may be necessary to partially replace the soil at the bottom of the trench with a better quality material or even a concrete base, and the cradle layer should always be laid on top of this base.

4.2.5. Alignment and Slope

The slope of the bottom and the alignment of the trench must be carefully controlled in accordance with the design, especially in installations that operate by gravity.

4.2.6. Trenches with Shoring

Trenches that require shoring need special attention and should be supervised by the engineer in charge. Metal or wooden shoring planks, arranged in such a way as to prevent the contained material from escaping into the trench, can be reused or removed from the site after the trench has been backfilled. If the planks are to be reused, it must be ensured that the backfill will not be damaged during removal, and the voids left must be filled and properly compacted.

4.2.7. Trenches with Water in them or Installation of Pipes under Water Table

As already mentioned in item 4.1.1, in its most general state, soil is an element made up of solid particles which, when organized, form a porous matrix whose voids can be filled with water and/or air. When all the voids are filled with water, the soil is called "saturated"; when they are filled only with air, it is called "dry soil". In the intermediate condition, the soil is called "unsaturated".

Trenches excavated below the ground's water level require lowering the water table to maintain the stability of the excavation. A suitable system with suction pumps must be used to lower the water level. The water level must be kept below the excavation level until the backfill material reaches a height equal to or greater than the original water table so that the trench remains stable. During the lowering of the water level, preventive measures must be taken to avoid the carrying away of fines and the creation of voids in the soil.

Pipes that are totally or partially submerged are subjected to thrust (buoyancy force or FF) and in this case care must be taken to prevent the pipe from moving or floating, with the risk of joints breaking and the installation being compromised. The use of ballast bags is advisable in such situations. A pipe floats when the thrust on it is greater than the forces that anchor it (pull/push it down).

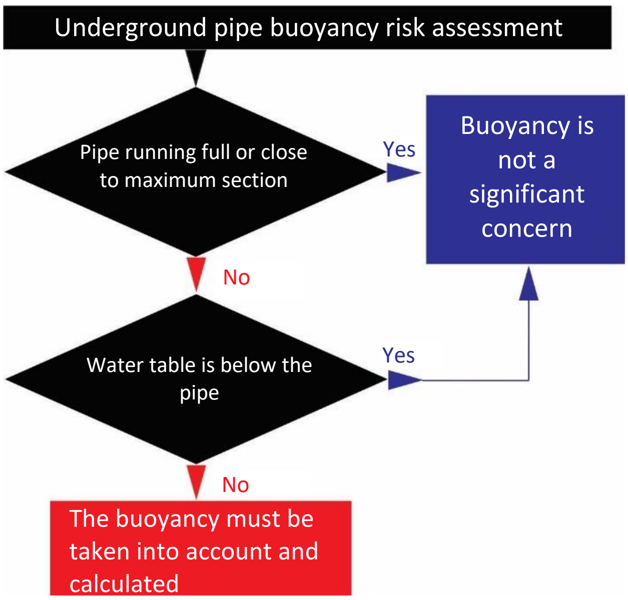


Figure 34: Buoyancy risk assessment flowchart for underground pipe

The anchoring forces opposing the buoyancy of the pipe, the sum of which can be called the Negative Thrust (E_N), are those relating to the weight of dry soil (P_{SE}), the weight of saturated soil (P_{SS}), the weight of the pipe (P_T) and the weight of the fluid inside the pipe (P_{FL}).

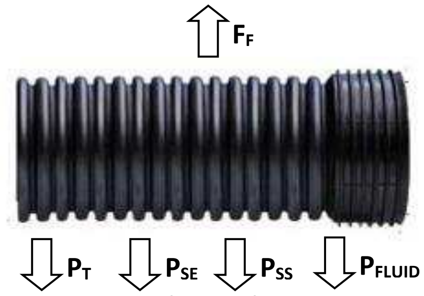


Figure 35 - Forces acting on submerged pipes or saturated soils

For calculation safety reasons, it is recommended to consider the pipe empty, i.e. $P_{FL} = 0$, when calculating the anchoring forces (E_N).

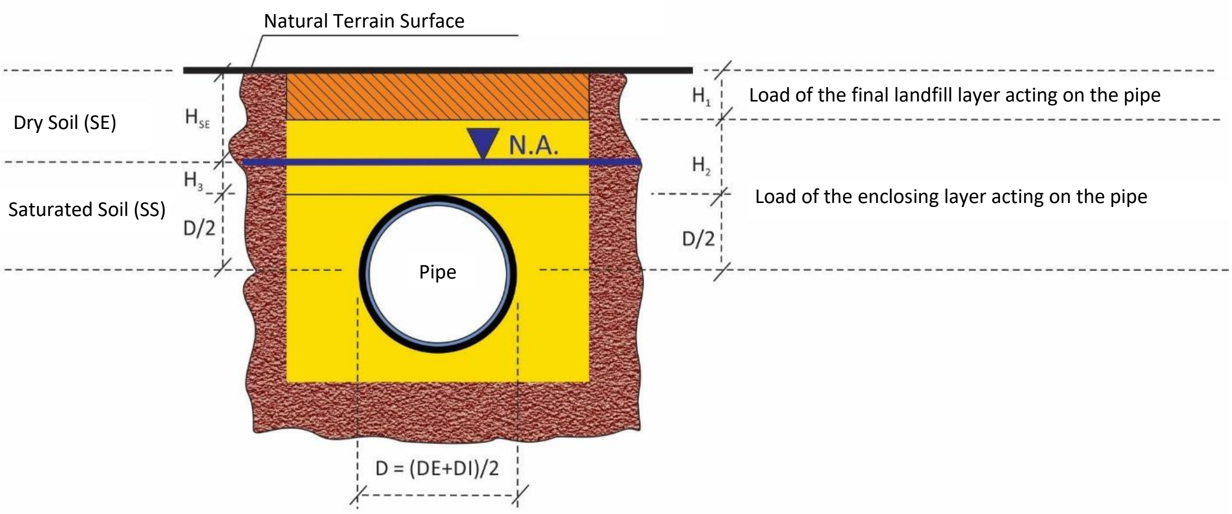


Figure 36 - Illustrative cross-section of a trench with water in it

In order for the pipe not to float, the following condition must be maintained: $F_F < E_N$.

ND	F_F (N/ml)	$F_F - P_T$ (N/ml)
250	594	562
300	930	881
400	1,470	1,392
500	2,333	2,205
600	3,380	3,192
800	5,648	5,358
1000	8,883	8,428
1200	13,040	12,427

Note: Considering acceleration of gravity = 10 m/s² and density of groundwater = 1000 kg/m³

Table 13 - Buoyancy force and weight of KNTS Drain pipe

4.2.8. Pipe Enclosure - Construction Recommendations

The material used for the enclosure must be free of rock fragments. Soils with high plasticity or high organic matter content should also be avoided. Likewise, the use of materials subject to erosion that can easily be carried away by liquids from any gaps in the joints should also be avoided in the enclosure, which could cause voids to open up and put the structure at risk.

The execution processes for the pipe enclosure are described below, as shown in Figure 28.

4.2.8.1. Cradle Layer

The first layer in the trench, the cradle, is the support for the pipe and has the function of providing a uniform distribution of stresses in the lower areas of the pipe's perimeter. The cradle also has the function of regularizing the place where the bottom of the pipe rests, avoiding uneven surfaces and sharp materials during installation. The recommended material for the cradle layer is uncompacted sand, but clay material can also be used, as long as there is no water or groundwater rising from the bottom of the trench.

In cases where the bottom of the trench has unstable soil, a stabilization procedure is required for laying the pipes, such as the construction of a foundation to reduce possible differences in the settlement of the bottom of the trench. Such a foundation can be made using rock dust or gravel, depending on the severity of the soil conditions at the bottom of the trench, but with a height of no less than 15 cm.

The cradle must be countersunk in the trench under each pipe bell location to maintain alignment at the bottom of the pipe. The thickness of the cradle must be 15 cm for support on soil or rock. It is ideal for the cradle to have compressibility equal to that of the compacted backfill of the backfill layers in the reverse and initial landfill zones, so that the system deforms uniformly during the construction process. After the cradle has been leveled, its central area can be loosened to a depth of up to 5 cm to lay the KNTS pipes and fill the valleys in the corrugation of the outer wall.

4.2.8.2. Reverse and Initial Landfill Zone Layer

The reverse zone, which is difficult to access, must be given special attention during backfilling and compaction. The material must be placed in the reverse zone of the pipe with a shovel and compacted with a portable socket (manual or mechanical). Compaction should be carried out carefully to ensure complete contact between the material and the pipe, thus avoiding excessive deflections in the pipe in the future.

In the reverse and initial fill zones up to the upper generating line of the pipe, uniform layers must be placed and compacted simultaneously on both sides of the pipe. Under no circumstances should compaction be carried out at different elevations on the sides of the pipe. For side filling, compaction generally progresses best when the backfill is first compacted close to the trench wall and then towards the pipe. The number of repeated applications of the compaction equipment, at a constant rate of movement, will increase the relative compaction. If the equipment is changed, the number of passes to achieve the specified relative compaction can be affected. Due to their characteristics, heavier and wider plate vibrators compact deeper and to a higher degree than lighter and narrower ones. Similarly, smaller, lighter impact compactors have a lower effective depth than larger, heavier ones.

4.2.8.3. Layer Compaction

The maximum and minimum permissible installation depths will be determined by the material selection and compaction level of the backfill in the pipe zone. The firmer the ground, the deeper the pipe can be installed, meeting a limited deflection in the design.

A more detailed approach to soil types and compaction levels is presented in item 4.1.2.

Caution is recommended during compaction, since the equipment can generate dynamic forces capable of damaging or misaligning the pipes during installation. Direct blows should never be made to the pipe, and care should be taken to ensure that the shape or alignment of the pipes is not altered by excessive compaction.

To adjust the pipe installation method to an optimum condition with a given type of fill, some observations should be made in the installation phase of the first pipe sections, correlating the resulting relative compaction as a function of soil type, method of placing and compacting the soil in the trench zones and pipe side fill areas, height of fill layers used, moisture content and number of passes. These observations allow the acquisition of good sensitivity to define the efforts required during installation.

Checking the increase in the pipe's vertical diameter is a reasonable benchmark for assessing the compaction effort used during installation, when backfill must be properly placed and compacted in the pipe trench area. Excessive levels of lateral compaction can result in an unwanted vertical increase in diameter. If this happens, the lateral compaction levels should be reviewed before proceeding with the installation.

Compaction on the top of the pipe must ensure that there is enough material not to impact on the pipe. At least 30 cm of cover should be considered when using a manually operated vibratory plate compactor.

4.3. Pipe Laying

The pipe must be laid carefully, respecting slopes and alignments.

4.3.1. Positioning the Pipe in the Trench

Pipes up to DN400 can be unloaded and lowered into the trench manually; from DN500 to 1200 they must be lowered with the aid of mechanical equipment using nylon straps fixed at two points on the pipe. Mechanical equipment can also be used to facilitate the joints.

If heavy construction equipment is moving around the trench, a distance of 1 to 2 m must be maintained from the pipe's laying axis so that damage can be avoided during the installation phase.

4.3.2. Parallel Pipes in Trench

When two pipes are installed parallel in the same trench, the recommended spacing between them is shown in Table 14:

Pipe nominal diameter	Recommended spacing between pipes
Up to ND600	300 mm
> ND600	OD/2

Table 14 – Recommended spacing between pipes

If more than two parallel pipes need to be installed in the network, it is recommended that different trenches be dug 1.0 m apart, with up to 2 pipes per trench. The purpose of this recommendation is to limit the trench width to the pipe-soil interaction condition so as not to compromise the pipe's vertical deflection limits, as discussed in this Manual.
If it is necessary to install pipes of different diameters in the same trench, it is recommended that their lower parts are laid at the same level. If this is not possible, suitable enveloping material should be used to fill in the space from the bottom of the trench to the level at which the cradle of the lowest part of the uppermost pipe will be formed. This material, as well as the material between the pipes, must be compacted to ensure the pipe-soil interaction condition.

4.3.3. Installing Pipes on Land with Steep Slope

The angle at which slopes can become unstable depends on the quality of the soil, and the risk of unstable conditions for installation increases significantly with the angle of the slope. In general, buried pipes should not be installed on slopes greater than 15 degrees, or in areas where the slope is unstable.

A steep slope also implies an increase in flow velocity, with HDPE pipes allowing flow velocities well above the limits recommended in the Standards for concrete pipes. See the approach to flow velocity in item 3.2.1 of this manual.

For underground installations, pipes can be installed on slopes greater than 15 degrees under special circumstances, provided that:

- The long-term stability of the installation can be ensured with appropriate geotechnical design;
- The pipes are buried using enclosure made of cohesive granular material with high shear strength or shear strength can be ensured by other means. The enveloping and final fill layers must be compacted to at least 94% Normal Proctor;
- The pipes must be installed in a straight alignment and with the smallest possible gap between pipes;
- The installation is adequately drained to prevent materials from collapsing and to ensure the soil's resistance to shear.

The individual stability of each pipe must be monitored throughout the installation phase, especially by checking the clearance at each pipe joint.

4.3.4. Projecting pipes or pipes with an upper generating line above the natural ground level

As discussed in item *3.1.2*, this is a special installation condition that is not considered to be of the "in trench" type. Examples include railway and road culverts. Two special precautions must be taken into account when deciding on this type of application: the side walls do not always provide the stability condition presented by side walls of excavated trenches in natural soil, and it may be necessary to build a gabion-type support structure or another that presents behavior equivalent to excavated trench walls. In most cases there are no termination boxes at the ends of the pipe section. Risks of vegetation growth and burning, if present on the installation site, must be considered.

4.3.5. Pipe Joints and Fittings

The joining method is based on placing the sealing ring in the valley of the 1st corrugation of the spigot of a pipe and fitting it into the bell of another pipe or fitting.
The performance of the elastic joint (hydrostatic pressure according to EN1277) is less than or equal to 0.5 Bar.

The following is a step-by-step description of the procedures for correctly joining pipes and fittings to ensure that the system is watertight.

Step 1: Preparing the surfaces to be joined.

- Use a damp cloth to clean the bell that will receive the spigot of the pipe with the sealing ring;
- At the end of the pipe, remove the protection that surrounds the sealing ring and check its integrity, as well as that it is positioned in the valley of the 1st corrugation;
- Clean the spigot and sealing ring.

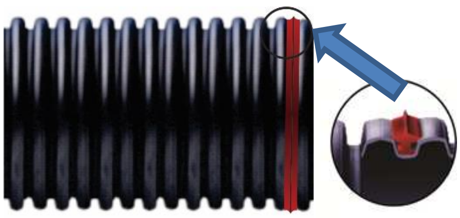


Figure 37 - Detail of the installed sealing ring
Note: The red color of the ring is for illustrative purposes. It is supplied in black.

Step 2: Lubrication.

- Lubricate the sealing ring and pipe bell with Kanalub lubricating paste;

Figure 38 - Application of lubricating paste

Step 3: Pipe alignment.

- Align the pipes vertically and horizontally;
- Move the spigot closer to the bell.

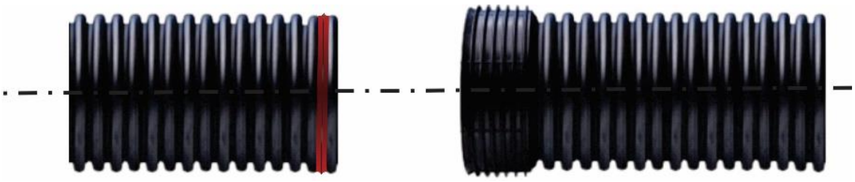


Figure 39 - Pipe alignment

- The spigot is inserted into the bell by means of a quick fit (after lubrication) in accordance with the conditions in the following paragraph, pushing or pulling one pipe bar towards the other until the spigot is completely inserted into the bell;
- For pipes up to DN600, a lever and wooden bulkhead can be used to facilitate this movement, as shown in Figure 40. The purpose of the wooden bulkhead is to prevent concentrated stress on the wall of the pipe spigot or bell.

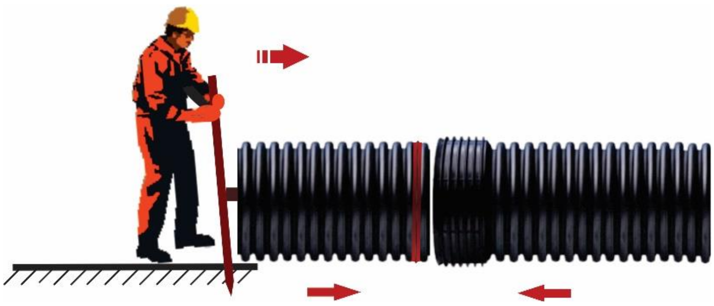


Figure 40 - Inserting the spigot in the bell

- For pipes up to and including DN600, inserting the spigot into the bell (after lubrication) can be done with the mechanical aid of an excavator, placing a wooden bulkhead as mentioned in the previous paragraph, pushing one bar of pipe towards the other. The spigot can be inserted into the bell, especially when installing curved fittings, using nylon straps with a minimum width of 3 cm, which should be positioned hugging the body of the pipe (never in the bell), on each part to be joined. With the aid of tightening ratchets, pull the straps to bring the pipes closer together until complete spigot-bell insertion.

Figure 41 - Use of straps and ratchets

4.3.6. Angular Deflection at the Joint

The KNTS Drain pipe joint, of the elastic joint type (spigot/bell/sealing ring), allows angular deflections within certain limits, for adjustments to the alignment and layout during the assembly stage and over time to absorb small ground movements without compromising watertightness.

The joint, which is easy to assemble, also provides mobility, as it allows longitudinal expansion by moving the ring inside the bell. Double-walled structured pipes are not designed for the bar to work under bending, only under compression.

Depending on the nominal diameter of the pipe, each joint allows a certain angular deflection limit. It is important that the pipes are laid in a perfectly aligned position on the cradle layer in the trench, and only after the junction and the enclosure of the pipe have been completely assembled up to the upper generating line should the angular deflection be carried out up to the limits indicated in table 15, so as not to compromise the structural integrity of the pipes, since each junction transfers part of the stresses to the pipe walls under deflection forces.

Pipe ND	Maximum Angular Deflection per Joint (degree)
up to 300	2.0
400 to 600	1.5
800 to 1200	1.0

Table 15 - Angular Deflection

4.3.7. Anchoring Fittings and Pipe Envelope in Concrete

When pipes or fittings need to be encased in concrete, such as blocks to support atypical loads or anchoring blocks for angled fittings, special care must be taken in addition to the other installation guidelines cited in this manual.
To anchor the KNTS pipe or fittings, during concreting they will be subject to high thrust/buoyancy forces. Therefore, to restrict the movement that can be caused by such stresses, the pipe/fitting can be tied to an anchoring base as shown in figure 42. Lashings can be made with flat polyester strapping, a minimum width of 3 cm, strong enough to withstand the

buoyancy forces, spaced no more than every 2 m. The straps must be pulled tight enough to prevent buoyancy, without excessive tightness that could cause additional deflection of the pipe/fittings.
When building anchor blocks for curved fittings, it is recommended to leave the joints free, without encasing them in concrete.

Figure 42 - Anchoring

The use of ballast bags, as discussed in item 4.2.7, is another way of avoiding pipe movement during concrete curing periods.

4.4. Repaving

The pipe must be covered in layers 30 cm thick, compacted, forming a minimum level of 80 cm above the upper generating line of the pipe, with material free of stones or sharp, pointed objects with sharp edges. The rest of the covering can be done with granular material from the excavated site itself, compacted in layers 30 cm thick. If the excavated material does not reach the required degree of compaction of 94% Normal Proctor, replace the material of the final fill layer with another of better quality.

A finish should be provided at the end of the pipe as a wing wall and energy dissipater, protecting the network from vandalism, fire or high fluid velocity.

4.5. Arrival and Departure at Pass Box or Manhole

The end of the pipe in or out of the Passage Box or manhole must always be finished with the end side of the pipe. Thus, for the first outlet pipe to be laid from the box, it is recommended to cut the bar close to the middle, use the spigot-spigot half and reserve the spigot-bell half for termination in the next box, so that the bell is not discarded at the beginning of the outlet section. Continue throwing the other bars in the direction of flow. It is recommended that at least three pipe corrugations be accommodated on the side wall of the box. The corrugations of the larger diameter pipes probably extend beyond the width of the box, so the outer wall of the box should be reinforced with a 20-cm layer of concrete.

Figure 43 - Arrival at Box

5. Handling and Transportation

When transporting and handling the pipes, avoid shocks or contact with elements that could compromise their integrity, such as sharp or pointed objects with sharp edges, stones, etc. Unloading must be carried out carefully, and the pipes must not be dropped directly into the ground to avoid denting, breaking, perforation or concentration of loads at a single point, see Figures 44 and 45.

Figure 44 - Transport and unloading precautions

For diameters up to 400 mm, unloading can be done manually and for pipes from 500 mm to 1200 mm, with the aid of equipment using nylon straps.

Figure 45 - Unloading and handling by hand and with nylon straps

The use of any other material for lifting, such as chains or steel cables, is not recommended as it can damage the pipes.

Occupational capacity per truck (width = 2.4 m and height = 2.8 m)								
ND	Truck 8 m 52 m³		Trunk 10 m 69 m³		Semi-trailer 12 m 81 m³		Trailer 14 m 110 m³	
	(m)	(bars)	(m)	(bars)	(m)	(bars)	(m)	(bars)
250	474	79	474	79	948	158	948	158
300	288	48	288	48	576	96	576	96
400	150	25	150	25	360	60	360	60
500	114	19	114	19	228	38	228	38
600	72	12	72	12	144	24	144	24
800	36	6	36	6	72	12	72	12
1000	24	4	24	4	48	8	48	8
1200	12	2	12	2	24	4	24	4

Table 16 - Occupational capacity per truck

6. Storage and Warehousing

The storage/warehousing of KNTS Drain pipes must be carried out supported on pieces of wood, on firm, level ground, free from any elements that could damage the material, such as: hard surfaces with sharp edges, sharp or pointed objects, stones, debris, etc.

Avoid hitting the ends of the pipes to avoid damaging them in any way. Do not drag the pipes. The pipe bells must be free from the storage pile, alternating between one pipe and another.

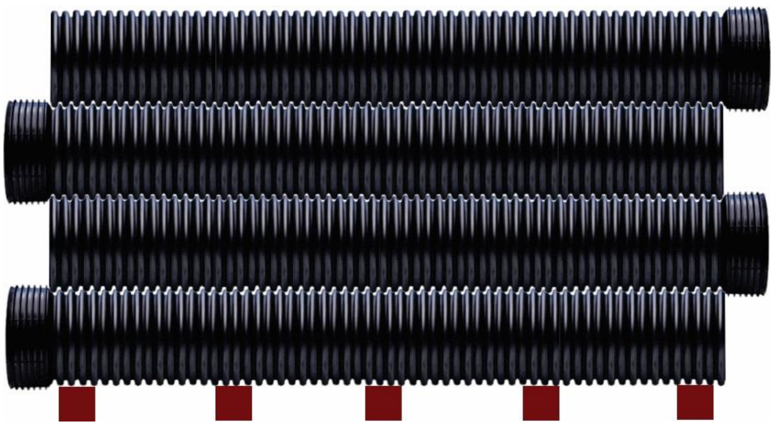


Figure 46 - Accommodation on wooden rafters

Pipes should not be stored directly on the ground to avoid deformation. They should be laid out horizontally, with the first layer placed on transverse pieces of wood at least 10 cm wide, spaced no more than 50 cm apart (Figure 46).

Vertical stakes, spaced every meter, should be placed for lateral support of the pipe layers or wide wooden beam wedges should be used.

Do not store pipes near heat sources and avoid contact with aggressive chemical agents such as solvents in general.

Stockpile at a maximum height of three meters to facilitate the laying and removal of the pipes of the last layer, and they should not be exposed outdoors for a period of more than 12 (twelve) months.

If the pipes and fittings need to be stored for longer than the period stipulated above, we recommend storing them in covered and ventilated areas or covering them with tarpaulins for more effective protection against direct sunlight.

7. Quality Aspects

7.1. KNTS Drain Pipe Regulatory Standards

The KNTS Drain piping system meets the strictest international product standards, defined by the International Organization for Standardization (ISO) and the European Committee for Standardization (CEN).

The characteristics and requirements of KNTS Drain products are determined in accordance with the following standards:

- DNIT 094/2014-EM.

- EN 681, part 1.

7.2. Product Identification

KNTS Drain pipes are legibly and indelibly marked with the following information:

- Kanaflex / KNTS Drain (name of company and product line);
- Nominal dimension (DN/ID);
- Ring Stiffness (SN);
- Material (PE);
- Traceability code (batch);

7.3. KNTS Drain Quality Control

Kanaflex maintains a strict quality control system for its KNTS Drain products, ensuring that the right raw materials are used and that the manufacturing process control requirements and the performance of its pipes, fittings and accessories are met.

7.3.1. Raw Material Control

Before production, the raw materials are assessed for their fluidity index and density, to ensure the right processing conditions and mechanical strength for the product.

On the left, a photo of the Plastometer (equipment for determining the fluidity index of polyethylene resins, according to ISO1133 and NBR9053 standards).

Figure 47 - Raw material control

7.3.2. Product Control in the Manufacturing Process

During the manufacturing process, the dimensional and mechanical characteristics of every batch produced are assessed to ensure that the product will meet the expected performance for its final application.

On the left, a photo of the equipment for determining compressive strength (equipment for determining Ring Stiffness, according to ISO9969 standards).

Figure 48 - Product and manufacturing process control

7.3.3. Final Inspection


Certificado de Conformidade

The final assessment includes checking that the requirements of each product have been met, in accordance with its codes, descriptions and marking.

A Certificate of Conformity is issued for each product batch, containing the full product description, invoice, regulatory standard and compliance with the main requirements assessed for each product batch.

Figure 49 - Final inspection

8. Bibliography

ABNT Standard NBR 6502 - Rocks and soils.

ABNT Standard NBR 6459 - Soil - Determination of liquidity limit.

ABNT Standard NBR 7180 - Soil - Determination of the plasticity limit.

ASTM D-2321 Standard -*Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications*.

ATV-DVWK-A 127 Standard - *Static Calculation of Drains and Sewers.*

EN 681 Standard - *Elastomeric seals - Materials requirements for pipe joint seals used in water and drainage applications - Part 1: Vulcanized rubber.*

DNIT 094/2014-EM Standard: Glass fiber reinforced polyester (GRP) and polyolefin (PE and PP) pipes for road drainage - Material specification.

ISO 1133 Standard - *Plastics - Determination of the melt mass-flow rate (MFR) and the melt volume-flow rate (MVR) of thermoplastics.*

ISO 9969 Standard - *Thermoplastics pipes - Determination of ring stiffness.*

Benedito Bueno, Yuri Costa. Dutos enterrados – aspectos geotécnicos, Oficina de textos, SP, 2012.

Danieletto, José Roberto. Manual de Tubulações de Polietileno e Polipropileno – Características, Dimensionamento e Instalação, Linha Aberta Comunicações, 2014.

Marston, A; Anderson, A. *The theory of loads on pipes in ditches and tests of cement and clay tile and sewer pipe. Bulletin 31, Iowa Engineering Experiment Station, 1913*.

Spangler, M. G. *The structural design of flexible pipe culverts. Bulletin 112, Iowa Engineering Experiment Station, 1941.*

Spangler, M. G. *Theory of loads on negative projecting conduits. Proceedings of HRB, 1950.*

Notes:

1) Kanaflex S.A. Indústria de Plásticos has as its principle the continuous improvement of the products it manufactures.

   Aiming at improvement, changes can be made to this technical manual without prior notice.

2) This technical manual is intended to help KNTS Drain users when laying underground pipes. Please contact Kanaflex if you have any questions that are not covered in this manual.

3) Kanaflex has and provides a technical assistance service at the start of construction. This service is intended to guide installers on the correct procedure for installing the pipe and cannot be considered an inspection. Our technicians do not interfere in engineering and design procedures, which are the responsibility of contractors, designers and installers.

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