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PP MONO
COMPACT SMOOTHWALL SEWER PIPE SYSTEM

Infrastructure compact smoothwall sewer pipe system of polypropylene

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CONTENTS

1 INTRODUCTION

PP Mono is a single-layer, compact, smoothwall system of polypropylene for sewerage infrastructure that meets the requirements of EN 14758-1.
PP Mono is manufactured by extrusion process in the town of Botevgrad. Pipes are joined to each other with double socket. The system is compatible with smoothwall pipes, as well as with externally corrugated sewer pipes. PP Mono is manufactured and tested according to EN 14758-1 „Plastics piping systems for non-pressure underground drainage and sewerage - Polypropylene (PP)“. The PP Mono system has nominal ring stiffness SN≥8kN/m^2, SN≥10kN/m^2, SN≥12kN/m^2 and SN≥16kN/m^2.

SN – nominal ring stiffness

1.1 Why is polypropylene the material of choice for the PP Mono pipe system?

Polypropylene (PP-B) is last generation thermoplastic material, used for manufacturing of piping systems. This material combines the stiffness of polyvinylchloride (PVC) with the elasticity of polyethylene (PE). This makes it well balanced and most suited for satisfying the complex requirements of the EN 14758-1 standard.

1.2 Why should the pipe system color be different from black?

The practice of thermoplastic systems production by extrusion shows that making the finished products in black color is most often associated with the use of recycled material (scrap) in production, which makes it practically impossible to achieve and maintain uniformity of color, unless the color is black.

This is the main reason for Pipelife to manufacture its products in a color different from black, as another strong evidence that only primary and non-recycled raw materials are used.

2 APPLICATION

The PP Mono system is designed for gravity take away of:

- Household waste water,
- Industrial waste water,
- Storm water,
- Waters of mixed type and
- Drainage waste water

Convenient transition from and to corrugated pipe systems! The PP Mono pipes are part of a sewer pipe system comprising fittings, PRO manholes, PRO-RG road gullies, modular pumping stations PROFOS and modular water treatment plants ECO.

3 BENEFITS

- Resistance to abrasion
- Chemical resistance (from pH=2 to pH=12)
- Resistance to high temperatures (60°C at continuous flow and 95°C to 100°C at short-time flow)
- Guaranteed ring stiffness SN≥8 kN/m^2, SN≥10 kN/m^2, SN≥12 kN/m^2, SN≥16 kN/m^2
- Easy transportation
- Fast and easy installation
- Guaranteed watertightness of the system in the range -0,3 to +0,5 bar for pipes joined together with double sockets and up to +10 bar for pipes joined together through butt welding
- 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 joining elements (fittings, maintenance holes and facilities)
- Compatibility with smoothwall pipes, as well as with corrugated pipes
- An integral part of an overall sewer system of pipes, fittings, manholes and facilities
- Guaranteed stability of the system in weak and loess soils
- All elements of the PP Mono system are manufactured under constant in-line control of the raw materials and finished product.

4 STANDARDS

4.1 Why are standards needed?

Standards comprise rules and regulations based on practical observations and theoretical investigation of the technical parameters the products should meet. They set minimum quality requirements for the specific product. At the same time they also guarantee compatibility 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 suitable for this particular application and meets all requirements to secure unrestricted, fault-free and long-lasting operation.

4.2 What standards and regulations does the PP Mono system comply with?

The PP Mono system is manufactured to comply with the requirements of the EN 14758-1:2023 standard „Plastics piping systems for non-pressure underground drainage and sewerage - Polypropylene (PP) - Part 1: Specifications for pipes, fittings and the system".

It complies with the applicable standards and regulations for design of sewer systems: „EN 752:2008 Drain and sewer systems outside buildings" and „Regulations for the design of drain and sewer systems" adopted with ordinance № RD-02-14-140 of 17.04.1989, pursuant to art. 201, par. 1 of the Regional and Urban Planning Act, BCA, 9 and 10 of 1989, as amended, BCA, 1 of 1993

5 NOMENCLATURE

5.1 PP Mono sewer pipes

SN≥8 kN/m², SN≥10 kN/m², SN≥12 kN/m², SN≥16 kN/m² according to the EN 14758-1 standard

Nominal diameter DN/OD	Outside diameter OD	Wall thickness [mm]	Effective pipe length [mm]	Material	Ring stiffness of the pipe	Standard	Commercial brand
110	110	3,8	6000	PP-B	SN≥8kN/m²	EN 14758-1	PP Mono
160	160	5,5					
200	200	6,9					
250	250	8,6					
315	315	10,8					
400	400	13,7					

Nominal diameter DN/OD	Outside diameter OD	Wall thickness [mm]	Effective pipe length [mm]	Material	Ring stiffness of the pipe	Standard	Commercial brand
110	110	4,2	6000	PP-B	SN≥10kN/m²	EN 14758-1	PP Mono
160	160	5,5					
200	200	6,9					
250	250	8,6					
315	315	12					
400	400	15,1					

Nominal diameter DN/OD	Outside diameter OD	Wall thickness [mm]	Effective pipe length [mm]	Material	Ring stiffness of the pipe	Standard	Commercial brand
110	110	5	6000	PP-B	SN≥12kN/m²	EN 14758-1	PP Mono
160	160	6,7					
200	200	8,5					
250	250	10,5					
315	315	13,2					
400	400	16,7					

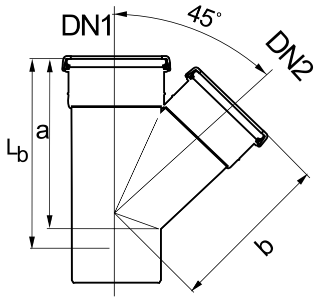
Nominal diameter DN/OD	Outside diameter OD	Wall thickness [mm]	Effective pipe length [mm]	Material	Ring stiffness of the pipe	Standard	Commercial brand
110	110	5,4	6000	PP-B	SN≥16kN/m²	EN 14758-1	PP Mono
160	160	7,3					
200	200	9,1					
250	250	11,4					
315	315	14,4					
400	400	18,2					

DN/OD – nominal outside (conditional) diameter of the manufactured pipe or fitting
DN/ID – nominal inside (conditional) diameter of the manufactured pipe or fitting
On customer's request it is also possible to produce pipe lengths of 1, 2, 3 and 4 meters.

5.2 Fittings

5.2.1 Y-Branch

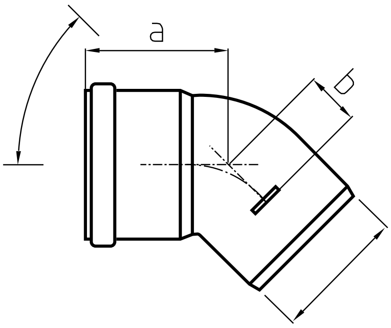
Marking: PP - KGEA .../.../45 (e.g. PP-KGEA 300/150/45)
(up to 12kN/m²)



DN	DN1	DN2	Lb	a	b	W [kg/pc]
100/100	110	110	232	226	203	0.5
125/100	125	110	257	225	208	0.6
125/125	125	125	277	254	229	0.8
150/100	160	110	295	284	253	1.2
150/125	160	125	275	264	250	1
150/150	160	160	355	344	317	1.9
200/100	200	110	279	272	266	1.5
200/150	200	160	304	304	363	2
200/200	200	200	444	427	377	3.4
250/100	250	110	458	453	457	4.6
250/150	250	160	458	453	447	4.9
250/200	250	200	458	453	450	5
250/250	250	250	553	532	467	6.4
300/100	315	110	552	535	547	8.1
300/150	315	160	552	535	537	8.4
300/200	315	200	552	535	540	8.5
300/250	315	250	552	535	513	9.1
300/300	315	315	686	661	581	12.2
400/100	400	110	672	646	758	15.6
400/150	400	160	672	646	728	15.9
400/200	400	200	672	646	708	16.1
400/250	400	250	672	646	686	16.7
400/300	400	315	672	646	663	17.4
400/400	400	400	1280	916	926	45

5.2.2 Bend

Marking: PP - KGB .../... (e.g. PP-KGB 200/30)
(up to 16kN/m²)

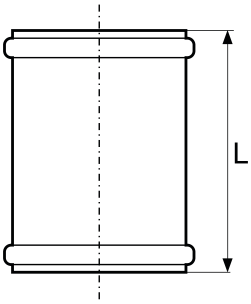


α	DN	150	200	250	300	400
	d	160	200	250	315	400
15°	a	122	147	183	220	269
	b	29	37	48	58	74
	W [kg/pc]	0.7	1.1	2.4	4.6	9.1
30°	a	135	162	204	245	300
	b	42	52	69	83	105
	W [kg/pc]	0.8	1.4	2.7	5.1	10.2
45°	a	148	179	225	272	333
	b	55	68	90	110	138
	W [kg/pc]	0.8	1.6	3.0	5.7	11.2
88°	a	200	242	305	371	779
	b	107	131	170	209	538
	W [kg/pc]	1.0	1.9	3.7	7.1	20.3

Note: pipes and fittings are delivered with socket and sealing ring made of synthetic rubber.

5.2.3 Socket

Marking: PP - KGU ... (e.g. PP-KGU 300)
(up to 12kN/m²)

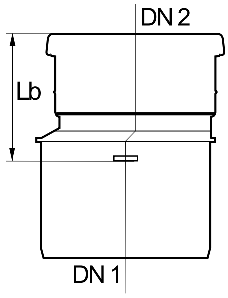


DN	100	125	150	200	250	300	400
L	144	160	192	230	282	336	382
W [kg/pc]	0.2	0.3	0.6	1.1	1.2	3.9	7.2

5.2.4 Reducer

Marking: PP - KGR .../... (e.g. PP-KGR 200/150)
(up to 16kN/m²)

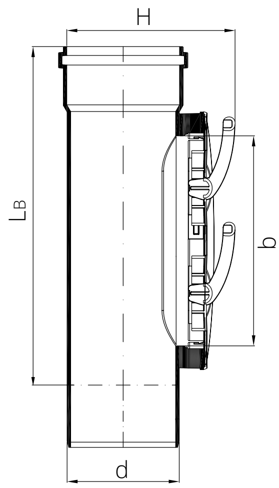
DN	DN1	DN2	Lb	W [kg/pc]
150/100	160	110	130	0.6
150/125	160	125	131	0.6
200/100	200	110	154	0.9
200/125	200	125	155	0.9
200/150	200	160	154	1.0
250/200	250	200	191	1.9
300/200	315	200	278	3.4
300/250	315	250	263	4.0
400/250	400	250	350	6.6
400/300	400	315	346	8.3



5.2.5 Maintenance hole with plastic lid with handle

Marking: KGRK ... (e.g. KGRK 300)
(up to 16kN/m²)

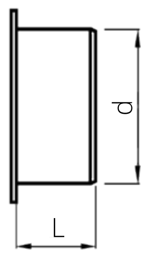
DN	100	125	150	200	250	300	400
d	110	125	160	200	250	315	400
b	301	301	301	301	301	301	301
H	196	222	251	295	330	400	485
Lb	468	474	488	548	680	680	1000
W [kg/pc]	2.3	2.5	3.1	4.6	8.5	13.0	30.0



5.2.6 End cap

Marking: KGM ... (e.g. KGM 300)
(up to 16kN/m²)

DN	100	125	150	200	250	300	400
d	110	125	160	200	250	315	400
L	53	42	49	59	98	103	105
W [kg/pc]	0.1	0.2	0.3	0.6	1.3	2.1	5.2



6 REQUIREMENTS FOR LAYING THE PP MONO 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 sewerage engineering 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 by which they are performed.
3. The appropriate stiffness class of the pipe.

The first step at the beginning of each project is to perform a 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, compacted to the required degree.

6.2.1 Laying upon native, undisturbed ground

n some cases it can be accepted to lay the PP Mono pipes right onto 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 native soil directly onto the bottom of the excavated trench. The purpose of the bedding is to bring the trench bottom up to grade and to provide strong and reliable support for the pipe with angle of laying in the range α = 60-180° (see. fig. 6.1)

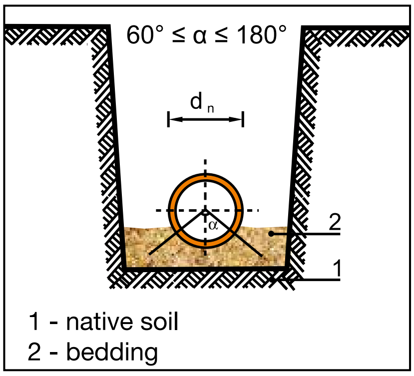


Fig. 6.1 Laying in natural conditions

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 to fulfill this intended purpose.
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 shall be removed and the trench shall be 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 shall be 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) shall be laid. This new bedding layer shall be laid onto geotextile.

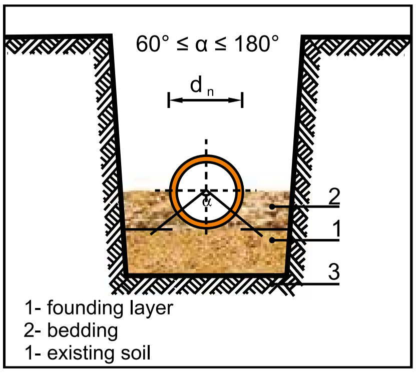


Fig. 6.2 Example of laying on stable soil

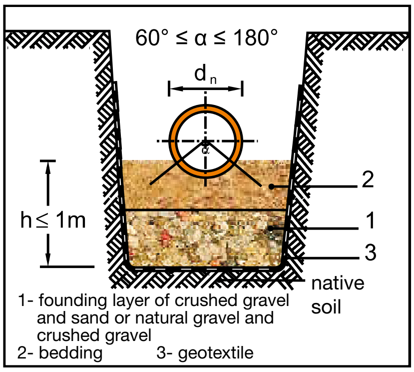
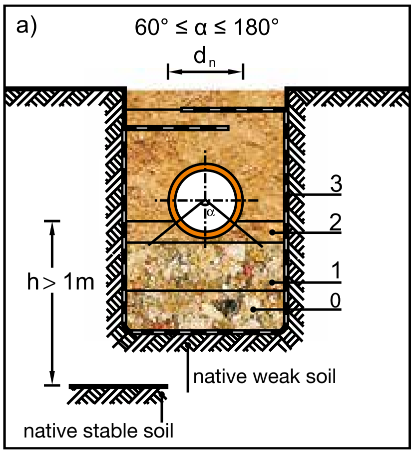


Fig. 6.3 Example of laying on weak soil (loess) at a depth ≤ 1.0 m

In any case the founding layer must be compacted from 85% to 95% Proctor density

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

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



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 essential for achieving satisfactory 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. Appropriate soils 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 matter (inclusions), such as snow, ice or frozen lumps of soil.

Fig. 6.5 Pipeline cross section

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

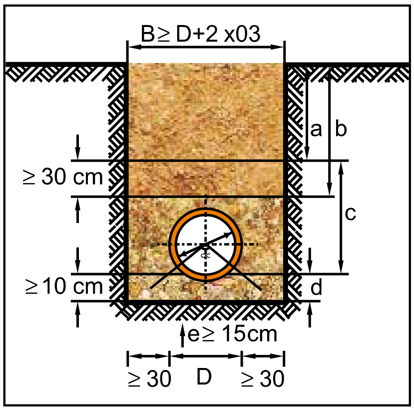


Table 3.1 Specifications of sidefilling and backfilling materials

SIDEFILLING AND SUBSEQUENT BACKFILLING		
Material	Grain size [mm]	Remarks
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

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% where the height of cover is < 4.0 m
  - 95% where 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 15 cm for pipe diameter D < 400 mm

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. For pipe diameters D < 400 mm with initial backfill 15 cm high, the final backfilling material must not contain grains larger than > 60 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, loamy and silty soils.

Table 3.2 Compaction methods

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		
		чакъл, пясък	глина, наноси		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

* before using compaction equipment

** compaction along the 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 clearance distance between the pipe and the trench wall for filling is b_{min}=30 cm. Therefore the minimum trench width (B) at the top of the pipe is:

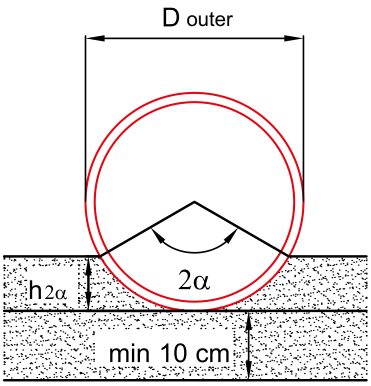
$\mathbf{B = D + (2 \times b_{min})}$

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

$\mathbf{B \geq 4 \times d_n}$

A similar situation may occur in granular soils with low density (ID < 0.33) or cohesive soils with top limit IL > 0.0

6.3.6 Filling necessary for achieving the desired angle of laying



DN [mm]	D outer [mm]	Angle of laying 2α			
		60°	90°	120°	180°
		h2α [cm]			
DN/OD160	160	1	2	4	8
DN/OD200	200	1	3	5	10
DN/OD250	250	2	4	6	12
DN/OD315	315	2	5	8	16
DN/OD400	400	3	6	10	20

7 INSTALLATION OF THE PP MONO PIPE SYSTEM

7.1 Joining PP Mono pipes through butt welding

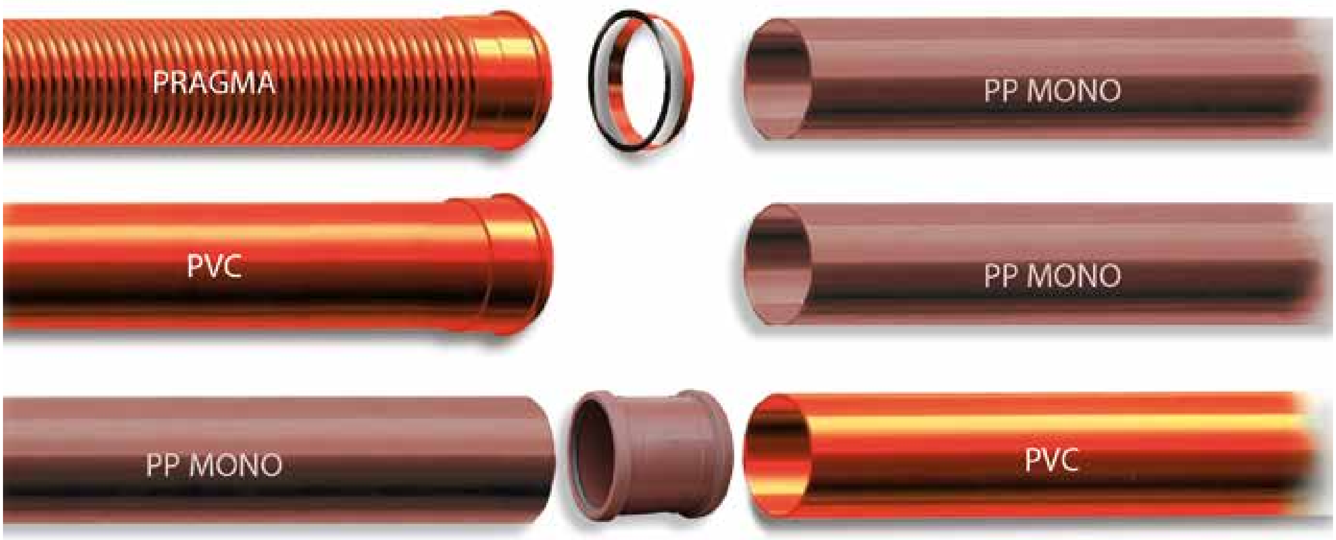
The PP Mono pipes have two smooth ends, which allows butt welding, similarly to polyethylene water supply pipes. Each butt welding machine can be set up to weld polyethylene, as well as polypropylene, which makes butt welding of PP Mono possible!

Butt-welded PP Mono pipes successfully pass the pressure test of 10 bar! Although such a high pressure is not typical for sewer systems, the test proves the exceptional resilience and strength of the joint!

7.2 Joining PP Mono pipes through pipe coupling double socket

Another pipe coupling option, provided by Pipelife, besides butt welding, is joining the pipes through double sockets, made of the same material as the pipe!
At customer‘s request, the pipes can be supplied either with the socket pre-installed at one end, or the sockets can be supplied separately (with two sealing rings)

7.3 Joining PP Mono pipes to smoothwall PVC pipes and corrugated Pragma pipes



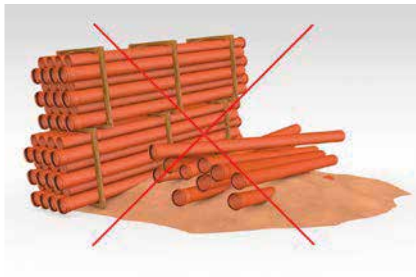
8 TRANSPORTATION, LOADING, UNLOADING AND STORAGE

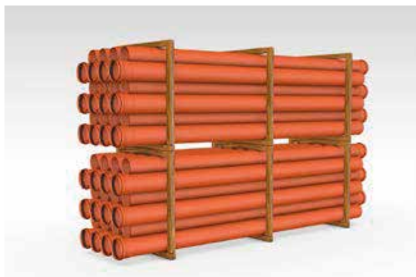
8.1 Transport

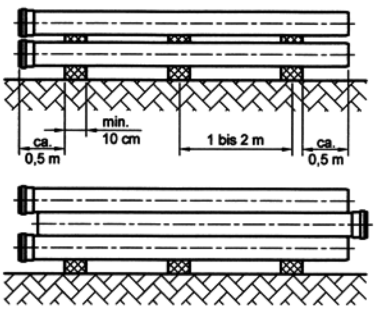
During transport the pipes must rest completely over the entire length. Therefore arrange the couplings – as shown in the second illustration – transposed. Support pipes that protrude over the truck bed. Otherwise the free ends of the pipes will swing and be subjected to great bending stress.
Protect the pipes from edges (e.g. loading platform) and perform the loading work with appropriate care.
Do not throw the sewer pipes down from the truck and do not drag them along the ground. This applies especially at temperatures below freezing point.

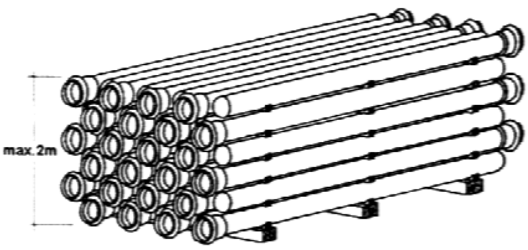
8.2 Storage

The pipes should not be stacked higher than 2 m and must rest on squared timbers. Full, not opened hobbocks (packaging units) can be stored on top of each other – wood on wood (max. 2 hobbocks one above the other). In the event of longer storage outdoors, cover the pipes to protect them from sun exposure.









9 HYDRAULIC DIMENSIONING OF THE PP MONO 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;

• 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 circular pipe flowing full 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

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 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 flowing partly full

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 pipe flowing full, [m³/s]

qn – volumetric flow in pipe flowing partly full, [m³/s]

hn – actual depth of 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]

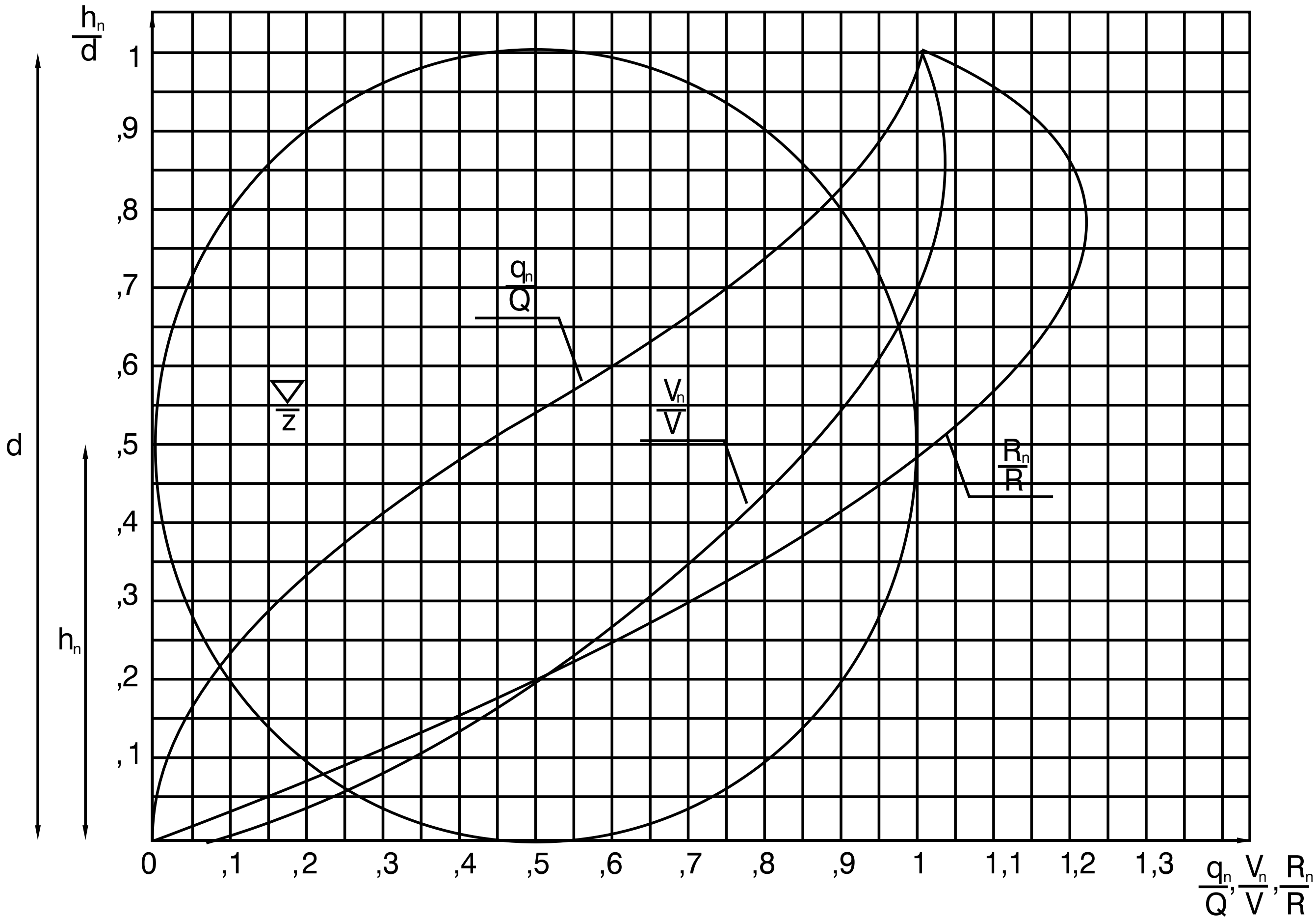
The values of the artificially raised absolute roughness are recommendable, but not mandatory. The designers could choose another artificially raised value for k or other method for determining local resistances.

9.3 Software and dimensioning tables

Besides the nomograms, provided hereunder, Pipelife offers to designers other helpful tools for hydraulic dimensioning, as well. Section „Technical Design” at www.pipelife.bg provides an online tool 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 flowing partly full



$\frac{h_n}{d}$ 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 flow

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

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

9.5 Hydraulic slopes and flow velocities in PP Mono 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 – actual depth of 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.

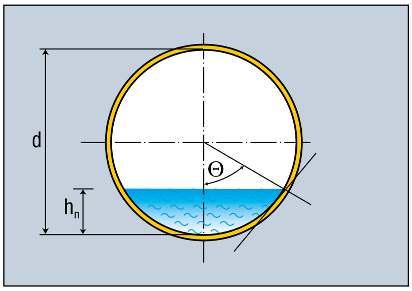


Fig. 9.1.
Angle of internal friction

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

Usually the minimum permissible velocities (Vsc) at full flow, securing the self-cleaning ability of the pipes must be not less than:

Vsc = 0,8 m/s for household sewers
Vsc = 0,6 m/s for storm sewers
Vsc = 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:
imin = 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 = specific weight of waste water, [kg/m3]
R = hydraulic radius, [m]
i = hydraulic slope, [m/m]

The actual tractive force is: 8)

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

Where:
$R = \frac{d}{4}$, hidraulic radius for circual 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 a pipe flowing party full (actual flow) 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 PP MONO SYSTEM

10.1 Interaction of the pipe with the surrounding soil

From a technical point of view the PP Mono polypropylene 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)

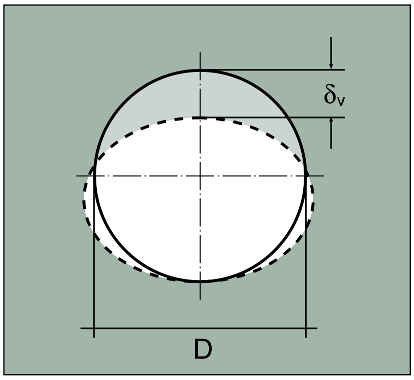


Fig. 10.1 Deflection of a circular pipe caused by vertical load

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, acting 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 stiffness of 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.

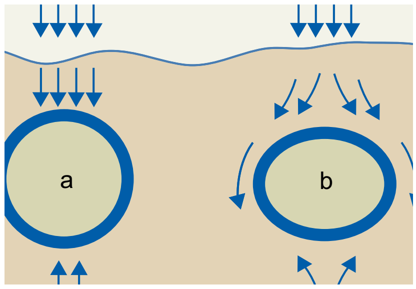


Fig. 10.2

Проектното поведение на гъвкави тръби може да се илюстрира с формулата на Spangler: 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
Ss – 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 (qv), which is generating stress and strain, as well as a counteracting horizontal load (qh).

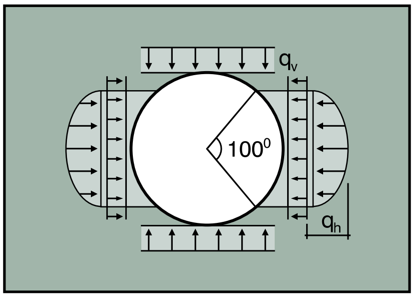


Fig. 10.3 Scandinavian earth pressure distribution model

VERTICAL LOADS

1. Earth load above the pipe: 12)

12)
$$q_z = \gamma_z \cdot H$$

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)

13)
$$q_w = \gamma_w \cdot h$$

In this case the vertical load is:14)

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

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.

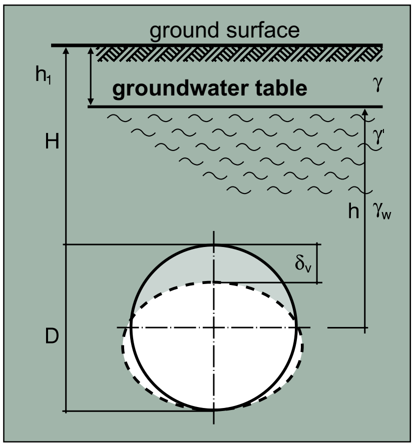


Fig. 10.4 Geometry of the embedment

10.3 Required data for static analysis of a PP Mono pipe system

With regard to the proper installation and operation of the PP Mono 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 online tool, provided by Pipelife in section „Technical design" at www.pipelife.bg.

Pipelife also provides the EASYPIPE program, 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:

Project data		**Project**				
		Client				
		Designer				
		Date				
Data about the soil around and in the trench zone		**Main soil groups**	**Zones (Figure 10.5)**			
			E1	**E2**	**E3**	**E4**
		G1 - cohesionless				
		G2 - slightly, insignificantly cohesive soils				
		G3 - mixed cohesive soils, coarse, raw clay (clogged with slime, sand, coarse sand and fine gravel, cohesive residual rocky soils)				
		G4 - cohesive (e.g. clay)				
Load data		**h – height of cover over the top of the pipe, [m] (fig. 10.6)**				
		Density of the embedment material, [kN/m3]				
		Additional static loads (e.g. in warehouses), [kN/m2]				
		Hw max – maximum groundwater table over the top of the pipe, [m] (fig. 10.7)				
		Hw min – minimum groundwater table over the top of the pipe, [m] (fig. 10.7)				
		Short-term internal pressure in the pipe, [bar]				
		Long-term internal pressure in the pipe, [bar]				
		Traffic loads (choose one of the following options)			**Traffic intensity**	
					normal	**irregular**
		LT12 – 12 tonnes - 2 (semi)axles				
		HT26 – 26 tonnes - 2 (semi)axles				
		HT39 – 39 tonnes - 3 (semi)axles				
		HT60 – 60 tonnes - 3 (semi)axles				
Covering		**First layer**		**Second layer**		
		Height h1, [m]	**Modulus of Elasticity E1, [MPa]**	**Height h2, [m]**	**Modulus of Elasticity E2, [MPa]**	
Laying	**Embank-ment / Trench**	**Trench width over the top of the pipe - b (m)-(from 0,1 to 20 m)**				
		Trench angle of repose - β (degrees)				
		Trench conditions from group A1 to A4 (see the available groups at the end)	**A1**	**A2**	**A3**	**A4**
		Embedment conditions from group B1 to B4 (see the available groups at the end)	**B1**	**B2**	**B3**	**B4**
		Type of bedding	**Angle of laying -2α**			
			60°	**90°**	**120°**	**180°**
		Sand cushion				
		Concrete lining				

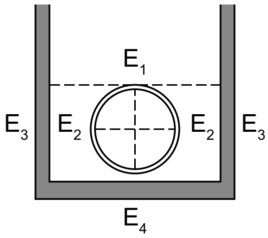


Fig. 10.5

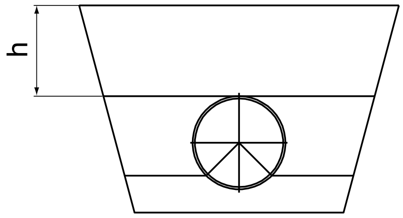


Fig. 10.6

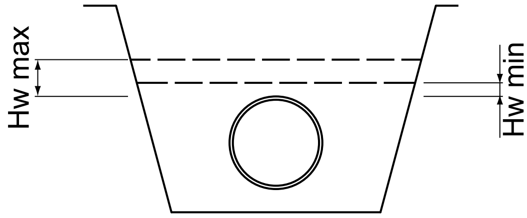


Fig. 10.7

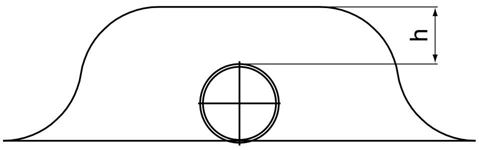


Fig. 10.8

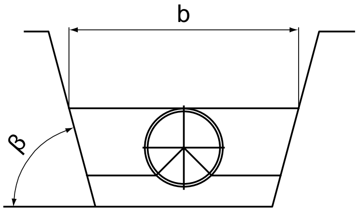


Fig. 10.9

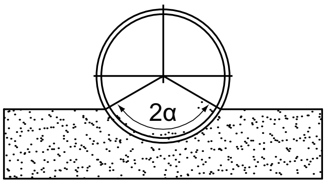


Fig. 10.10

"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.

10.4 Soil types according to 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]	Uninter. 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	Dune sands and sediments, river sand	YES
		Well-graded sands, gravel/sand mixtures	[SW]	Uninter. 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
		Loamy 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	
		Loamy 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 pastic clay	(TA)(TL) (TM) [CL]	Medium to high stability, slow reaction, low to medium plasticity	Alluvial clay, clay	
Organic		Soils of mixed grain size with humus and talc inclusions	[OK]	Vegetational and non-vegetational inclusions, rots, lightweight, high porosity	Upper layers, hard sand	NO
		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	

Note: The shown images may not exactly correspond to the actual products.

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