PRAGNUM Infrastructure sewer system

Contents

1 INTRODUCTION

1.1 Why is the Pragnum system needed

The globalization and the massive influx of people to the big cities, the intensity of climatic changes and the ever increasing requirements for protection of the environment necessitate deployment of larger drainage systems. The PIPELIFE company, being a leader in this field, aims to meet this challenge and the ever increasing complexity of the engineering solutions by introducing the PRAGNUM sewer system onto the market.

Pragnum is complementing the range of profiled pipes of the Pragma pipe system with diameters from DN/ID 1100 to DN/ID3000, as well as with the non-standard diameters DN/ID 700and DN/ID 900. The Pragnum system is also complementing the product range of type PRO maintenance manholes, allowing the construction of maintenance manholes for inspection of sewerage systems with diameters larger than DN/ID 600.

1.2 What is the Pragnum system?

The pipes of the Pragnum system are manufactured in two stages. A smooth wall pipe is extruded during the first stage. A profile is wounded onto it at the second stage.
This method allows the manufacture of larger diameters up to DN/ID 3000.

By combining various profile configurations and winding steps, it ispossible to manufacture pipes with a large variety of ring stiffness.

1.3 Raw materials used

The raw material used in the manufacture of the Pragnum pipe systems is polyethylene. The main reason for using polyethylene is that this material allows electric fusion welding of the sockets. This method of joining pipes together is extremely important in pipe systems with diameters larger than DN/ID 1000, because it best secures watertightness of the system.

1.4 Operational lifetime

To demonstrate the long-lasting performance of polyolefin (polyethylene and polypropylene) sewer systems, a study was conducted by Teppfa, the European Association of Plastic Pipe Fittings Manufacturers, in collaboration with the Borealis and LyondellBasell raw material producers. The purpose of the study is to provide sufficient validated data in order to declare an expected duration of at least 100 years of operation of the sewer systems produced according to the standards. In the course of the study, their thermal oxidation decay, maximum allowable stress, long-term behavior at constant tensile strength and the influence of impurities and temperature were investigated. For the study, new pipes and those in use for over 40 years have been used. All of these methods are implemented in accordance with valid international standards (ISO) and the accumulated knowledge of polymer materials science.

The results have shown that the operational lifetime of polyolefin sewer systems is at least **100 years** if the materials, products and installation practices meet the relevant requirements.

2 APPENDIX

The Pragnum system is designed for gravity take away of:
- Household waste water
- Industrial waste water
- Storm water and
  Waste water of mixed type

The Pragnum system is also used in the construction of:
- PRO-PRAGNUM maintenance manholes
- Tanks
- Sewer pumping stations PROFOS (feeding tank)
- Gullies

3 BENEFITS

- Resistance to abrasion

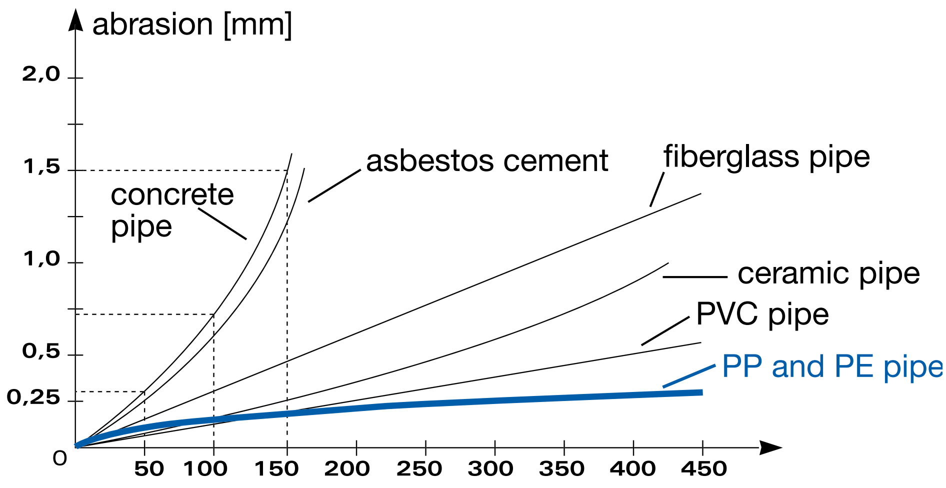


Fig. 3.1

- Chemical resistance (from pH=2 to pH=12)
- Resistance to high temperatures (45°C at continuous flow and 60°C at short-time flow)
- Impact resistance – as per the requirements of DIN 16961-2
- Allows the manufacture of pipe systems with a large variety of ring stiffness from SR24≥2 kN/m^2 to SR24≥125 kN/m^2 (for the whole system of pipes and fittings - as per the requirements of DIN 16961-2) as per the static analysis and provisions of the engineering design.
- Easy transportation
- Fast and simple installation
- Easy cutting and dimensioning
- All elements of the pipe system have an integrated socket for electric fusion welding.
- Guaranteed watertightness of the system in the range up to +0,5 bar, as per the requirements of DIN 16961-2.
- Lightweight
- Long operational life
- Low hydraulic roughness coefficient – theoretical 0,0011 mm, operational 0,015 mm (local resistances not included)
- High hydraulic capacity
- Complete set of connecting elements (fittings and maintenance manholes)
- Integrated part of a comprehensive sewerage system of pipes, fittings, manholes and facilities
- Bright inner surface for convenient inspection
- Maintaining system integrity in loess and weak soils, guaranteed by the electric fusion joints.
- All elements of the Pragnum system are manufactured under constant quality control of the raw materials and the finished product.

4 STANDARDS

4.1 Why are standards necessary?

Standards combine rules and regulations based on practical observations and theoretical investigations regarding the technical parameters the products should meet. They set minimum quality requirements for the specific product. At the same time they also guaranteecompatibility of products, manufactured by different manufacturers.

All this makes the standard extremely important, as it provides guarantees to all stakeholders: designers, engineers, architects, builders, clients, supervisory bodies and others, that the product they use is appropriate for this particular application and meets all requirements to secure unrestricted, fault-free and long-lasting operation.

4.2 Which standards and regulations the Pragnum system complies with?

Item	Standard
Pipe	DIN 16961, EN 13476-1 or on demand ASTM F 894 NBR 7373 JIS K 6780
Statics	ATV A 127 ISO 9969
Hydraulics	ATV A110
Piping installations	EN 1610
Welding	DVS 2207
Internal standard	KWS

Table 4.1

The Pragnum system is manufactured to comply with the requirements of the BDS EN 13476-1:2008 standard "Plastic piping systems for non-pressure underground drainage and waste water collection. Piping systems with multi-layer walls of unplasticized polyvinyl-chloride (PVC-U), polypropylene (PP) and polyethylene (PE). Part 3: Requirements to pipes and couplings with smooth inner surface and profiled outer surface and to B-type systems" and DIN 16961. It complies with the applicable standards and regulations for design of sewerage systems: "BDS EN 752:2008 Sewerage systems outside buildings” and "Regulations for the design of sewerage systems” adopted with order № RD-02-14-140 of 17.04.1989, pursuant to art. 201, par. 1 of the Regional and Urban Planning Act, Bulletin for Construction and Architecture (BCA) 9 and 10 of 1989, amend., BCA 1 of 1993.

4.3 What do the standards require?

The DIN 16961 and BDS EN 13476-1:2008 standards set minimum requirements to the profiled pipe systems with respect to the following characteristics:

Ring stiffness - cross stiffness. Tested according to DIN 16961.

The equation and the method of calculation of the ring stiffness, determined by DIN 16961 and BDS EN ISO 9969 are provided in the tables hereunder.

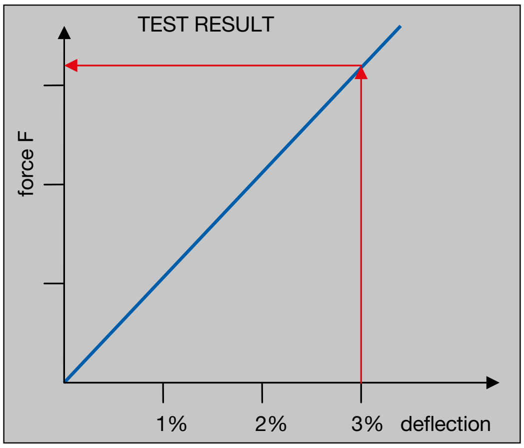
Ring stiffness according to:	
DIN 16961	**ISO 9969**
SR_{24} [N/mm^2]	SN [N/mm^2]
16	4
32	8
64	16
125	31.25

Table 4.2

Ring stiffness	Formula	Explanation
According to: DIN 16961	$SR_{24} = \frac{E_{24}.I_x}{r^3}, [N/mm^2]$	E_{24} – modulus of elasticity after 24 hours, [N/mm²] I_x – moment of inertia, [mm⁴/mm] r – inner radius (r = di/2), [mm]
According to: ISO 9969	$SN = \frac{E_k.I_x}{d_i^3}, [N/mm^2]$	E_k – modulus of elasticity after 1 minute, [N/mm²] I_x – moment of inertia, [mm⁴/mm] d_i – inner diameter, [mm]

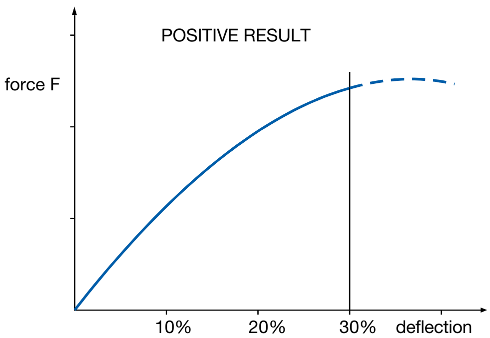
Табл. 4.3

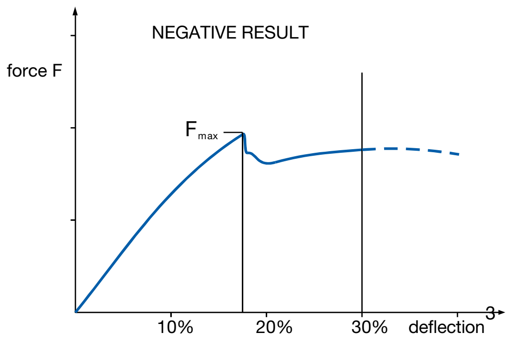
Графиката по-долу показва, че коравината е съотношението между приложената сила и деформацията на пръстена, като деформацията нараства с постоянна скорост.



► Ring flexibility - cross flexibility. Tested according to BDS EN ISO 13968:2008 (old EN 1446)

The standard requires unchanged structure and elasticity of the material at ring deflection up to 30%.





► Creep ratio. Tested according to DIN EN ISO 899-2

Creep is the tendency of plastics to deform slowly under the influence of a permanent load. Creep ebbs away over a period of around two years.

Creep is critical for the watertightness of the socket connection. The DIN 16961-2 standard requires creep ratio for **PE pipes** as follows:

Duration	Creep ratio (stress 2 N/mm² at 23°C) kN/m² min.			
	PE-HD[1]	PVC-U	PP[2] 23°C	
			Homopolymer	Copolymer
1 min (short-term) Eck≥	8 x 10^5	36 x 10^5	12.5 x 10^5	8 x 10^5
24 hours Ec 24 ≥	3.8 x 10^5	30 x 10^5	5.1 x 10^5	3.6 x 10^5
2000 hours Ec 2000 ≥	2.5 x 10^5	23 x 10^5	4.2 x 10^5	2.1 x 10^5
50 years Ec 50 ≥	1.5 x 10^5 [3]	17.5 x 10^5 [3]	2.7 x 10^5	1.2 x 10^5
Check as per section:	5.2.2			

[1] Higher value for $E_{c\ 50}$ needs to be proved by an authorized authority
[2] Higher values need to be proved by an authorized authority
[3] See also ATV-A 127

Table 4.4

The creep ratio is inversely proportional to the modulus of elasticity. The higher the modulus of elasticity, the lower the creep is and vice versa.

► Requirements to dimensions and tolerances of pipes, connecting parts and systems. Tested according to BDS EN 1852-1, БДС EN 12666-1

The main geometric characteristics are provided in the BDS EN 13476 standard. The correct dimensions and tolerances ensure that all system elements are identical, match one another and this connection allows perfect assembly in the best possible way.

The dimensions of the pipes and fittings are determined according to their inner diameter DN / ID. Standard DIN 16961-1 determines the following nominal diameters from DN/ID 100 to DN/ID 3600.

► Impact resistance. Tested according to BDS EN 744, BDS EN 1411, BDS EN 12061

This test is reassuring us that the pipes and fittings will not be damaged during handling, transportation, storage and installation.

According to the BDS EN 13476 standard - part 2 and 3, there is only one major requirement: TIR ≤ 10% at temperature 0°C.

The point of damage is assessed as a true impact (dynamically acting) rate (TIR) for the production lot, where the maximum TIR value is 10% [TIR =total number of damages, divided by the total number of impacts, as a percentage, distributed over the whole lot].

► Water tightness of the pipe connections. Tested according to DIN EN 1610. The integrity of the electric fusion welds is tested according to DVS 2207

These methods test the ability of the system to retain fluids inside and outside the system (filtration/infiltration).

The connections are stress tested. For storm water and sewer pipe systems this is one of the fundamental characteristics.

The standard requires watertightness of the connections at a positive pressure up to 0,5 bar.

► Mechanical strength and flexibility of segment-welded connecting parts. Tested according to DVS 2207 and DVS 2209

The standard specifies that the mechanical strength of the connecting elements should be equal to or greater than the strength of the pipes.

► Resistance to high temperatures. Tested according to BDS EN 1437 and BDS EN 1055

During operation the thermoplastic pipe systems for drainage and household sewers must be able to resist certain temperatures of the waste water. For this purpose, the systems made of thermoplastics must be resistant to the temperatures provided hereunder, when laid in the ground outside the buildings.

According to the empirical studies of TEPPFA

continuous water temperature of 45°C for dimensions ≤ 200 mm
continuous water temperature of 35°C for dimensions > 200 mm

5 PRODUCT RANGE

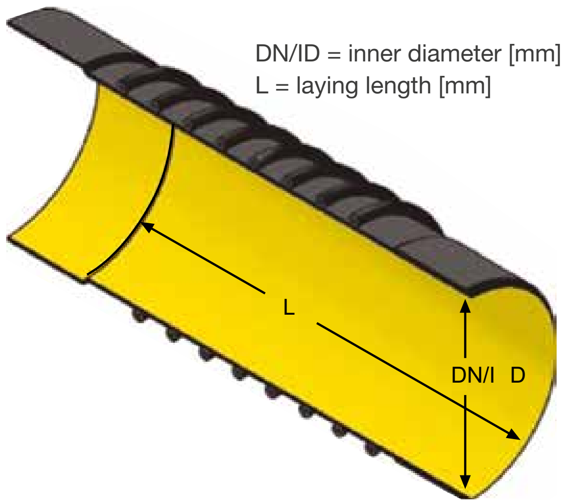
5.1 Pipes and fittings
5.1.1 Pipes

DN [mm]	DN/ID [mm]
700	700
900	900
1100	1100
1200	1200
1300	1300
1400	1400
1500	1500

DN [mm]	DN/ID [mm]
1600	1600
1800	1800
2000	2000
2200	2200
2500	2500
2800	2800
3000	3000

Table 5.1

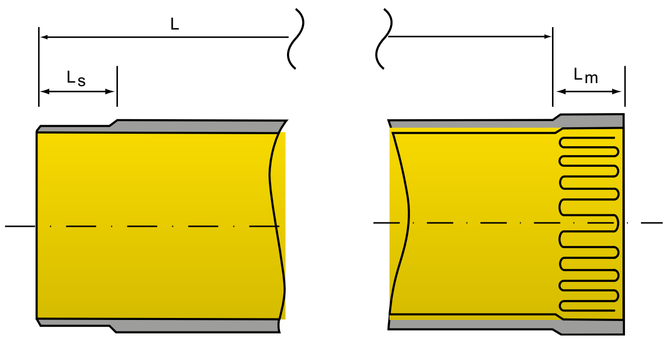
TAvailable pipe lengths are 3, 6 and 12 meters.
These lengths do not include the length of the socket.



DN/ID = inner diameter [mm]
L = laying length [mm]

5.1.2 Connecting elements

All connecting elements are made of pipes with VW or SQ profile. Usually the connecting elements are designed depending on the required stiffness and as per the welding factors. The connecting element may have a socketed and/or smooth end and may be connected to the existing pipe system by electric fusion welding or a socket with rubber elastomeric gasket.
All dimensions of the connecting element comply with the requirements of the DIN16961-1 standard. The standard length of the smooth end (Ls) is 140 mm, and the standard length of the socket (Lm) is 140 mm.



All connecting parts are made of pipes

- Branches:

Branches can be produced and supplied in any type and shape. The angle can be customized from 15° to 90°.

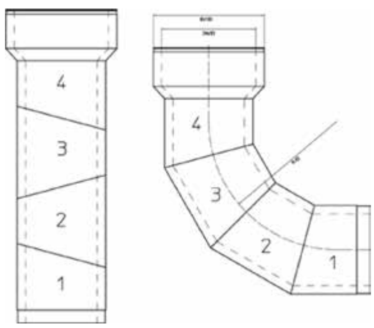
- Bends:

Bends can be manufactured at various angles, and the sweep radius to pipe diameter can be customized.

α	number of segments
15°	2
30°	2
45°	3
60°	3
75°	4
90°	4

Table 5.2

Bend



Segmentation and arrangement of segments for the manufacture of a 90° bend

Note: Product images may differ from the actual products.

- Reducers:

Reducers can be made centric and eccentric, according to requirements. For standard reducers the maximum difference in diameters is 200 mm. Other differences in diameter are also available on demand.

- Sealing flanges:

When the PRAGNUM pipes should pass through walls, we recommend our easy-to-install-in-concrete sealing flanges. Tightness is secured through an elastomeric ring.

All pipes and connecting elements have an integrated electric fusion socket. As an option, an elastomeric rubber seal is also available.

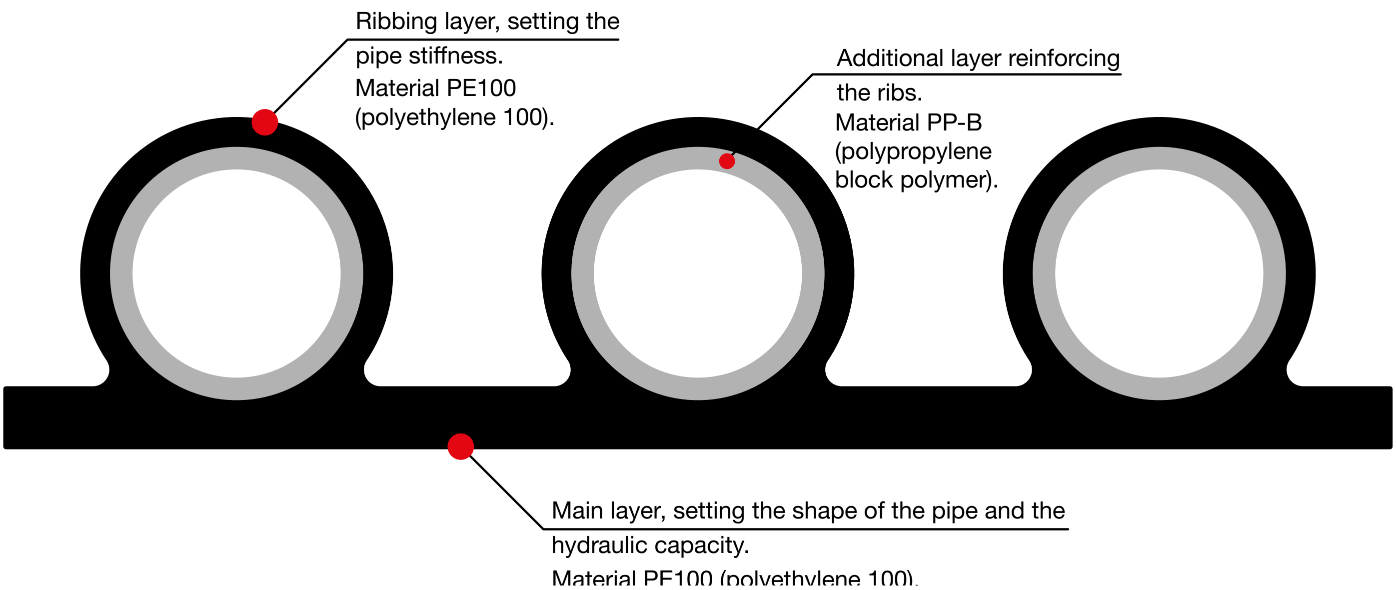
Branches with integrated electric fusion welding connections

Bend DN/ID 2400 mm

Different types of connecting elements

5.1.3 Types of profiles

Except for the compact VW profile, showed further in the text, the standard profile of the pipe consists of a main layer made of PE100, setting the shape and hydraulic capacity of the pipe, a ribbing layer made of PE100, setting the stiffness of the pipe and an additional layer of PP-B (polypropylene block polymer), reinforcing the ribs.



- Profile type PR:

The main advantages of the PR series profile are the smooth inner surface and profiled outer surface. The light weight and high stiffness are also of importance. The field of application of this type of profile is in piping systems, such as drainage, storm water collectors, sewerage and ventilation.

Note: Product images may differ from the actual products.

- Profile type SQ:

This profiled pipe has smooth inner and outer surface, including inner profiles with one or several layers. This profile features a very long-lasting stiffness, which makes it very appropriate for extremely high loads and large diameters. A PR profile, for instance, can be added without problem to a SQ profile or a solid-wall pipe.

- Profile type SP:

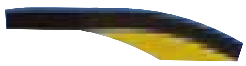
Where the standard profiles are not suitable for the impact of different types of loads, the PRAGNUM pipe systems make possible to combine various types of profiles to achieve the desired result.
This technology allows achieving the following effects: a) the two profiles can be added statically, which results in increased pipe strength; b) adding a profile to the smooth surface is reducing the longitudinal deformation of the pipe in the ground.

- Compact pipes

These pipes have smooth inner and outer surface. The pipes are single-layer (compact). Apart from that, these compact pipes are tempered, which means there are no residual stresses.

- Profile type VW:

The VW profile is a compact solid pipe with smooth inner and outer surface. These pipes can also be used under increased internal operating pressure. The minimum wall thickness is 5 mm, and the maximum one is 80 mm.



s\ DN/ID	5	6	7	8	9	10	11	12	13	14	15	18	20	25	30	35	40
	Тегло, [кг/м]																
700	10.6	12.8	14.9	17.1	19.2	21.4	23.6	25.8	28.0	30.1	32.3	39.0	43.4	54.7	66.0	77.6	89.3
900	13.6	16.4	19.1	21.9	24.7	27.4	30.2	33.0	35.8	38.6	41.4	49.8	55.5	69.7	84.1	98.7	113.4
1100	16.7	20.0	23.4	26.7	30.1	33.5	36.9	40.2	43.6	47.0	50.4	60.7	67.6	84.8	102.2	119.8	137.5
1200	18.2	21.8	25.5	29.1	32.8	36.5	40.2	43.9	47.5	51.3	55.0	66.1	73.6	92.4	111.3	130.4	149.6
1300	19.7	23.6	27.6	31.6	35.5	39.5	43.5	47.5	51.5	55.5	59.5	71.5	79.6	99.9	120.3	140.9	161.6
1400	21.2	25.4	29.7	34.0	38.2	42.5	46.8	51.1	55.4	59.7	64.0	77.0	85.6	107.4	129.4	151.5	173.7
1500	22.7	27.3	31.8	36.4	41.0	45.5	50.1	54.7	59.3	63.9	68.5	82.4	91.7	115.0	138.4	162.0	185.8
1600	24.2	29.1	33.9	38.8	43.7	48.6	53.4	58.3	63.2	68.1	73.1	87.8	97.7	122.5	147.5	172.6	197.8
1800	27.2	32.7	38.1	43.6	49.1	54.6	60.1	65.6	71.1	76.6	82.1	98.7	109.8	137.6	165.6	193.7	222.0
2000	30.2	36.3	42.4	48.4	54.5	60.6	66.7	72.8	78.9	85.0	91.2	109.5	121.8	152.7	183.7	214.8	246.0
2200	33.2	39.9	46.6	53.3	60.0	66.7	73.3	80.1	86.8	93.5	100.2	120.4	133.9	167.8	201.8	235.9	270.1
2500	37.8	45.3	52.9	60.5	68.1	75.7	83.3	90.9	98.5	106.1	113.8	136.7	152.0	190.4	228.9	267.6	306.4
2800	42.3	50.8	59.3	67.7	76.2	84.7	93.3	101.8	110.3	118.8	127.3	153.0	170.1	213.0	256.0	299.2	342.6
3000	45.3	54.4	63.5	72.6	81.7	90.8	99.9	109.0	118.1	127.3	136.4	163.8	182.2	228.1	274.1	320.4	366.7

Table 5.4 - Weight of VW type profile pipes

s - solid wall thickness [mm]. Other dimensions and materials are available on demand. Weight excluding socket and spigot.

Note: Product images may differ from the actual products.

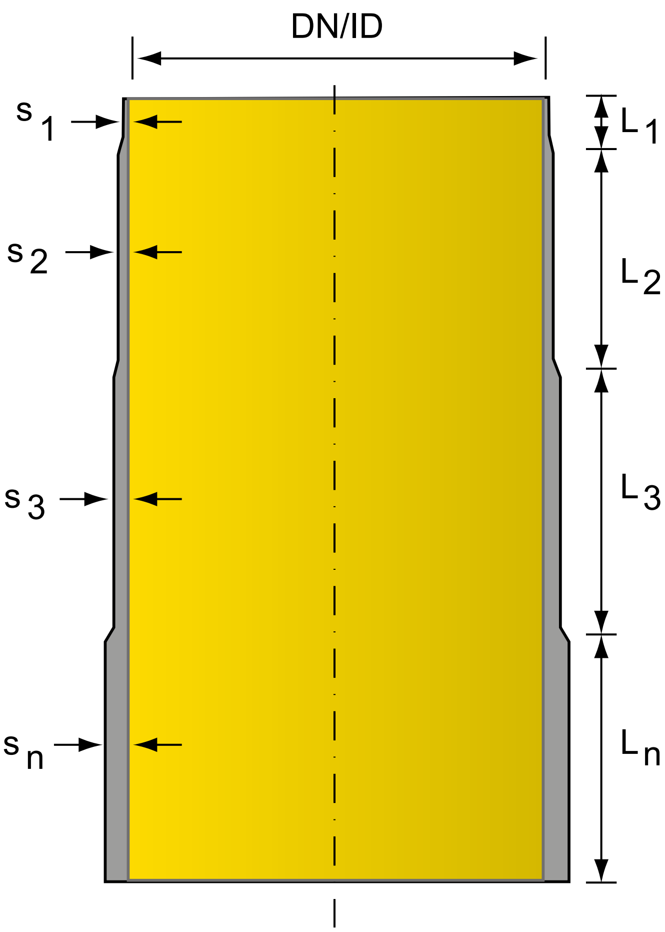
- Profile type ST

Pipes with profile type ST are specially made for vertical tanks, where different wall thicknesses in one pipe are required to save material.

The calculation method is according to DVS 2205.

Stepped pipes	average	maximum
nominal width (Di)	300 [mm]	3000 [mm]
number of steps (n)	two	six
length of steps (L)	200 [mm]	pipe length
wall thickness of the steps (s)	5 [mm]	300 [mm] for PE 150 [mm] for PP
step height	5 [mm]	

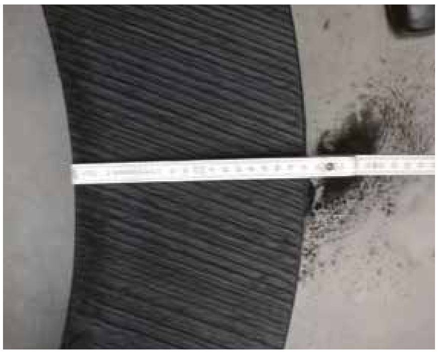
Table 5.5 - Technical specifications of stepped pipes



Cross section of a vertical storage tank

Si = wall thickness at step (i)
Li = step length (i)

Note: Product images may differ from the actual products.



Solid wall pipe made of polyethylene
s = 180 mm

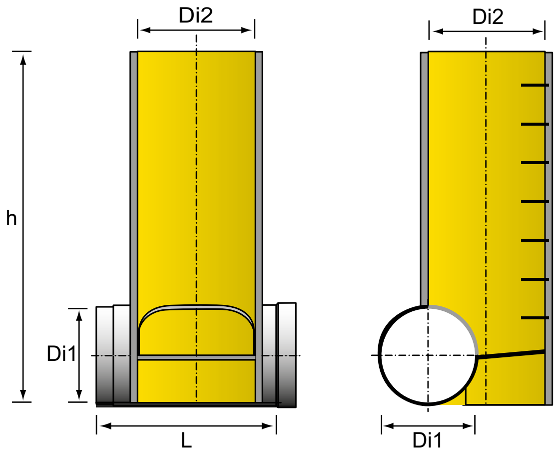
Vertical storage tanks made of polyethylene

Vertical stepped tank for industrial use

Various types of pipes

5.2 PRO-PRAGNUM maintenance manholes – made according to BDS EN 13598-2

5.2.1 Side-entry manhole

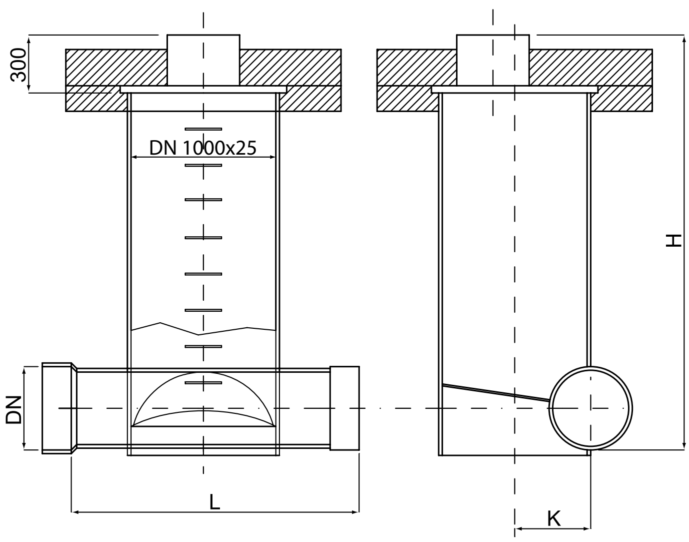


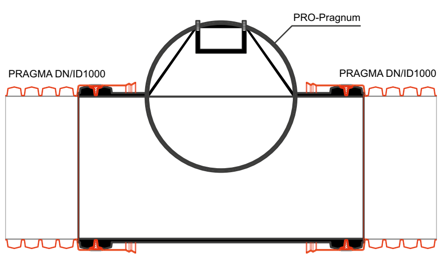
DN of base	DN/ID of entry	Number of entries	Type of inlet/ outlet pipe	Connection type	Possible angles of entry	Height
1000	From 700 to 1200 at 100 mm	1	Pragma - DN 800 to DN 1000 Pragnum - DN 700 to DN 2500	Pragma – elastomeric gasket Pragnum – electric fusion socket or elastomeric gasket	from 90° to 270°	According to designed height Max. 10 m

Table 5.6

The process of production of PRO-PRAGNUM manholes allows additional entries at various angles and diameters, both horizontally and vertically, as per the requirements of the design. For further information please contact the product managers at Pipelife.

- The bases of the PRO-PRAGNUM maintenance manholes are made of pipes with SQ or VW profile with minimum wall thickness 25 mm. The maximum laying depth of the manholes is 10 m.
- All manholes have:
  -Integrated invert channels
  -Manhole steps
- The manholes end with a concrete frame with an opening for the maintenance hole and a concrete slab with an opening for the manhole cover.
- The Pragnum system is compatible with other Pipelife systems. It allows extension of the maintenance part of the PRO-Pragnum manholes using elements of the PRO range, joining sewer house connections of corrugated Pragma pipes or smooth-wall PVC-KG pipes to a Pragnum pipe collector, as well as coupling collector corrugated Pragma pipes with a PRO-Pragnum maintenance manhole.





Note: Product images may differ from the actual products.

6 REQUIREMENTS FOR LAYING THE PRAGNUM PIPE SYSTEM

6.1 General assumptions

The most important factor for achieving a satisfactory installation of a plastic collector is the interaction between the pipe and the surrounding soil. Most of pipe's stability is provided by the soil in the pipe zone. Therefore the quality of backfill and its degree of consolidation in the pipe zone are of paramount importance. Therefore each sewerageengineering design should clearly specify the laying conditions, such as:

1. Existing soil conditions and their suitability to be used as a trench base and backfill.
2. Geotechnical evaluation of the soil, used for bedding and backfilling, as well as the method they are performed.
3. The appropriate stiffness class of the pipe.

The first step at the beginning of each project is to perform geotechnical investigation of the soil, where the pipe will be laid. This investigation, as well as the laboratory tests, should be carried out to determine the soil type and structure, its degree of compaction and the groundwater table.

6.2 Bedding conditions

The design of the bedding depends on the geotechnical properties of the soil in the pipe zone. Generally, there are two known approaches in the selection of bedding:
natural laying upon the native soil layer without additional processing and laying upon a bedding, made of selected soil material, compacted to the required degree.

6.2.1 Laying upon native, undisturbed ground

In some cases it can be accepted to lay Pragnum pipes right on the bottom of the prepared trench, but only upon granular, dry soil, free of any medium- and large-size rocks (> 20 mm). Such soils are fine-grained gravel, coarse sand, fine sand and sandy clays.
In such soil conditions the pipe is laid onto a thin (10 to 15 cm) uncompacted bedding of the native soil directly onto the bottom of the excavated trench. The purpose of the bedding is tobring the trench bottom up to grade and to provide strong and reliable support for the pipe within angle of laying range α = 60-180° (see fig. 6.1)

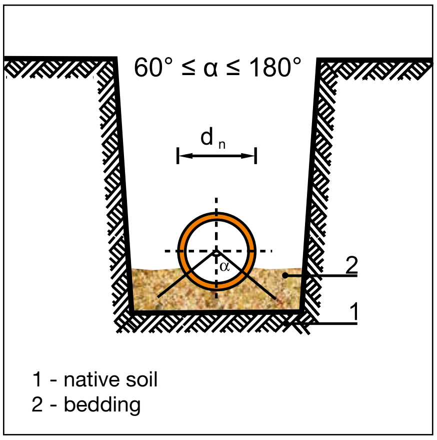


Fig. 6.1 Laying in natural conditions

6.2.2 Laying upon artificial base

In some cases the pipe should be laid upon a pre-conditioned base:

1. When the native soil could serve as a base, but due to structural faults is not able fulfil this function.
2. In rocky soils, cohesive soils (clays) and silty soils.
3. In weak and soft soils, such as organic silts and peat sediments (loess soils)
4. In all other cases, where the engineering design requires the making of additional bedding. A solution to cases 1 and 2 is provided in the example in fig. 6.2. The pipeline is laid onto two layers made of sandy soils or fine-grained gravels with maximum grain size up to 20 mm.

- The foundation layer is made of well compacted soils 25 cm thick (minimum 15 cm).
- The bedding is from 10 to 15 cm – thick uncompacted.

Where soils are weak, depending on the thickness of the layer, two solutions are suggested below the laying level of the sewer pipe.

1. Where the thickness of the weak soil layer is ≤ 1,0 m (see fig. 6.3).

In this case the layer of weak soil is removed and the trench is covered with a new layer of well compacted mixture of crushed gravel and sand (ratio 1:0.3) or a mixture of natural gravel and crushed gravel (ratio 1:0.3).

This new founding layer is laid onto geotextile.

2. Where the thickness of the weak soil layer is > 1,0 m (see fig. 6.4)

In this case an additional new 25 cm layer of well-compacted mixture of crushed gravel and sand (ratio 1:0,6) or a mixture of natural gravel and sand (ratio 1:0,3) is laid. This new, bedding layer is laid onto geotextile.

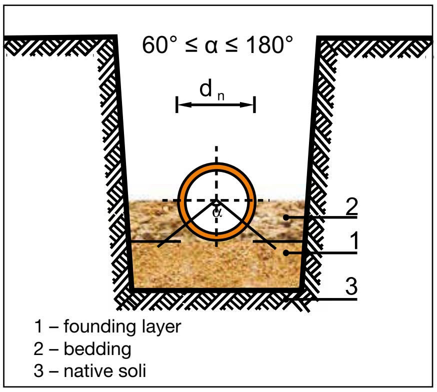


Fig. 6.2 Example of laying on stable soil

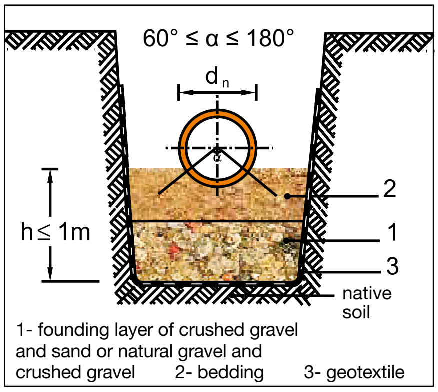


Fig. 6.3 Example of laying on weak soil (loess) at a depth ≤ 1.0 m

Във всички случаи уплътнението на фундиращия пласт трябва да бъде от 85% до 95% по Proctor

0 – additional 25 cm founding layer of crushed gravel and sand or natural gravel and crushed gravel

1 – founding layer of crushed gravel and sand or natural gravel and sand

2 – bedding

3 – geotextile

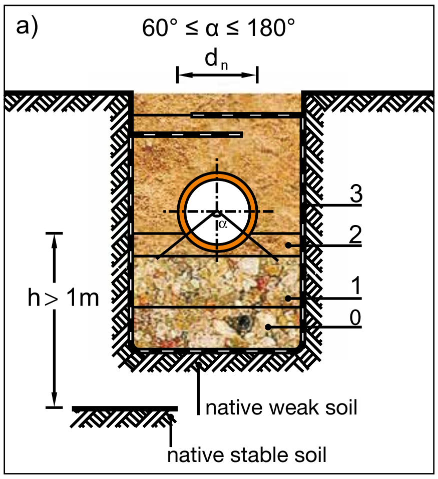


Fig. 6.4 Example of laying on weak soil (loess) at a depth > 1.0 m

6.3 Sidefill, backfill and final backfill

Besides the appropriate founding layer and bedding, the soil type and its density in the various types of backfills are of essential importance for achieving satisfying quality of installation of flexible pipes.

6.3.1 Sidefilling and subsequent backfilling

The choice of material, suitable for filling the pipe zone and directly above the top of the pipe to the top of the trench, is based on achieving optimum stability and soil stiffness after compaction.

Suitable soil materials include most types and classes of natural granular materials with maximum grain size not exceeding 10% of the nominal pipe diameter, but not more than 60 mm. The backfill material must be free of other materials (inclusions), such as snow, ice or frozen lumps of soil.

a – main backfill
b – soil cover
c – pipe zone
d – bedding (if required)
e – founding layer (if required)

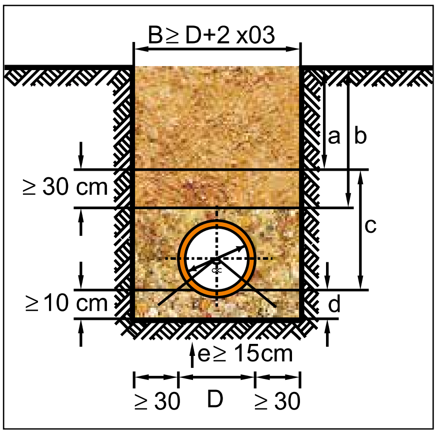


Fig. 6.5 Pipeline cross section

SIDEFILLING AND SUBSEQUENT BACKFILL		
Material	Grain size [mm]	Notes
Gravel, Crushed stone	8-22, 4-16 8-12, 4-8	most appropriate soil material, maximum 5 to 20% grains with diameter 2 mm
Gravel	2-20	appropriate soil material, maximum 5 to 20% grains with diameter 0,2 mm
Sand, Moraine gravel	0.2-20	Relatively appropriate soil material, maximum up to 5% grains with diameter 0,02 mm

Table 3.1 Characteristics of the materials for filling the pipe zone and the backfill

6.3.2 Degree of compaction

The required degree of compaction of the backfill depends on the loading conditions.

- Under roadways the minimum soil compaction in the pipe zone is 95%
- Outside roadways, the backfill must be compacted up to:

- 85% if the height of cover is < 4.0 m
- 95% if the height of cover is ≥ 4.0 m

The backfill material should be compacted in layers from 10 to 30 cm high. The height of the backfill over the top of the pipe should be not less than 30 cm.

6.3.3 Final backfilling

The material used in the final backfilling of the trench could be the native soil, if it is possible to achieve the designed compaction grade with maximum grain size 30 mm.

Under roadways the minimum compaction of the final backfill should be 95%.

6.3.4 Tamping of the embedment material

The required compaction grade depends on the overall loading and must be provided in the engineering design. Tamping should be carried out by employing different types of tamping. Depending on the equipment, the layers' height and the susceptibility of the soil to compaction various compaction grades can be achieved. Table 3.2 provides data for gravelly, sandy, clay-like and silty soils.

COMPACTION METHODS							
Equipment	Weight [kg]	Maximum layer height prior to compaction [m]		Minimum height of the initial backfill over the pipe [m]*	Number of passes to attain compaction		
		gravel, sand	clay, silt		85% by modified Proctor test	90% by modified Proctor test	95% by modified Proctor test
Rapid treading	-	0.10	-	-	1	3	6
Hand tamping	min. 15	0.15	0.10	0.30	1	3	6
Vibrating tamper	50-100	0.30	0.20-0.25	0.50	1	3	6
Separated mechanized tamping**	50-100	0,20	-	0.50	1	4	7
Mechanized tamping	50-100 100-200 400-600		- - 0.20	0.50 0.40 0.80	1 1 1	4 4 4	7 7 7

Table 3.2 Compaction methods
** before using compaction equipment*
*** compaction along both sides of the pipe*

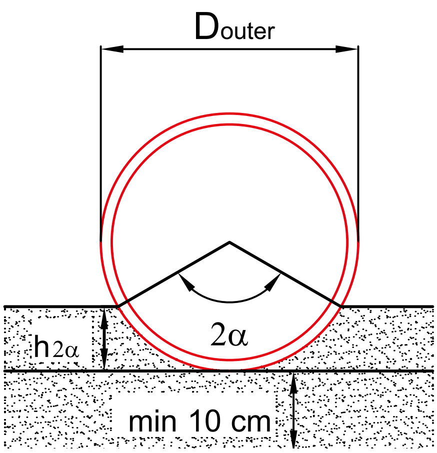
6.3.5 Trench width

The width of the trench should allow correct placement and compaction of the filling material. The minimum gap to the side of the pipe for the filling should be b_{min}=30 cm. Therefore the minimum trench width (B) at the top of the pipe is:
$B = D + (2 \times b_{min})$

If the stability of the native soil base is less than the one provided in the engineering design, the trench width (B) should be:
$B \geq 4 \times d_n$

A similar situation may arise in granular soils with low density ($I_D < 0.33$) or cohesive soils with top limit $I_L > 0.0$.

6.3.6 Filling necessary for achieving the desired angle of laying



Due to the large variety of profiles that a Pragnum pipe could be made of, and the various ring stiffness grades, the wall thickness is also varying, hence the outer diameter of the pipe. Therefore, in each particular case, the height of the filling, required to achieve the desired angle of laying should be calculated by the following formula:

$$h_{2\alpha} = 0.1\frac{D_{outer}}{2}\left[1 - sin\left(\frac{\pi(180-2\alpha)}{360}\right)\right]$$

where:

$h_{2\alpha}$ – required filling to achieve the desired angle of laying, [cm]

D_{outer} – outer pipe diameter, [mm]

2α - angle of laying, [°] – 60°, 90°, 120° or 180°

7 INSTALLATION OF THE PRAGNUM PIPE SYSTEM

7.1 Electric fusion welding

This is the most secure system for joining together polyethylene pipes with diameter of more than DN 1000, as the entire pipeline becomes a homogenous whole body.
A welding wire integrated into the socket or the spigot is heated up using a special welding device thus allowing the two pipe ends (socket or spigot) to join together. The electric fusion welding is very preferred, easy and secure method for pipe installation in very narrow trenches in a short time.

DN/ID [mm]	Voltage [V]	Welding time in seconds at ambient temperatures from 20°C to 15°C	Number of welding machines
700	25 V	1080 to 1120	1
900	38 V	900 to 945	1
1100	41 V	1100 to 1155	1
1200	43 V	1200 to 1260	1
1300	46 V	1300 to 1430	1
1400	47 V	1400 to 1500	1
1500	48 V	1800 to 1850	1
1600	48 V	1950 to 2100	1
1600	32 V	1000 to 1050	2
1800	40 V	880 to 930	2
2000	39 V	1100 to 1155	2
2200	41 V	1200 to 1260	2
2500	43 V	1300 to 1430	2
2800	47 V	1400 to1500	2
3000	48 V	1800 to 1850	2

Table 6.1

Process of electric fusion welding

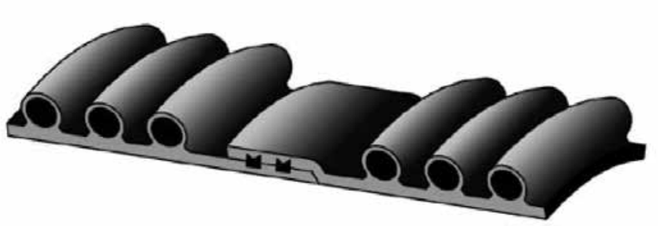
Electric fusion welding of a manhole and a pipe

Electric fusion welding of a large-size pipe in a narrow trench

Electric fusion socket and electric fusion device

Note: Product images may differ from the actual products.

7.2 Connection with socket and gasket



The socket design of the Pragnum pipes allows them to be joined together as desired by the designer, also through an elastomeric rubber gasket. This type of connection is particularly suitable in installations where electric fusion welding is not appropriate or hard to fulfil. The system has a solid smooth socket and spigot with an integrated EPDM gasket. The minimum wall thickness of the socket conforms to the EN13476-3 standard, table 7, and inaddition the ring stiffness of the socket and the ring stiffness of the spigot combined are higher than the ring stiffness of the pipe.

8 TRANSPORTATION, LOADING, UNLOADING AND STORAGE

8.1 Transportation

The PRAGNUM pipes are easily transported, because they are lightweight and easy to handle. The pipes need to be securely fixedand arranged.

8.2 Loading and unloading

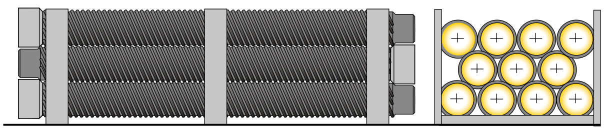
Forklift trucks with 5 m forks are very suitable for moving the pipes around the production floors.

No additional heavy equipment is needed on site. Usually the pipes can be unloaded and moved to thetrench, using the lifting equipment, which is always available on the site.

8.3 Storage

The pipes and connecting parts need to be stacked onto a flat surface free of rocks and sharp objects to avoid damage. It is important the socket on top not to get into contact with thesocket under. This means that every other layer of pipes should be rotated 180°. In any case the pipes should be secured against rolling, especiallyif they are stacked on several layers one above the other. The height must not exceed 4 m.

Usual stacking of PRAGNUM pipes



In addition to the security measures, care should be taken to prevent deformation of the stacked pipes. In most cases there should be three raised wooden battens to secure appropriate distribution of the load.

Note: Product images may differ from the actual products.

9 HYDRAULIC DIMENSIONING OF THE PRAGNUM SYSTEM

9.1 General assumptions

The hydraulic dimensioning includes the choice of parameters for gravity sewers, which normally operate partially full. The goal of the hydraulic dimensioning is to determine the most economical diameter, needed to convey the water volume. Practically the hydraulic parameters of the pipe are calculated based on the following main assumptions:

1. Assumed continuity of the flow, namely:
   - height or depth (h), water volume (f) and velocity (v) remain constant for each cross section of the examined pipeline length;
   - the power or head line (hydraulic slope), the water surface and the slope of the bottom of the pipe are parallel to each other;
2. The water flow in the pipe is turbulent.

9.2 Basic formulas

As a result of the assumed continuity of the flow, the water volume for a full profile (cross section) of a circular pipe is calculated by the following formulae:

1) $$Q = V \cdot F \,;\; F = \frac{\Pi \cdot d^2}{4}$$

2) $$Q = \frac{\Pi \cdot d^2 \cdot V}{4}$$

where:

Q – volumetric flow, [m³/s]

V – mean flow velocity, [m/s]

F – area of pipe cross section, [m²]

The head loss along the pipe length is calculated on the basis of the initial hydraulic slope. The initial hydraulic slope for closed circular pipes with established turbulent water flow is calculated by the Darcy-Weisbach equation:

3) $$i = \lambda \cdot \frac{1}{d} \cdot \frac{v^2}{2g}$$

The friction resistance factor along the pipe length (λ) is calculated by the Colebrook- White formula

$$\frac{1}{\sqrt{\lambda}} = -2\lg\left(\frac{2{,}51}{Re \cdot \sqrt{\lambda}} + \frac{k}{3{,}71 \cdot d}\right)$$

$$Re = \frac{V \cdot d}{\nu}$$

where:

i – hydraulic slope, [m/m]

d – inner diameter of the pipe, [m]

V – mean flow velocity, [m/s]

g – acceleration of gravity, [m/s²]

λ - friction resistance factor

Re – Reynolds number

ν - kinematic viscosity factor [m²/s] (for water at 10°C ν = 1,308x10-6 [m²/s])

k - absolute roughness factor of the pipe wall, [mm]

The Bretting formula for pipes with partly full pipe flow

4) $$\frac{q_n}{Q} = 0.46 - 0.5 \cdot \cos\left(\Pi \cdot \frac{h_n}{d}\right) + 0.04 \cdot \cos\left(2\Pi \cdot \frac{h_n}{d}\right)$$

where:

Q – volumetric flow in full profile, [m³/s]

q_n – volumetric flow in partially full profile, [m³/s]

h_n – depth of profile flow, [m]

d – inner pipe diameter, [m]

Absolute pipe wall roughness factor – k, [mm]

Laboratory roughness	0,0011 [mm]
Roughness of pipe in operation (excluding local resistances)	0,015 [mm]
Artificially raised roughness with respect to local resistances in main sewer collectors	0,25 [mm]
Artificially raised roughness with respect to local resistances in secondary sewer collectors	0,40 [mm]

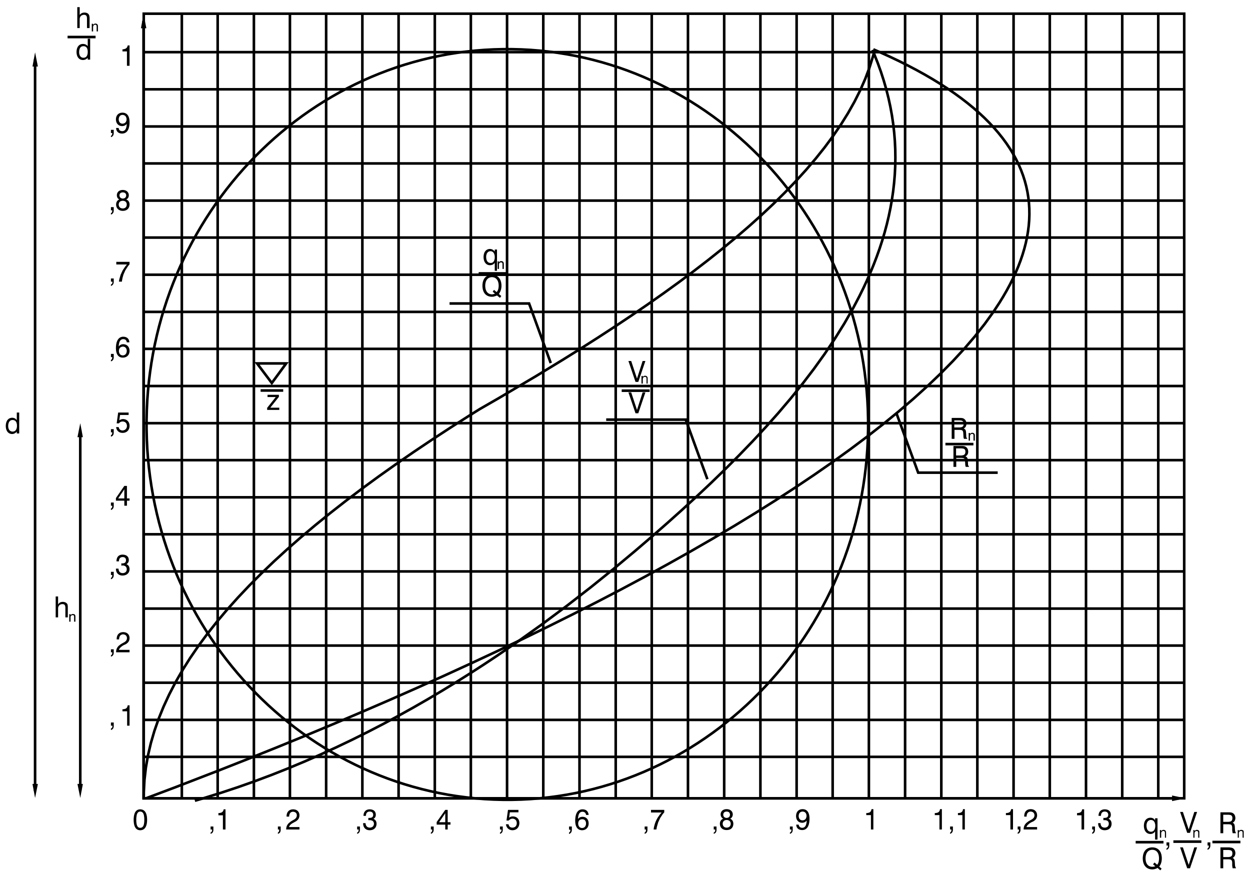
The values of the artificially raised absolute roughness are recommendable, but not mandatory. The designers could choose another artificially raised value for k or other method for determining local resistances.

9.3 Software and dimensioning tables

Besides the nomograms, provided hereunder, Pipelife offers to the designers other helpful tools for hydraulic dimensioning, as well. Section "**For designers**" at www.pipelife.bg provides a **web program** for hydraulic dimensioning of a discrete sewer section, a program for hydraulic analysis of a sewer network and dimensioning tables for fillings h/D=0.5, h/D=0.7 и h/D=1.0.

9.4 Hydraulic nomograms

9.4.1 Nomogram for hydraulic dimensioning of circular pipes with partially full profile



$\frac{h_n}{d}$ ratio of flow depth to pipe diameter (d)

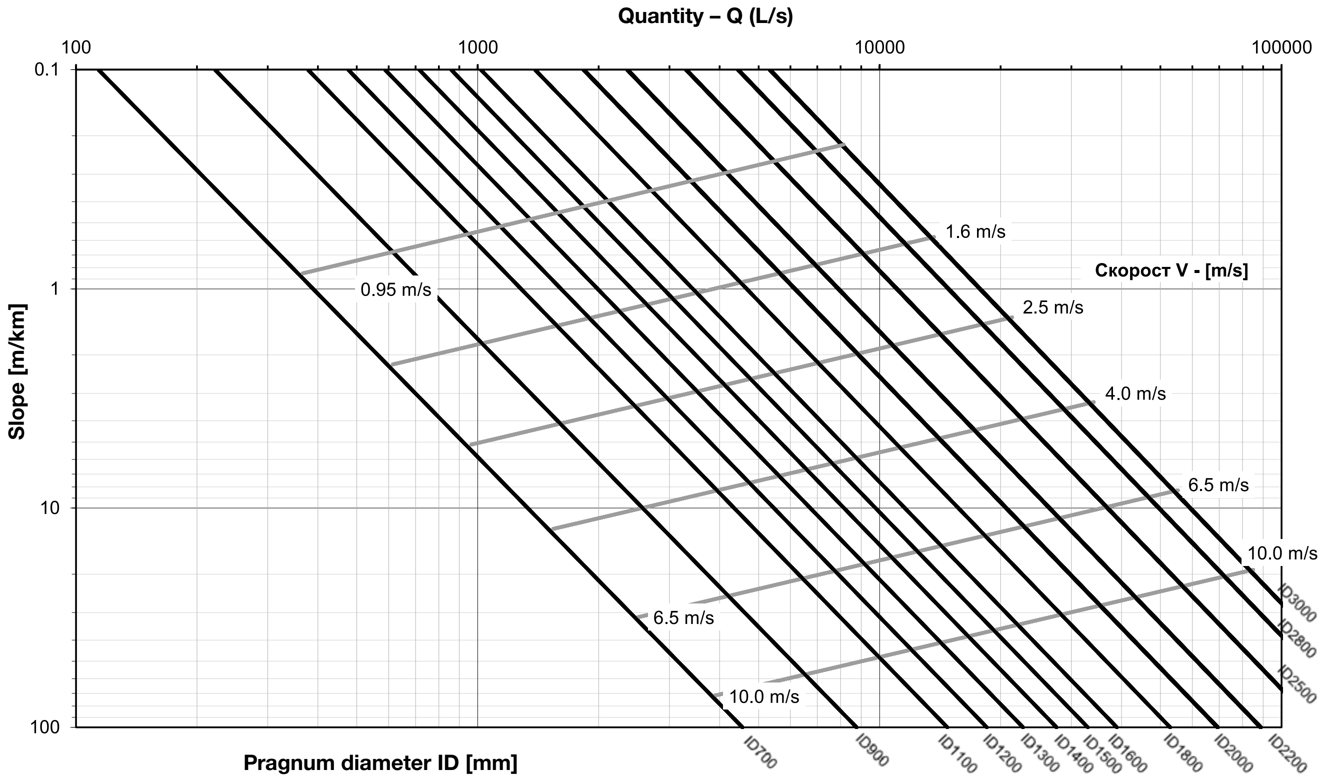
$\frac{q_n}{Q}$ ratio of the actual discharge at filling (h_n) to discharge at full profile

$\frac{V_n}{V}$ ratio of the actual velocity at filling (h_n) to velocity at full profile

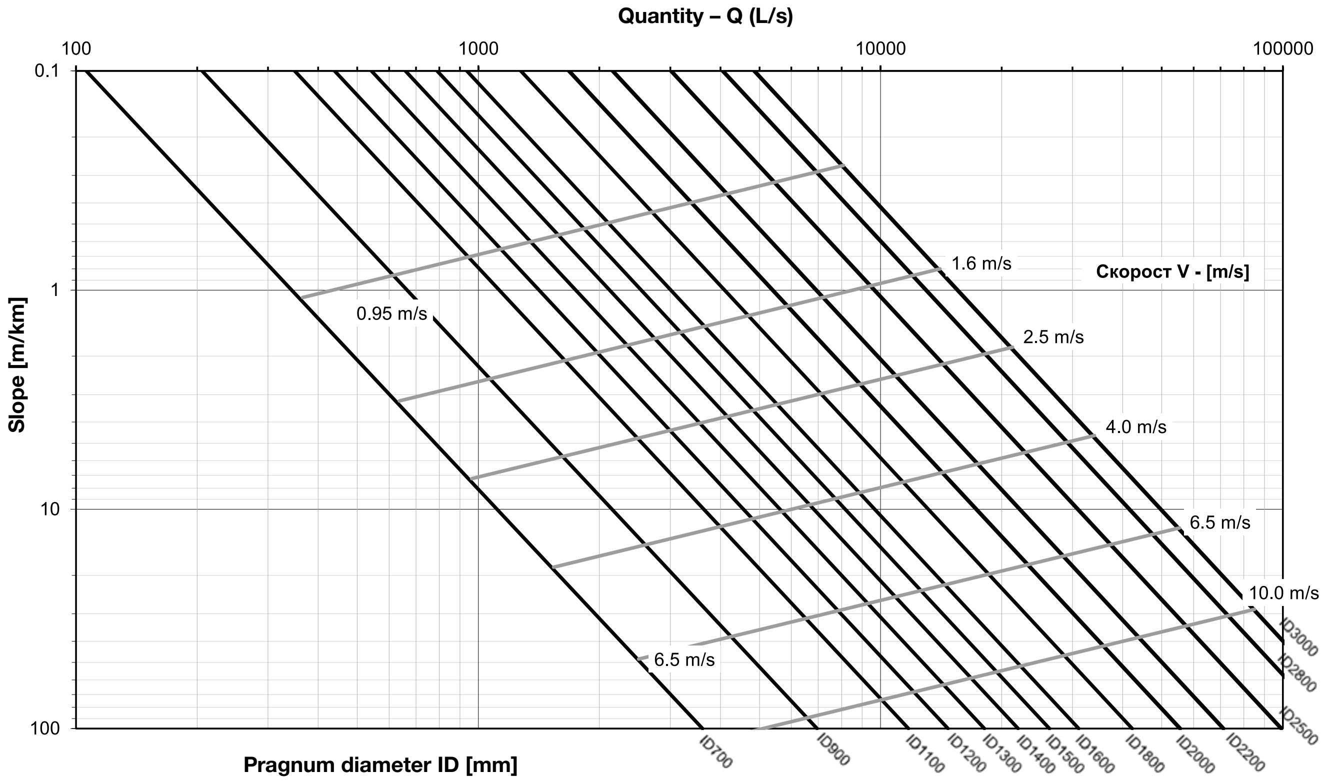
$\frac{R_n}{R}$ ratio of the hydraulic radius at filling (h_n) to hydraulic radius at full profile

9.4.2 Nomogram for hydraulic dimensioning of non-pressure flow in circular Pragnum pipes with full profile

For k = 0.015 [mm], water temperature t = 10°C, full profile
Darcy-Weisbach/Colebrook-White formula



For k = 0.25 [mm], water temperature t = 10°C, full profile
Darcy-Weisbach/Colebrook-White formula



9.5 Hydraulic slopes and flow velocities in Pragnum pipes

The minimum slope of the sewer is determined with respect to achieving the minimum flow velocity that would prevent the suspended particles from settling and clogging the pipe.

The self-cleaning ability of the flow, preventing settling and deposition of particles on the bottom of the pipe depends on the angle of internal friction Θ (see fig. 9.1)

Θ is determined by the formula 5):

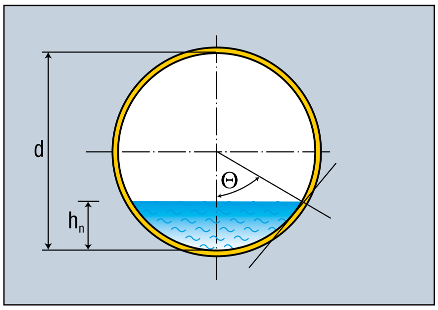
5) $$\frac{h_n}{d} = \frac{1}{2} \cdot (1 - \cos \Theta)$$

where:
hn – depth of profile flow, [m]
d – inner pipe diameter, [m]
Θ - angle of internal friction, [°]

If Θ = 35°

Then hn/d = 0,1

The area of deposition can be assumed as a relatively horizontal layer on the bottom of the sewer.



Фиг. 9.1. Ъгъл на вътрешно триене

The safe lower limit of velocity, which prevents sedimentation processes depends on the type of the settling particles (sediments).

Usually the minimum permissible velocities (V_{SC}) at full profile, securing the self-cleaning ability of the pipes must be not less than:

V_{SC} = 0,8 m/s or household sewers
V_{SC} = 0,6 m/s for storm sewers
V_{SC} = 1,0 m/s for mixed sewers

After determining the slope of the pipeline, the permissible velocity must be selected, taking into account the diameter of the pipe. The following simple formula has been used so far: 6)

6) $$i_{min} = \frac{1}{d}$$

where:
i_{min} = minimum permissible slope
d = inner pipe diameter

The minimum slope of the sewer collector can also be expressed through the tractive force of the waste water, expressed as: 7)

7) $$\tau = \gamma \cdot R \cdot i$$

where:
γ = специфично тегло на отпадна вода, [kg/m³]
R = хидравличен радиус, [m]
i = хидравличен наклон, [m/m]

The actual tractive force is: 8):

8) $$\tau_0 = \gamma \cdot R \cdot i \cdot k_1$$

където:
$R = \frac{d}{4}$, hydraulic radius for cicular pipes, full profile

k_1 = corrective coefficient, $k_1 \ f\left(\frac{h_n}{d}\right)$

The formulae above show that the critical tractive force for partially full (actual) flow profile is: 9)

9) $$\tau_0 = \gamma \cdot i \cdot \frac{d}{4} \cdot \frac{R_n}{R}$$

The critical tractive force, responsible to ensure the self-cleaning ability of the sewer collector is: 10)

10) $$\tau_0 \geqslant 1.5\,\text{Pa} \quad \text{(for storm water)}$$

$$\tau_0 \geqslant 1.5\,\text{Pa} \quad \text{(for sewerage)}$$

Therefore formula 9, after conversion, proves that the minimum slope of the pipeline is: 10a)

10a) $$i_{min} = \frac{0.612 \cdot 10^{-3}}{d \cdot \frac{R_n}{R}} \quad \text{(for storm water)}$$

10b) $$i_{min} = \frac{0.815 \cdot 10^{-3}}{d \cdot \frac{R_n}{R}} \quad \text{(for sewerage)}$$

10 STATIC DIMENSIONING OF THE PRAGNUM SYSTEM

10.1 Interaction of the pipe with the surrounding soil

From a technical point of view the Pragnum polyethylene system is a flexible structure possessing great weight-bearing capacity without observable deficiencies. The classical method for calculating the stability of a structured material is to describe the actual relation between stress and the arising strains when the material is loaded.

The vertical load onto the pipe is causing deformation, deflection (δV), which leads to a decrease in the vertical diameter of the flexible pipe and an elliptical shape (see fig. 10.1)

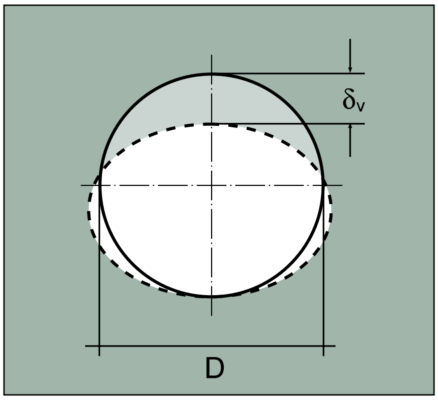


Fig. 10.1 Deflection of a circular pipe caused by vertical load

The deformation of the pipe is causing peripheral stress in the wall, by exerting pressure onto the surrounding soil. At the same time the inert soil is reducing the peripheral stress in the wall of the pipe. These bending peripheral forces in the pipe wall, caused by the deflection, are in momentary equilibrium with the push of the soil, which is directed against the outer wall of the pipe. The push of the soil, opposite to the force of the pipe depends on the vertical load, the soil type and the density of the pipe zone, as well as on the ring stiffnessof the pipe.

For rigid pipes, such as made of concrete, etc, it is the pipe, which actually bears the whole load on itself, while the flexible pipe is making use of the horizontal reaction of the soil, caused by the deformation and the deflection of the pipe. The several years of experience show that the flexible pipes (b) outclass the pipes (a), made of concrete or other rigid material in their ability to withstand road traffic and other loads. The (b) pipes selectively avoid bearing loads by bending in. Thus the surrounding soil bears the load.

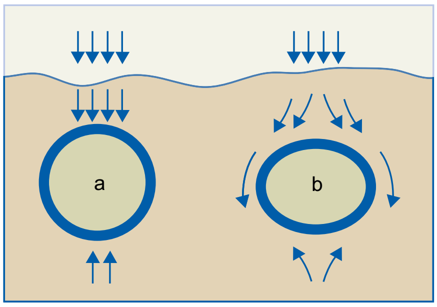


Fig. 10.2

The design behaviour of the flexible pipes can be illustrated by the Spangler formula: 11)

11)

$$\frac{\delta_v}{D} = \frac{f(g)}{(SN + S_s)}$$

where:

δv – deformation of pipe diameter

D – original undeformed pipe diameter

q – vertical load

SN – ring stiffness of the pipe

S_s – soil stiffness

Formula (11) describes the relative deflection of a pipe, subjected to vertical loading (qv), supported by the ring stiffness of the pipe and the stiffness of the soil. This formula clearly illustrates that the pipe deflection could be limited to acceptable levels by increasing one of the two factors - the stiffness of the pipe or the soil compaction in the pipe zone. Additionally, it can be said that pipes with greater ring stiffness are less dependent on soil compaction in the pipe zone. On the other hand, making an optimal embedment of the pipe using appropriate well compacted materials (high installation costs) allows the use of pipes with lower ring stiffness (SN) (lower material cost). Deciding between one and the other option is a question of a feasibility analysis.

10.2 Loads

The distribution of earth pressure in the pipe zone by the Scandinavian method is shown in fig. 10.3. The pipe laid in the ground is subjected to a vertical load (q_V), which is generating stress and strain, as well as a counteracting horizontal load (q_h).

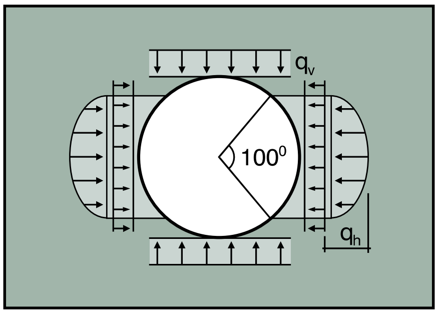


Fig. 10.3 Scandinavian earth pressure distribution model

VERTICAL LOADS

1. Earth load above the pipe: 12)

$$q_z = \gamma_z \cdot H \tag{12}$$

where:
γ_Z = 18 to 20 kN/m³ for pipes over the groundwater table

For pipes laying below the groundwater table, the total pressure will increase with the hydrostatic pressure: 13)

$$q_w = \gamma_w \cdot h \tag{13}$$

In this case the vertical load is: 14)

$$q_z=\gamma_z(H\text{-}h)+(\gamma_{zw}\cdot h)+(\gamma_w\cdot h) \tag{14}$$

where:
γ_{ZW} = 11 kN/m³
γ_W = 10 kN/m³

Under normal conditions of pipe installation the vertical load component (qv) is greater than the horizontal load component (qh). The (qv-qh) difference leads to a decrease of the vertical diameter and increase of the horizontal diameter. When the wall pipe deforms, it generates passive earth pressure at a magnitude, which depends on the vertical load and the ratio of soil compaction to ring stiffness of the pipe. The latter explanation is also expressed as pipe ring stiffness (SN). The components of the load, which are distributed over the pipe vertically, are:

- the effect of the soil over the pipe
- the effect of loads, distributed over the ground surface, such as buildings, vehicles, etc.

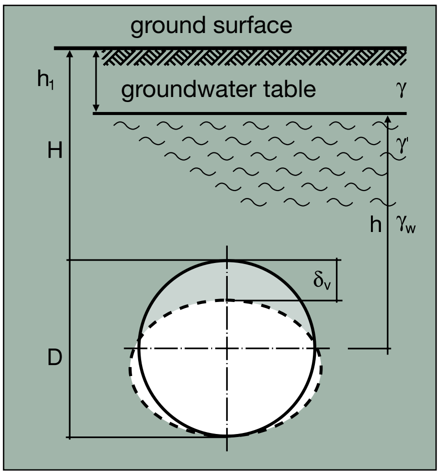


Fig. 10.4 Geometry of the embedment

10.3 Soil types according to BDS ENV 1046

Soil type	Soil group					Filling
	Soil groups as per ATV127	Typical name	Symbol	Distinctive feature	Examples	
Gravelly	G1	Poorly-graded gravel	(GE) [GU]	Steep granulometric curve, predominantly poorly-graded	Crushed stone, river and coastal gravel, moraines, cinder, volcanic ash	YES
		Well-graded gravels, gravel/sand mixtures	[GW]	Uninterrupted granulometric curve, several granulometric groups		
		Poorly-graded gravels, gravel/sand mixtures	(GI) [GP]	Steep granulometric curve, missing one or several granulometric groups		
		Poorly-graded sands	(SE) [SU]	Steep granulometric curve, predominantly one granulometric group	Dune sands and sediments, river sand	YES
		Well-graded sands, gravel/sand mixtures	[SW]	Uninterrupted granulometric curve, several granulometric groups	Morainal sand, coastal sand, beach sand	
		Poorly-graded sands, gravel/sand mixtures	(SI) [SP]	Steep granulometric curve, missing one or several granulometric groups		
	G2 and G3	Silty gravels, poorly-graded gravel/silt/sand mixtures	(GU) [GM]	Wide / interrupted granulometric curve with fine silty grains	Crushed gravel, sharp debris, loamy gravel	YES
		Clay-like gravels, poorly-graded gravel / sand / clay mixtures	(GT) [GC]	Wide / interrupted granulometric curve with fine silty grains		
		Silty sands, poorly-graded silt/sand mixtures	(SU) [SM]	Wide / interrupted granulometric curve with fine silty grains	Quicksand, soil, sandy loess	
		Clay-like sands, poorly-graded sand / clay mixtures	(ST) [SC]	Wide / interrupted granulometric curve with fine silty grains	Sandy soil, alluvial clay, alluvial marl	
Cohesive		Inorganic silts and very fine sands, rock flour, silty or clay-like fine sands	(UL) [ML]	Low stability, short reaction, zero to weak plasticity	Loess, clay	YES
	G4	Inorganic clays, distinctly plastic clay	(TA)(TL) (TM) [CL]	Medium to high stability, slow reaction, low to medium plasticity	Alluvial clay, clay	
Organic		Soils of mixed grain size and additions of humus and talc	[OK]	Vegetational and non-vegetational inclusions, rots, lightweight, high porosity	Upper layers, hard sand	YES
		Organic silt and organic silty clays	[OL](OU)	Moderately stable, slow to very fast reaction, low to medium plasticity	Marine chalk, upper soil layer	
		Organic clay, clay with organic inclusions	[OH](OT)	High stability, zero reaction, medium to high plasticity	Mud, soil	
Organic		Peat, other highly organic soils	(HN)(H2) [Pt]	Non-composite peat, fibrous, colored in brown to back	Peat	NO
		Slime	[F]	Slimes in silt deposits, often mixed with sand / clay / talc, very soft	Slime	

10.4 Required data for static analysis of a Pragnum pipe system

With regard to the proper installation and operation of the Pragnum system sewer pipes, it is important to calculate the effect of the static and dynamic loads. For this purpose it is necessary to take into account the type of soil, presence of groundwater, compaction grade of the filling by Proctor. The calculation can be done using the web program, provided by Pipelife in section "For designers" at www.pipelife.bg.

Pipelife also possesses the program EASYPIPE, which could be used, if necessary, to make a more detailed static analysis of the laid pipes. Both programs are based on the methodology for static analysis of buried pipes as per ATV127. The following data need to be provided to Pipelife's engineering department to make this analysis:

<table>
<tr><td colspan="2" rowspan="4">Project data</td><td>Project</td><td colspan="4"></td></tr>
<tr><td>Client</td><td colspan="4"></td></tr>
<tr><td>Designer</td><td colspan="4"></td></tr>
<tr><td>Date</td><td colspan="4"></td></tr>
<tr><td colspan="2" rowspan="6">Data about the soil around and in the trench zone</td><td rowspan="2">Main soil groups</td><td colspan="4">Zones (fig. 10.5)</td></tr>
<tr><td>E1</td><td>E2</td><td>E3</td><td>E4</td></tr>
<tr><td>G1 - cohesionless</td><td></td><td></td><td></td><td></td></tr>
<tr><td>G2 - slightly, insignificantly cohesive soils</td><td></td><td></td><td></td><td></td></tr>
<tr><td>G3 - mixed cohesive soils, coarse, raw clay (clogged with slime, sand, coarse sand and fine gravel, cohesive residual rocky soils)</td><td></td><td></td><td></td><td></td></tr>
<tr><td>G4 - cohesive (e.g. clay)</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2" rowspan="13">Load data</td><td colspan="4">h – height of cover over the top of the pipe, [m] (fig. 10.6)</td><td></td></tr>
<tr><td colspan="4">Density of the embedment material, [kN/m³]</td><td></td></tr>
<tr><td colspan="4">Additional static loads (e.g. in warehouses), [kN/m²]</td><td></td></tr>
<tr><td colspan="4">$H_{W\ max}$ – maximum groundwater table over the top of the pipe, [m] (fig. 10.7)</td><td></td></tr>
<tr><td colspan="4">$H_{W\ min}$ – minimum groundwater table over the top of the pipe, [m] (fig. 10.7)</td><td></td></tr>
<tr><td colspan="4">Short-term internal pressure in the pipe, [bar]</td><td></td></tr>
<tr><td colspan="4">Long-term internal pressure in the pipe, [bar]</td><td></td></tr>
<tr><td colspan="3" rowspan="2">Traffic loads (choose one of the following options)</td><td colspan="2">Traffic frequency</td></tr>
<tr><td>normal</td><td>irregular</td></tr>
<tr><td colspan="3">LT12 – 12 tonnes - 2 (semi)axles</td><td></td><td></td></tr>
<tr><td colspan="3">HT26 – 26 tonnes - 2 (semi)axles</td><td></td><td></td></tr>
<tr><td colspan="3">HT39 – 39 tonnes - 3 (semi)axles</td><td></td><td></td></tr>
<tr><td colspan="3">HT60 – 60 tonnes - 3 (semi)axles</td><td></td><td></td></tr>
<tr><td colspan="2" rowspan="3">Covering</td><td colspan="3">First layer</td><td colspan="2">Second layer</td></tr>
<tr><td>Height h_1, [m]</td><td colspan="2">Modulus of Elasticity E_1, [MPa]</td><td>Height h_2, [m]</td><td>Modulus of Elasticity E_2, [MPa]</td></tr>
<tr><td></td><td colspan="2"></td><td></td><td></td></tr>
<tr><td rowspan="9">Laying</td><td rowspan="9">Emban-kment / Trench</td><td colspan="4">Trench width over the top of the pipe - b (m) - (from 0,1 to 20 m)</td><td></td></tr>
<tr><td colspan="4">Trench angle of repose - β (degrees)</td><td></td></tr>
<tr><td rowspan="2">Trench conditions from group A1 to A4 (see the available groups at the end)</td><td>A1</td><td>A2</td><td>A3</td><td>A4</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Embedment conditions from group B1 to B4 (see the available groups at the end)</td><td>B1</td><td>B2</td><td>B3</td><td>B4</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Type of bedding</td><td colspan="4">angle of laying -2α</td></tr>
<tr><td>60°</td><td>90°</td><td>120°</td><td>180°</td></tr>
<tr><td>sand cushion</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>concrete lining</td><td></td><td></td><td></td><td></td></tr>
</table>

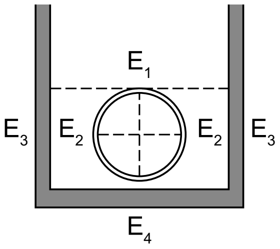


Fig. 10.5

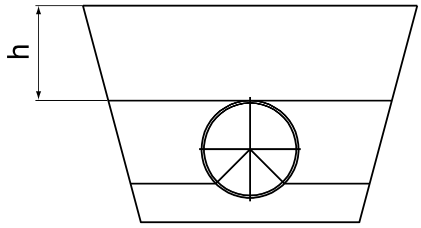


Fig. 10.6

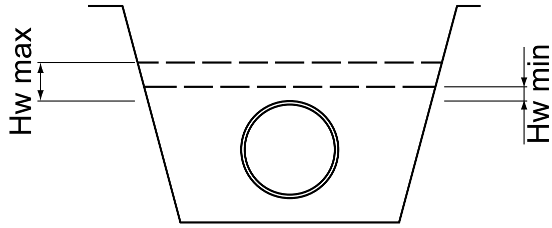


Fig. 10.7

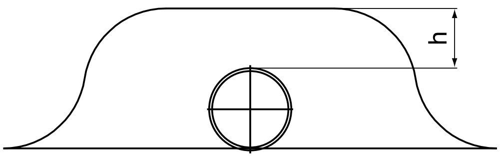


Fig. 10.8

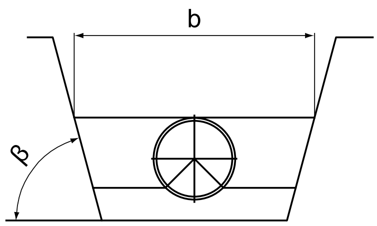


Fig. 10.9

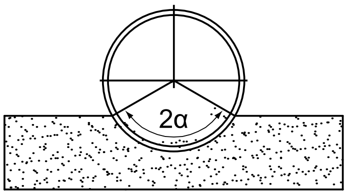


Fig. 10.10

"Cover conditions" - ('A1' to 'A4') describe the method of shoring and backfilling the trench above the pipe zone (from top of pipe to ground surface-terrain level).

A1 - The trench is filled with native soil and compacted in layers (without checking the degree of compaction), compacting also along the walls of the pipe.

A2 - Vertical trench shoring using special beams and plates, which are not removed until after the backfilling. The formwork panels or the equipment used are removed in stages during backfilling. Uncompacted trench backfilling. Washed backfilling (suitable only for soils from group G1).

A3 - Vertical trench shoring using prefabricated corrugated plates, lightweight plates, wooden beams, formwork panels or equipment, which are not removed until after the backfilling.

A4 - The backfilling is compacted in layers of native soils with degree of compaction proven as per the requirements of ZTVE-StB; it is also applied in beam pile walls. The A4 conditions are not applicable to soil from group G4.

"Embedment conditions" ('B1' to 'B4') describe the method of trench shoring and backfilling the zone around the pipe (from the bottom of the trench to the top of the pipe).

B1 - The bedding cushion is compacted in layers with the native soil or in an embankment (without checking the degree of compaction), it is also applied in beam pile walls.

B2 - Vertical shoring of the pipe zone using plates arranged along the bottom of the trench and not removed until after the backfilling and compaction.

B3 - Vertical shoring of the pipe zone using corrugated prefabricated plates, lightweight plates and compaction.

B4 - The bedding cushion is compacted in layers with the native soil or in the embankment, proving the required degree of compaction in accordance with ZTVE-StB. The conditions provided for group B4 are not applicable for soils from group G4.

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