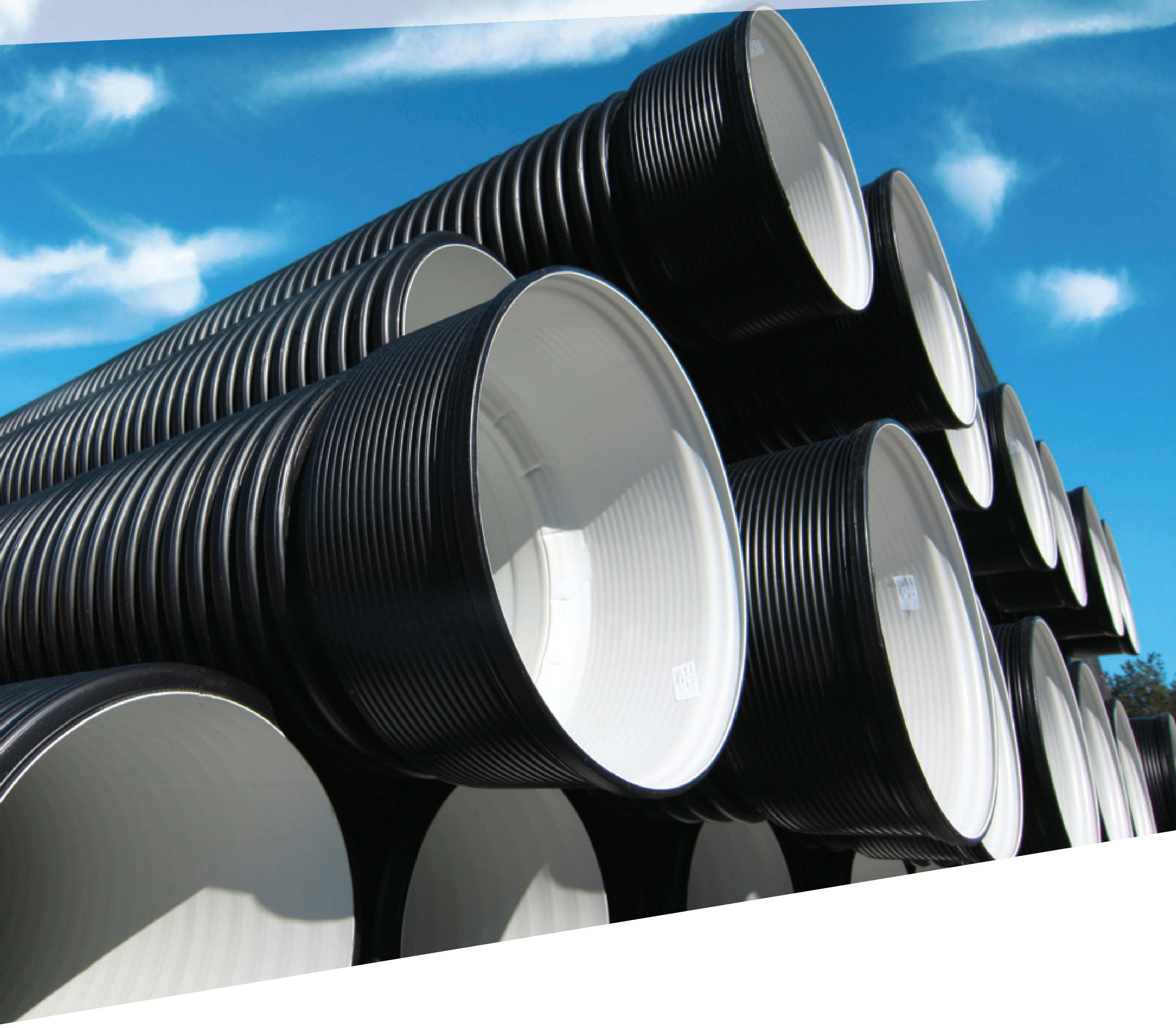
POLYPROPYLENE SEWAGE PIPES

Pecor Quattro

ADVANTAGE BY INNOVATION



ViaCon

The Pecor Quattro system offered by ViaCon is widely used in transport infrastructure engineering and designed for:

- construction of gravity sewer systems
- construction of road and rail culverts
- construction of animal-friendly culverts and culverts under forest roads
- construction of drainage culverts
- construction of industrial ventilation systems
- construction of agricultural ventilation systems

Parameters

Pecor Quattro pipes are manufactured from polypropylene (PP) and consist of two walls, where the outer wall is corrugated to provide high ring stiffness of SN8 (8 kPa), and the inner wall is smooth to guarantee optimal flow conditions. Pecor Quattro pipes are manufactured in DN/ID diameter range from 200 mm to 1000 mm. The pipe socket moulded at the production stage is an integral part of the pipe, allows for fast installation, and, coupled with an elastomeric gasket fastened on the spigot provides the joints with the required tightness.

The Pecor Quattro system is manufactured in compliance with the PN-EN 13476-1 [1], PN-EN 13476-3 [2] standards, and has an IBDIM Technical Approval No. AT/2012-02-2815 [3] for pipes used in transport infrastructure engineering.

The Pecor Quattro system was positively evaluated by the General Institute of Mining (GIG) for use in areas affected by mining operations [4].

The Pecor Quattro system consists of the following:

- Pecor Quattro SN8 pipes in DN/ID diameter range from 200 mm to 1000 mm
- fittings (elbows, tees)
- connecting pieces (adapters, sleeves, muffs, PP/PVC adapters)
- Pecor Quattro wells



As a standard Pecor Quattro pipes are manufactured in black and grey (black outer corrugated wall, and light-grey inner wall). Other colours are available on request, e.g.: orange outer wall and light-gray inner wall.

The Pecor Quattro pipes with ring stiffness of SN8 can be used for all load classes [5].

Advantages of the Pecor Quattro system:

- obviate the need to use heavy equipment for installation
- diversity of solutions
- quick and simple installation (low weight)
- reduced transport costs
- best mechanical and hydraulic properties
- corrosion resistance

Material

Pecor Quattro pipes are made of polypropylene (PP). This material is characterised by outstanding mechanical properties at low density, which translates to high ring stiffness of the pipe.

Polypropylene is also characterised by high heat resistance (operating temperature up to 93°C, short-term up to 110°C), low surface roughness, and extremely high abrasion resistance.

As block copolymer of polypropylene is the only substance used in the manufacture of Quattro pipes, pipe walls become brittle in temperatures as low as below -10°C.

Table 1. Physical and mechanical characteristics of polypropylene (PP)

No.	Characteristic	Test method	Units	Value
1	Density	ISO 178	kg/m³	900
2	Mass flow rate (MFR)	ISO 1133	g/10min	0,23-0,50
3	Modulus of elasticity	ISO 178	MPa	1500-1850
4	Tensile strength	ISO 527-2	MPa	29-32
5	Thermal conductivity	EN 12664	W/mK	0,23
6	Thermal coefficient of linear expansion	DIN 51007	mm/mK	0,14

Pecor Quattro pipes are manufactured with the use of polypropylene with a colorant (pigment) so as to obtaining the desired colour:

- outer wall: RAL 9004 black or RAL 2001 orange
- inner wall: RAL 7035 light-gray

Polypropylene (PP) is characterised by very good resistance to most chemicals. Table 2 presents a summary of polypropylene resistance to various chemicals. The following resistance grades were used:

S – satisfactory
L – limited
I – insufficient

Table 2. Summary of polypropylene (PP) chemical resistance

Substance	Concentration	Temperature		
		20°C	60°C	100°C
Acetone	100%	S	L	-
Benzoic aldehyde	0.1%	Z	-	-
Acetaldehyde	40% 100%	I	-	-
Ethyl alcohol	96%	S	S	S
Isopropyl alcohol	100%	S	S	-
Methyl alcohol	100%	S	S	-
Aqueous solution of ammonia	Diluted	S	S	-
Aniline	100%	S	L	-
Nitrates	Saturated solution	S	S	-
Benzene	100%	L	I	-
Gasoline (aliphatic hydrocarbons)	80/20	L	I	-
Acetic anhydride	100%	S	-	-
Chlorine	Chlorine	S	I	-
Chlorates	Saturated solution	S	S	-
Cyclohexanol	10%	S	S	-
Detergents	2%	S	S	S
Phenol	90%	S	S	-
Formaldehyde	40%	S	S	-
Xylene	100%	L	I	-
Nitric acid	50 to 98%	L	I	-
Hydrochloric acid	>30%	S	S	-
Lactic acid	10÷90%	S	S	-
Formic acid	1÷50%	S	S	-
Acetic acid	25%	S	S	S
Acetic acid	Frigid	S	L	-
Sulfuric acid	96%	S	S	-
Otassium hydroxide	Unsaturated solution	S	-	-
Hydrogen sulfide, gaseous	100%	S	S	-
Sodium hydroxide	Saturated solution	S	S	-
Toluene	100%	L	I	-
Hydrogen peroxide	30%	S	L	-

Note: the complete list of resistance to chemicals is available at the technical department of ViaCon.

Elastomeric gaskets are used to provide the socket/spigot connection with the required tightness. Chemical resistance of the gasket is in the range between pH2 and pH12. The list of chemicals that the gaskets are resistant to is defined in the ISO 7620 guidelines.

The gaskets are manufactured in compliance with the following standards: PN-EN 681-1:2002 [6] and PN-EN 681-2:2003/A2:2006 [7].

Technical characteristics of Pecor Quattro pipes

Pecor Quattro pipes are manufactured as two-wall pipes, with the smooth inner wall and the corrugated outer wall (Fig. 1). Apart from stiffening function, the corrugation is intended to harmonise the behaviour of the pipe with the surrounding ground. The size of corrugation varies with the pipe diameter. The corrugation diagram of Pecor Quattro pipes is shown in Fig. 2 and the dimensions are presented in Tab. 3.

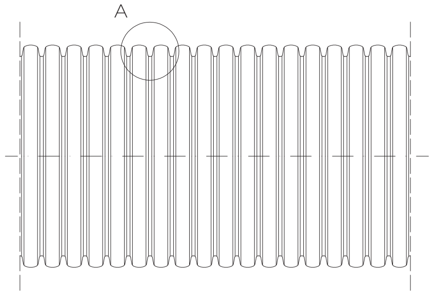


Fig. 1. View of a Pecor Quattro pipe

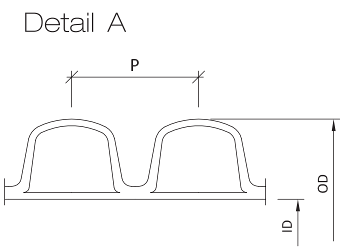


Fig. 2. Pecor Quattro corrugation diagram

Table 3. Geometric characteristics of Pecor Quattro pipes

DN/ID	ID [mm]	OD [mm]	Clear cross-section [m²]	Corrugation repetition P [mm]
200	196	224	0,03	22,4
300	296	338	0,07	31,4
400	394	451	0,12	39,5
500	492	564	0,19	53,0
600	591	674	0,27	66,0
800	788	902	0,49	88,0
1000	988	1130	0,77	106,0

Mechanical and physical characteristics – requirements

Mechanical and physical characteristics of the Pecor Quattro pipes are presented in the following three documents:

- Polish standard – PN-EN 13476-3 [2]
- IBDiM technical approval AT/2012-02-2815 [3]
- INSTA SBC EN 13476 [12]

Tables 4 and 5 present the requirements for mechanical and physical characteristics of pipes and fittings.

Table 4. Mechanical and physical characteristics of Pecor Quattro pipes

No.	Characteristics	Units	Requirements	Test method acc. to
1	Changes by heating: - test temp. (150 ± 2)°C - test time e ≤ 8 mm; 30 min e > 8 mm ; 60 min	-	No delamination, cracks, blisters	PN-EN ISO 12091
2	Ring stiffness tested for pipe samples with a length of 300 mm for pipe stiffness class: - SN8	kN/m²	≥ 8	PN-EN ISO 9969
3	Pipe ring elasticity: - test temp. (23 ± 2)°C - deformation 30% of the diameter - test force should increase without drops	-	no cracks, marks or signs of delamination on pipe walls	PN-EN ISO 13968
4	True impact resistance (TIR) tested with a falling weight method at a temp (O ± 1) °C and sample length of 200 mm, ram tip type (d) 90, weights with the following weight: 160 < $d_{im,max}$ ≤ 200 of 1,6 kg 200 < $d_{im,max}$ ≤ 250 of 2,0 kg 250 < $d_{im,max}$ ≤3 15 of 2,5 kg 315 < $d_{im,max}$ of 3,2 kg Weight drop height for: $d_{em,min}$ > 110 is 2000 mm	%	TIR ≤ 10	PN-EN 744
5	Changes by heating: - test temp. (150 ±2)°C - test time e ≤ 8 mm; 30 min e > 8 mm; 60 min	-	No delamination, cracks, blisters	PN-EN ISO 12091
6	The tightness of the connections with an elastomeric ring gasket, test temp. (23 ± 2)°C, test parameters: Spigot bend 10% Socket bend 5% 1. Low internal hydrostatic pressure 0,05 bar 2. High internal hydrostatic pressure 0,5 bar 3. Air pressure - 0,3 bar	-	no damage or leakage during and after the test ≤ - 0,27 bar	PN-EN 1277 condition B
7	The tightness of the connections with an elastomeric ring gasket, test temp. (23 ± 2)°C, test parameters: Angular bend for: - DN ≤ 3 15 mm - 2° - 315 < DN ≤ 630 - 1,5° - 630 < DN - 1°, test temp. (23 ± 2)°C: 1. Low internal hydrostatic pressure 0,05 bar 2. High internal hydrostatic pressure 0,5 bar 3. Air pressure - 0,3 bar	-	no damage or leakage during and after the test ≤ - 0,27 bar	PN-EN 1277 condition C
8	The tightness of the connections with an elastomeric ring gasket, test temp. (23 ± 2)°C, test parameters: Spigot bend 10% Socket bend 5% Angular bend for: - DN ≤ 3 15 mm - 2° - 315 < DN ≤ 630 - 1,5 ° - 630 < DN - 1°, test temp. (23 ± 2)°C: 1. Low internal hydrostatic pressure 0,05 bar 2. High internal hydrostatic pressure 0,5 bar 3. Air pressure -0,3 bar	-	no damage or leakage during and after the test ≤ - 0,27 bar	PN-EN 1277 condition D

Table 5. Characteristics of Pecor Quattro fittings

No.	Characteristics	Units	Requirements	Test method acc. to
1	Fitting ring stiffness, test temp. (23 ± 2)°C	kN/m²	8	PN-EN ISO 13967
2	Fitting elasticity or mechanical strength: - test time 15 min, - minimum moment for: [DN] ≤ 250 0,15[DN]³ x 10⁻⁶ kNm [DN] > 250 0,01[DN] kNm lub - minimum displacement: 170 mm	-	no signs of delamination, cracks, marks, leakage	PN-EN 12256
3	Fitting impact resistance (drop method) - conditioning temp. (0 ± 1)°C - drop height: DN ≤ 125 mm; 1000 mm DN > 125 mm; 500 mm impact place: socket inlet	-	no damage	-

Ring stiffness of Pecor Quattro pipes

Ring stiffness is the parameter that describes the strength of Pecor Quattro pipes. Pecor Quattro pipes are manufactured in stiffness class SN8. Ring stiffness is a parameter that is declared by the produced for each manufactured batch of pipes. The declared nominal ring stiffness of Pecor Quattro pipe is the minimum guaranteed value for the given batch.

Ring stiffness tests are performed by the company laboratory so as to determine the force required to deform the inner diameter of the pipe by 3%. Ring stiffness is tested in compliance with PN-EN ISO 9969 [8].

Marking Pecor Quattro pipes

Pecor Quattro pipes are marked in compliance with the guidelines of PN-EN 13476-3 [2].
Example marking of Pecor Quattro pipes:

ViaCon Pecor Quattro B PP DN/ID 600 UD SN8 PN-EN 13476-3

Description:

- ViaCon – producer
- Pecor Quattro – system name
- B construction certification sign
- PP – material
- DN/ID 600 – nominal diameter
- UD – area of application
- SN8 – ring stiffness
- PN-EN 13476-3 – applicable standard

PRODUCTION PROGRAMME

Pecor Quattro Pipes

Pecor Quattro pipes with a socket

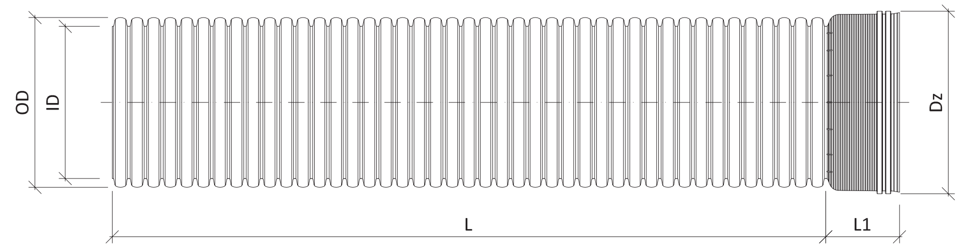


Fig. 3 Pecor Quattro pipes with a socket

Table 6. Dimensions of Pecor Quattro pipes with a socket

DN/ID	ID [mm]	OD [mm]	Dz [mm]	L1 [mm]	L [mm]	
200	196	224	256	150	3 000	6 000
300	296	338	375	165	3 000	6 000
400	394	451	493	185	3 000	6 000
500	492	564	614	250	3 000	6 000
600	591	674	731	290	3 000	6 000
800	788	902	960	345	3 000	6 000
1000	988	1130	1192	385	3 000	6 000

Pecor Quattro pipes without a socket

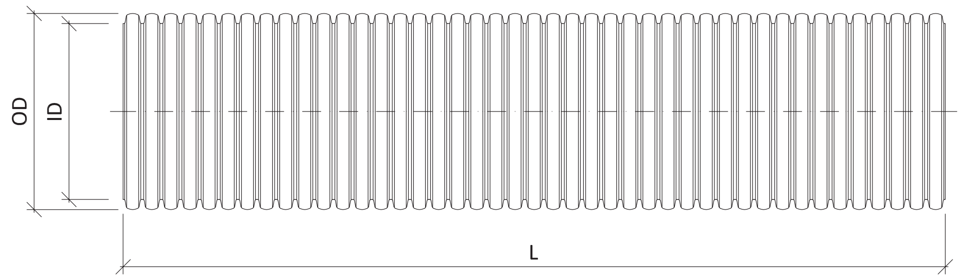


Fig. 4 Pecor Quattro pipe without a socket

Table 7. Dimensions of Pecor Quattro pipes without a socket

DN/ID	ID [mm]	OD [mm]	L* [mm]		
200	196	224	6 000	7 000	8 000
300	296	338	6 000	7 000	8 000
400	394	451	6 000	7 000	8 000
500	492	564	6 000	7 000	8 000
600	591	674	6 000	7 000	8 000
800	788	902	6 000	7 000	8 000
1000	988	1130	6 000	7 000	8 000

*) pipes with custom length can be manufactured on request

Pecor Quattro fittings – made by welding

Two-socket Pecor Quattro connectors with an internal limiter, designed to connect pipes cut at the construction site

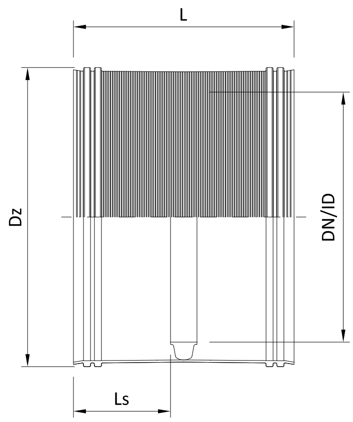


Table 8. Dimensions of Pecor Quattro connectors

DN/ID	Dz [mm]	L [mm]	Ls [mm]
200	253	245	121
300	376	310	153
400	496	366	181
500	615	550	248
600	732	635	284
800	960	730	320
1000	1192	848	370

Pecor Quattro sleeve connector without an internal limiter. Designed to connect pipes cut at the construction site, where it is not possible to move the pipes along their longitudinal axis

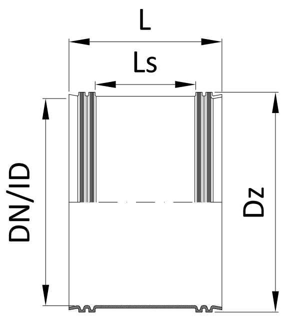


Table 9. Dimensions of Pecor Quattro sleeve connectors

DN/ID	Dz [mm]	L [mm]	Ls [mm]
500	614	446	280
600	737	519	341
800	953	525	399
1000	1196	550	413

Pecor Quattro/PVC adapter (socket/spigot) – adapters designed to connect Pecor Quattro pipes with smooth-wall pipes e.g.: PVC pipes

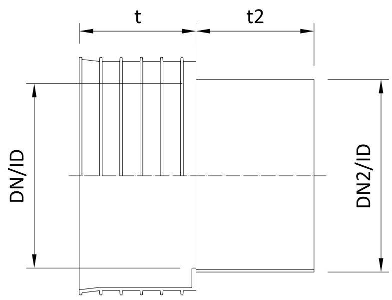
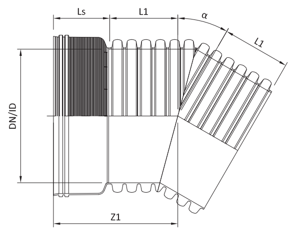


Table 10. Dimensions of Pecor Quattro/smooth-wall (e.g. PVC) pipe adapters

DN/ID	DN2/ID [mm]	L [mm]	t2 [mm]
200	160	121	95
	200	121	110
300	250	153	150
	315	153	190
400	400	181	220
500	500	301	390

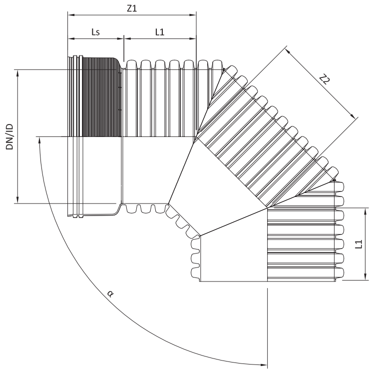
Pecor Quattro elbows – to connect Pecor Quattro pipes

Table 11. Dimensions of elbows α=15°, 30°, 45° for Pecor Quattro pipes



DN/ID	Z1 [mm]	L1 [mm]	Ls [mm]
200	400	250	150
300	465	300	165
400	535	350	185
500	650	400	250
600	790	500	290
800	945	600	345
1000	1085	700	385

Table 12. Dimensions of elbows α=90° for Pecor Quattro pipes

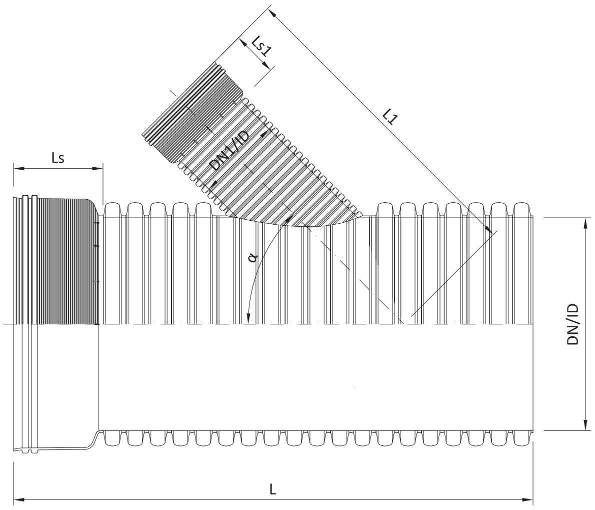


DN/ID	Z1 [mm]	L1 [mm]	Z2 [mm]	Ls [mm]
200	400	250	150	150
300	465	300	200	165
400	535	350	250	185
500	650	400	320	250
600	790	500	390	290
800	945	600	500	345
1000	1085	700	620	385

Note: elbows with custom dimensions can be manufactured on request.

Pecor Quattro tees

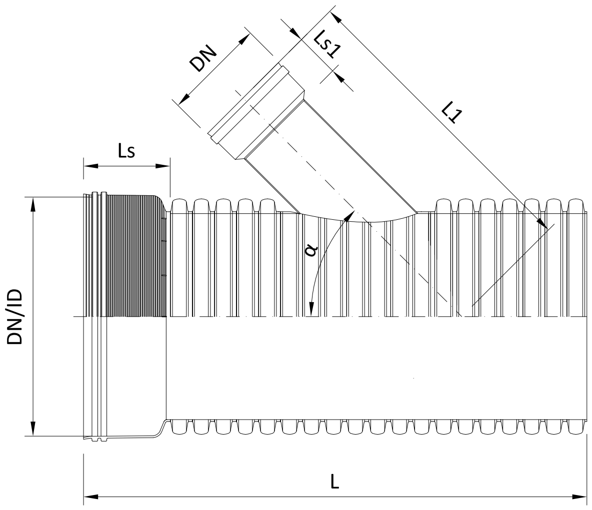
Table 13. Dimensions of tees α=45° for Pecor Quattro pipes



DN/ID	DN1/ID	L [mm]	L1 [mm]	Ls [mm]	Ls1 [mm]
200	200	722	620	150	150
300	200	838	700	165	150
	300	986	770	165	165
400	200	1073	780	185	150
	300	999	850	185	165
	400	1096	930	185	185
500	200	1139	860	250	150
	300	660	930	250	165
	400	713	1010	250	185
	500	800	1130	250	250
600	200	666	940	290	150
	300	716	1010	290	165
	400	770	1090	290	185
	500	856	1210	250	250
800	300	828	1170	345	165
1000	300	942	1330	385	165

Pecor Quattro/smooth wall pipe α=45° – to connect Pecor Quattro pipes with smooth-wall (e.g. PVC) pipes

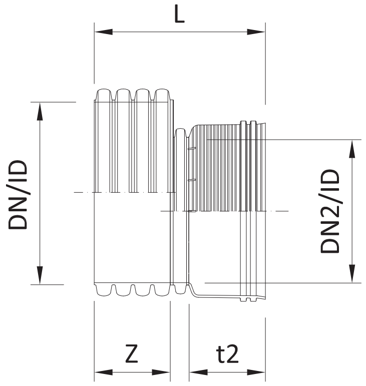
Table 14. Dimensions of tees α=45° for Pecor Quattro/PVC



DN/ID	DN	L [mm]	L1 [mm]	Ls [mm]	Ls1 [mm]
200	160	644	540	150	95
	200	690	580	150	116
300	160	719	620	165	95
	200	764	660	165	116
	250	814	700	165	132
400	160	832	700	185	95
	200	877	740	185	116
	250	926	780	185	132
	315	992	840	185	156
500	160	930	780	250	95
	200	975	820	250	116
	250	1025	870	250	132
	315	1091	920	250	156
600	160	1065	860	290	95
	200	1110	900	290	116
	250	1159	950	290	132
	315	1225	100	290	156
800	200	1266	1060	345	116
1000	200	1469	1220	385	116

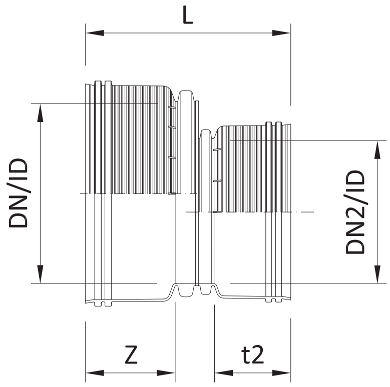
Pecor Quattro eccentric reducers – designed to reduce the diameter of Pecor Quattro pipes

Table 15. The dimensions of one-socket reducers for Pecor Quattro pipes (spigot/socket)



DN/ID	DN2/ID [mm]	L [mm]	Z [mm]	t2 [mm]
300	200	373	192	150
400	200	381	200	150
	300	405	200	165
500	300	470	265	165
	400	498	265	185
600	400	563	330	185
	500	641	330	250
800	600	806	440	290
1000	800	973	530	345

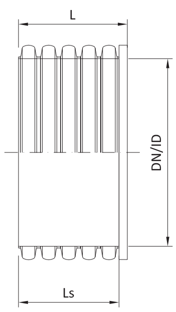
Table 16. The dimensions of two-socket reducers for Pecor Quattro pipes (socket/socket)



DN/ID	DN2/ID [mm]	L [mm]	Z [mm]	t2 [mm]
300	200	378	165	150
400	200	406	185	150
	300	430	185	165
500	300	508	250	165
	400	536	250	185
600	400	589	290	185
	500	667	290	250
800	600	799	345	290
1000	800	934	385	345

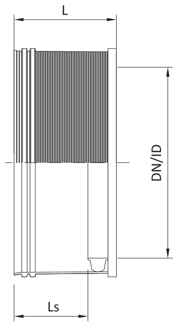
Plugs (caps)

Table 17. Inner plug – dimensions reducers for Pecor Quattro pipes (socket/socket)



DN/ID	L [mm]	Ls [mm]
200	187	179
300	228	220
400	245	237
500	326	318
600	404	396
800	448	440
1000	538	530

Table 18. Outer cap – dimensions



DN/ID	L [mm]	Ls [mm]
200	129	121
300	161	153
400	189	181
500	309	248
600	358	284
800	416	320
1000	484	370

CONSTRUCTION

Installation of Pecor Quattro pipes

Pecor Quattro pipes are joined by, among others, pressing the spigot of a pipe with a previously mounted gasket into the socket of another pipe. For proper installation follow these steps:

- check the pipe, socket and gasket for any damage
- remove any impurities from the spigot (the last groove) and the inside of the socket
- permanently mark (e.g. using a waterproof marker) the insertion depth on the spigot (the depth at which the pipe will be inserted in the socket)
- attach a cleaned elastomeric gasket into the last groove, between the first and second ring
- apply joining lubricant to the inside of the socket (connector) and the outer surface of the gasket **Note:** do not use lubricants that might damage the gasket, e.g. petroleum-based greases or oils
- Insert the spigot with the gasket into the socket up to the mark on the pipe. The installation can be considered to be finished if the entire perimeter of the socket end is as deep as marked

Structural Pecor Quattro pipes can be inserted at any installation length. If it is necessary to cut the pipe to the desired length, the cut should be made in the groove between the rings. Do not cut pipes in any other place. After cutting, remove any impurities.

Trenches for laying Pecor Quattro pipes

General information

Pecor Quattro pipes are designed for laying in open trenches. Open trenches can be supported or not supported, with embankments, or with embankments and partial supporting. The technology of making open trenches for sewer pipelines shall be compliant with the following standards: PN-B-10736:1999 [9] and PN-EN 1610:2002 [10].

Open non-supported trench

Open trenches without vertical-wall support can be made only in dry soil free of any groundwater, and in ground where there is no embankment at the trench edges in the area with a width of at least equal to the trench depth.

The following trench depths are allowed:

- 4,0 m – in rocky soil
- 2,0 m – in very cohesive soil
- 1,0 m – in other soils

Open trenches with no support and with embankments can be made if there is no groundwater and if there is no load applied within the area of the soil wedge. If there are no other design recommendations, open trenches with embankments can be made down to 4 m, with the following embankment slope:

- 2:1 – very cohesive soil
- 1:1 – stony, rocky cracked soi
- 1:1,25 – other cohesive soils and clay rubble
- 1:1,50 – non-cohesive soil

In case of open trenches, provide easy and quick drainage of rainwater from the strip with a width equal to three times the trench depth.

No transport infrastructure is allowed within the soil wedge of open trenches without support. The distance "b" of the trench edge measured in the plan from the adjacent edge of the road shall be calculated using the formula set out in PN-B-10736:1999 [9]:

$$b \geq \frac{H}{tg\varphi} + 0,5$$

where:

H – trench depth (measured from ground level to the level of the trench bottom)
φ – angle of internal friction of soil

Open supported trench

Open trenches shall be protected against rainwater flooding by extending the upper edge of the support for at least 15 cm above the ground level. If the trench is made below the groundwater level, the water level should be lowered to 0.5 m below the bottom of the trench. The type of support and the lowering of the groundwater level in the open trench should be specified in the design. Heavy equipment are not allowed to stay over the pipeline when removing the support. After the support is removed you must keep required backfill parameters.

Trench depth and width

Both the depth and the width of the trench should be determined on the basis of the detailed design. The depth of the trench should be sufficient to prevent the transported liquid from freezing.
It is recommended (PN-ENV 1046:2007 [11]) that the depth of cover in vehicle traffic bearing areas be not less than 0,6 m. It is also recommended that the cover provides sufficient protection against pipe displacement in areas with high level of groundwater.

Pursuant to the provisions of PN-EN 1610:2001 [10], the minimum width of the trench depends on the external diameter of the channel (Tab. 19) and its depth (Tab. 20) it should be assumed bigger parameters that shown on tables. For installation reasons, the width of the trench can be greater than the values shown in Tab. 19. and Tab 20. The width of the trench shall be determined by the designer.

Table 19. Minimum width of a trench depending on the diameter of the channel (PN-EN 1610:2002 [10])

Nominal diameter DN [mm]	Minimum trench width W_{min} = OD + x [m]		
	Open supported trench	Open non-supported trench	
		β > 60 °	β ≤ 60 °
≤ 225	OD + 0,40	OD + 0,40	
> 225 ≤ 350	OD + 0,50	OD + 0,50	OD + 0,40
> 350 ≤ 700	OD + 0,70	OD + 0,70	OD + 0,40
> 700 ≤ 1200	OD + 0,85	OD + 0,85	OD + 0,40
>1200	OD + 1,00	OD + 1,00	OD + 0,40

Description:

W_{min} - minimum trench width
OD - pipe outer diameter [m]
β - angle of the trench wall [o]

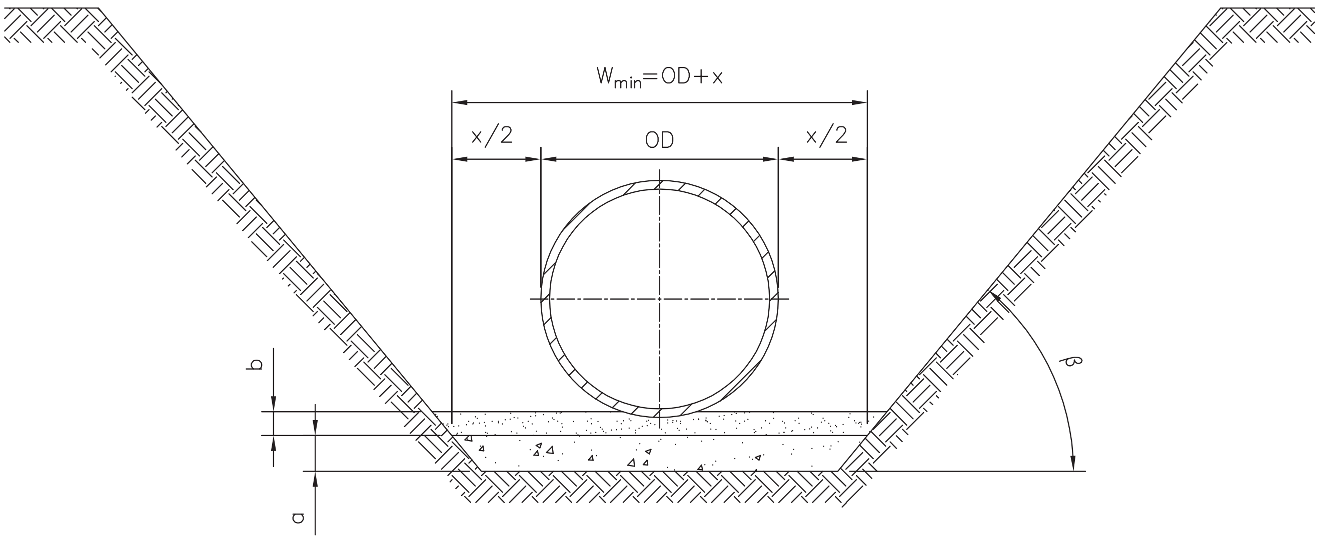


Fig. 5. Trench width

Table 20. Minimum width of a trench depending on the depth (PN-EN 1610:2002 [10])

Trench depth [m]	Minimum trench width [m]
< 1,00	no requirements
≥ 1,00 ≤ 1,75	0,80
> 1,75 ≤ 4,00	0,90
> 4,00	1,00

Foundation soil, bed and backfill

General information

To guarantee proper behaviour of a flexible pipe (in line with the ground), a number of requirements related to the preparation of the foundation, bed and backfill shall be met. The quality of the execution of these works determine the proper behaviour and lifespan of the pipeline.

The minimum load-bearing capacity of the ground on which the flexible pipe will be laid shall be determined by the designer. Due to the lower pressure of flexible pipes on the foundation, in comparison with concrete pipes, the former can be laid in low-bearing soil. For foundations that do not meet the load-bearing condition a reinforcement shall be designed, e.g. by replacing the ground soil or using geosynthetics, etc.

In the event of high fluctuations of groundwater level (a few times a year) above the level of the foundation of the pipeline, individual means set out in the design shall be made to prevent the backfill from loosening and flushing-out (migration) of fine factions.

Bed and backfill material

The grain size of the aggregate used for bed and backfill of the pipe (gravel, mine run, sand-gravel mix) depends on the size of the corrugation rings.

For Pecor Quattro pipes, the maximum recommended size of individual grains at the place of contact with the pipe wall and in its immediate vicinity (approx. 0,3 ÷ 0,5 m) is 31,5 mm.

Larger grains are allowed in the remaining area, provided that the following conditions are met:

- uniformity coefficient Cu ≥ 4
- curvature coefficient 1 ≤ Cc ≤ 3
- water permeability coefficient k10 > 6 m/day

Principles of applying bed:

- the width of the bed in the cross section of the pipe shall be greater than the pipe diameter so as to enable thorough compaction, min. width of the trench is provided in Tab. 19 and Tab. 20
- the thickness of the lower bed shall be not less than 15 cm (recommended: 20 cm), and the thickness of the upper bed not less 10 cm (Fig. 6)
- the upper bed layer should be laid loosely so that the rings of the pipe corrugation may freely sink into it to ensure proper behaviour of the pipe in line with the soil
- the compaction ratio of the bed may not be lower than Is = 0,98 as per normal Proctor test.

Principles of applying backfill:

- the backfill should be placed in layers evenly on each side of the pipe; the thickness of a loose layer should not exceed 30 cm (Fig. 6)
- the backfill layers around and above the pipe should be compacted with light compacting equipment (plate or jumping jack compactors). No mechanical compaction by heavy equipment is allowed until the backfill is at least 30 cm above the pipe (i.e. the so-called initial backfill has been made). It is critical to properly lay the so-called supporting backfill in the fillet area
- during backfill compaction, the pipe should be stabilised to prevent it from moving at the time of filling
- the compaction ratio of the backfill aggregate, compliant with the PN-B-0605 standard: Geo-engineering. Earthwork reports. General requirements and EN 1997-1 (EUROCODE 7) should be at least 0,98, and 0,95 in the immediate vicinity of the structure.

It is not allowed to enter heavy equipment over the pipeline and during the construction before the min cover is achieved. In case of necessity to go over the pipeline during its construction, minimum cover for the loads from vehicle crossing over should be determined in the design. Any deviations from the above mentioned principles shall be agreed with the designer and the technical department of ViaCon.

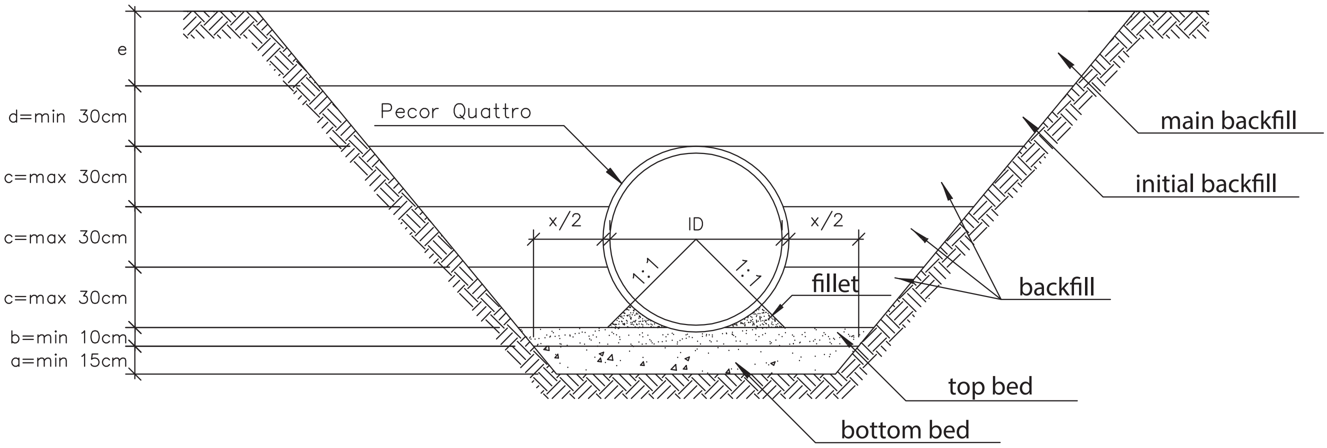


Fig. 6. Applying the bed and backfill for Pecor Quattro pipes

When the initial backfill is applied, place the main backfill. Table 21 shows the soil compaction recommendations according to PN-ENV 1046:2007 [11] for good and moderate density class, depending on the soil and the type of equipment used for compaction.

Table 22 shows the Standard Proctor Density (SPD) indicators for 3 classes of density.

Table 21. Recommended thickness of layers and number of cycles (PN-ENV 1046:2007 [11])

Equipment	Number of cycles for a density class		The maximum thickness of a layer after compaction for a soil group [m]				Minimum thickness above the top of the pipes before compaction
	good	moderate	Group 1	Group 2	Group 3	Group 4	[m]
Foot or hand compacto min. 15 kg	3	1	0,15	0,10	0,10	0,10	0,20
Vibratory compactor min. 70 kg	3	1	0,30	0,25	0,20	0,15	0,50
Vibratory plate							
min. 50 kg	4	1	0,10	-	-	-	0,15
min. 100 kg	4	1	0,15	0,10	-	-	0,15
min. 200 kg	4	1	0,20	0,15	0,10	-	0,20
min. 400 kg	4	1	0,30	0,20	0,15	0,10	0,30
min. 600 kg	4	1	0,40	0,30	0,20	0,15	0,50
Vibrating vibrator							
min. 15 kN/m	6	2	0,35	0,25	0,20	0,20	0,60
min. 30 kN/m	6	2	0,60	0,50	0,30	0,30	1,20
min. 45 kN/m	6	2	1,00	0,75	0,40	0,40	1,80
min. 65 kN/m	6	2	1,50	1,10	0,60	0,60	2,40
Double vibrating roller							
min. 5 kN/m	6	2	0,15	0,10	-	-	0,20
min. 10 kN/m	6	2	0,25	0,20	0,15	-	0,45
min. 20 kN/m	6	2	0,35	0,30	0,20	-	0,60
min. 30 kN/m	6	2	0,50	0,40	0,30	-	0,85
Three-roll heavy roller (no vibrations) min. 50 kN/m	6	2	0,25	0,20	0,20	-	1,00

Table 22. Standard Proctor Density indicators for different compaction classes (PN-ENV 1046:2007 [11])

Compaction class	Compaction description	Backfill material group			
		Group 4 [%]	Group 3 [%]	Group 2 [%]	Group 1 [%]
N	not compacted	75 do 80	79 do 85	84 do 89	90 do 94
M	moderate density	81 do 89	86 do 92	90 do 95	95 do 97
W	good density	90 do 95	93 do 96	96 do 100	98 do 100

DESIGNING

General information

Flexible structures made of plastic pipes interact during load bearing with the surrounding backfill, i.e. express ground arching. Such pipes, just as any other engineering structures, are prone to both constant and varying loads.

Flexible structures made of plastic pipes may be laid in any soil, provided that the soil meets the load-bearing conditions (based on the appropriate geological and engineering studies).

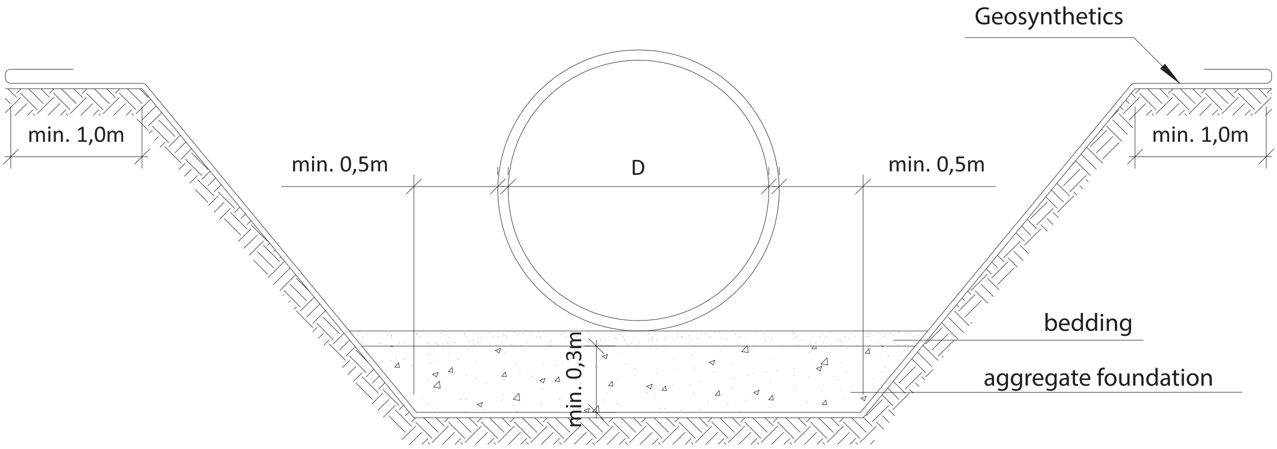


Fig. 7. Laying pipes on low-bearing soil.

The load-bearing capacity of the soil is considered sufficient, if it provides stability to the road structure or the embankment above it.

If the load-bearing condition of the soil is not met, the soil shall be reinforced by:

- applying geosynthetics
- increasing the thickness of the aggregate foundation
- replacing the soil if necessary
- using other effective means of providing the soil with the sufficient load-bearing capacity

It is not allowed to lay plastic pipes directly on any rigid foundations, including rocky soil. In such cases, a compactable layer (sand, gravel, etc.) shall be applied with a thickness of at least 20 cm. Pipes may be laid only on such a layer.

In designing multi-opening culverts, i.e. if the backfilled pipes are laid parallel to each other, make sure to provide sufficient distance between the pipes so as to enable adequate compaction. Figure 8 shows the minimum distances between the pipes.

if	$D \leq 0{,}6$ m	then	$C \geq 0{,}3$ m
if	$0{,}6 < D \leq 1{,}8$ m	then	$C \geq D/2$
if	$D > 1{,}8$ m	then	$C \geq 0{,}9$ m

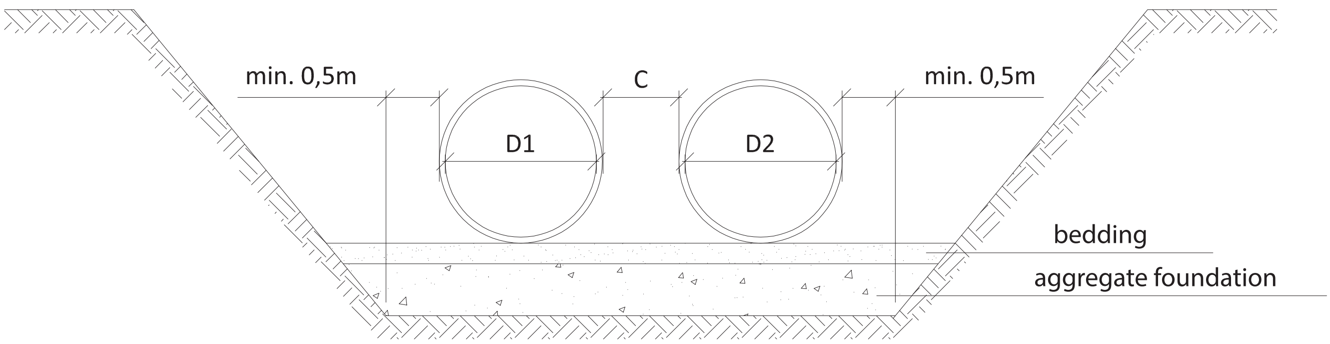


Fig. 8. Distance between pipes laid in the same trench.

Flow sizing

When designing engineering structures made of plastic pipes as culverts, comply with the applicable guidelines and the provisions of the document "Bridge and culvert clear clearances. Calculation principles with notes and examples" [13].

The recommended minimum inner diameter of a pipe depends on the requirements for adequate maintenance of the inner space of the culvert and the risk of ice clogging. Culverts can be filled completely (pressurised flow) or with free movement of water. Pressurised pipes should be equipped with adequate inlet and outlet protection against flooding-out.

Design flow should be calculated to determine the clearance of the object. The Manning model is recommended for this purpose:

$$Q = \frac{A \cdot R_h^{\frac{2}{3}} \cdot I^{\frac{1}{2}}}{n}$$

where:

n – roughness coefficient [-]
A – cross-sectional area of the pipe [m^2]
R_h – hydraulic cross-section radius [m]
I – watercourse level drop [-]

The roughness coefficient "n" can be assumed as declared by the manufacturers of plastic pipes. Generally it is between 0.007 and 0.014.

Minimum applied backfill

If the backfill was applied in accordance with the above requirements for culverts with high load, the amount of applied backfill depends on the diameter of the pipe. For pipes with a diameter from 600 to 1000 mm it should be not less than 0,50 m; for pipes with a diameter greater than 1000 mm the backfill height shall not be less than 0,5 of the pipe diameter. For other pipe diameters the minimum height of the applied backfill shall be 0,30. However for sewage system it is recommended to use load capacity not less than 0,6 m.

If the structural layers of the pavement are thicker than the recommended minimum height of the applied backfill, the thickness of the backfill below the pipe can be lowered 0,1 m (it shall be backed by static calculations).

For all types of plastic pipes it is possible to reduce the height of the applied backfill if a load-bearing reinforced concrete slab is applied or if the backfill is reinforced with a geo-mesh with rigid nodes (minimum strength in both directions: 20 kN/m). The reduction of internal forces shall be specified on an individual basis.

External loads

Flexible structures made of plastic pipes with ring stiffness below 8 kN/m^2 (determined according to PN-EN ISO 9969:1997) can be applied under all types of roads. Nonetheless, please note that any moving loads may not exceed the maximum level specified in the design.

Rigid pipes made of traditional materials such as: concrete, reinforced concrete, stoneware, and embedded in the soil are virtually non-deformable under the loads. Due to the lack of cross-sectional deformation, the load distribution is greatest in the top and bottom area of the pipe, in particular if the soil is poorly compacted on the sides of the trench. Such load distribution is extremely disadvantageous, as bending moments in the cross-sections subject to the greatest loads are very high, and the maximum concentration of the load occurs immediately after backfilling the trench and removing the support.

Plastic pipes laid in trenches behave in a different manner. Due to their flexibility, they interact with the surrounding soil in transferring the loads. Therefore, in sizing the engineering objects of this type, the behaviour of the pipes is considered in connection with the surrounding soil. The distribution of loads that act on such pipes is very even, and the induced distribution of internal forces is very advantageous for the pipe under analysis, as the values of extreme bending moments are distinctly lower in relation to rigid pipes of the corresponding size.

Nonetheless, the pipe deformation process is not free, as the soil that surrounds the plastic restricts the extent of the cross-sectional deformation (elongation of its horizontal diameter). This restriction increases with the stiffness of the soil on the sides of the pipe, which depends on the type of soil and its compaction. The pressure of the pipe sides onto the soil is counteracted with the passive pressure of the soil.

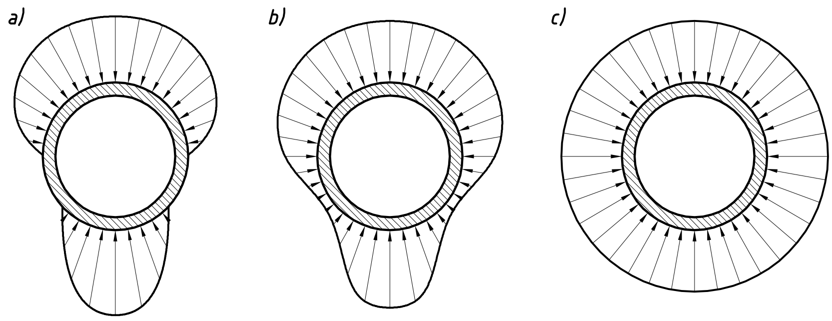


Fig. 9. Load distribution in pipes: a) rigid, b) elastic, c) perfectly flexible, under identical laying and load conditions.

Detailed information about the principles and methods of designing structures made of flexible plastic pipes can be found in the design and technology recommendations for flexible road engineering structures made of plastic. Annex to the Regulation No. 30 of the General Director for National Roads and Motorways from 2nd November 2006. IBDiM, Wrocław Branch [5].

TRANSPORT AND STORAGE

Transport

Pipes, fittings and connectors can be transported by any means adequate for their size. The items should be loaded in a manner that restricts their movements during transport. Care should be taken during handling so as not to damage the pipes, fittings, connect ors or any subcomponents. The pipes should not be dragged, but carried. Due to the risk of damage to the corrugation rings, sockets or other pieces during unloading, it is not allowed to drop the pipe from the means of transport, or to use chains or steel cables for unloading.

Storage

Pecor Quattro pipes should be stored on flat surface, in horizontal orientation, on wooden sleepers with a thickness that prevents the socket from reaching the floor. To avoid socket deformation, wooden inserts shall be placed between all layers of Pecor Quattro pipes. Sockets must not come into contact. Pipes should be secured against movement. Pipes, fittings and other elements of the system may be stored outdoors for 12 months from the date of manufacture, without additional safety precautions.
If the storage period is longer, provide adequate protection against weather, e.g. UV radiation.
If pipes, fittings and sumps are covered with tarpaulin non-permeable to light, adequate ventilation shall be provided. All elements should be protected against fire.

Literature and standards

[1] PN-EN 13476-1 Plastics piping systems for non-pressure underground drainage and sewerage. Structured-wall piping systems of unplasticised poly(vinyl chloride) (PVC-U), polypropylene (PP) and polyethylene (PE). Part 1: General requirements and performance characteristics.

[2] PN-EN 13476-3 Plastics piping systems for non-pressure underground drainage and sewerage. Structured-wall piping systems of unplasticised poly(vinyl chloride) (PVC-U), polypropylene (PP) and polyethylene (PE). Part 3: Specifications for pipes and fittings with smooth internal and profiled external surface and the system, type B.

(3) IBDiM AT/2012-02-2815 technical approval: „Pipes and fittings (made of polypropylene) for road culverts and drainage, and to cover wires and cables".

[4] Technical opinion on the compliance with conditions of use of PECOR QUATTRO system and pipes in mining damage areas. Katowice 29.08.2013.

[5] Design and technology recommendations for flexible road engineering structures made of plastic. Annex to the Regulation No. 30 of the General Director for National Roads and Motorways from 2nd November 2006. IBDiM, Wrocław Branch.

[6] PN-EN 681-1:2002 Elastomeric seals. Material requirements for pipe joint seals used in water and drainage applications. Part 1: Rubber.

[7] PN-EN 681-2:2003/A2:2006 Elastomeric seals. Material requirements for pipe joint seals used in water and drainage applications. Part 2: Thermoplastic elastomers.

[8] PN-EN ISO 9969 Thermoplastics pipes. Determination of ring stiffness.

[9] PN-B-10736:1999 Earthwork. Open trenches for the water and sewerage pipes. Technical conditions for execution.

[10] PN-EN 1610:2002 Construction and testing of drains and sewers.

[11] PN-ENV 1046:2007 Plastic piping systems. Outdoor systems for water or wastewater transfer. Underground and above ground installation practice.

[12] INSTA SBC EN 13476 Specific Rules for Nordic Certification in accordance with EN 13476- 1, 2 and 3 Plastic piping systems for non-pressure underground drainage and sewerage. Structured-wall piping systems of unplasticised poly (vinyl chloride) (PVC-U), polypropylene (PP) and polyethylene (PE).

INNOVATIVE INFRASTRUCTURE

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