SEWAGE PIPING

Hydraulic installation development in general and specifically that relating to urban water sewage must take into account certain social and environmental demands; it must also contribute to the preservation of available resources for future generations as much as possible. These requirements have significantly influenced the development of our sewage piping as the design of the various network components, are intended to achieve better-sealed and longer-lasting installations with lower running costs. Moreover, this installation optimization is achieved with materials that require less energy consumption and, therefore, reduced CO_2 emissions into the atmosphere throughout the component life cycle in the installation. Summing up, the choice of the materials employed in the sewage network must also contribute to sustainable development regarding future needs

A first classification would be to distinguish between rigid and flexible materials, both with their advantages and drawbacks. The first basically refer to conventional materials, employed over a very long time, whereas the second are plastic materials, which have undergone mush more development during the last few decades

Table 1 list those most widely used.

Sewage piping material (Table I)

RIGID MATERIALS	PLASTIC MATERIALS	
Mass concrete	Smooth compact PVC	Smooth compact PE
Reinforced concrete	Smooth honeycomb PVC	Corrugated PE
Fibre cement	Smooth multi-layer PVC	Corrugated PP
Vitrified stoneware	Corrugated PVC	PRFV filament winding
Nodular cast iron	Ribbed PVC	Centrifuged PRFV
Ductile cast iron	Spiral PVC	Polymer concrete

Hydraulic capacity

This is a property that is very closely related to the need to conduct waste water quickly without any stagnation. There are factors in waste water sewage networks are not present in fresh water, such as deposits on the piping bottom and walls, inspection manholes and the larger number of joints etc. For this ,reason, in the piping uniform rugosity equivalent K, (Prandtl-Colebrook), all these facts are incorporated ,assigning various values to the pipeline according to the fluid type circulating through it (clean water rainwater, sewage or industrial etc). The effect of usage and piping conservation on the mentioned equivalent rugosity are also taken into account. The commonly used values in waste water pipelines are given below.

Coefficient K values for various materials
(Table 2)

PIPING TYPE	K (mm)
Stoneware	0.10-0.25
Smooth internal wall PVC	0.10-0.25
Smooth internal wall PE-AD	0.10-0.25
Centrifuged PRV	0.10-0.25
PRV filament winding	0.20-0.50
Fibre-cement	0.25-0.40
High-quality smooth concrete	0.40-0.80
Medium-quality smooth concrete	0.80-1.50
Rough concrete	1.20-4.00
Onsite manufactured concrete	2.50-6.00

The lower values in Table 2 are essentially applicable to new piping or that with a good conservation system, with long, straight sections between inspection manholes, to main collectors and outfalls. The higher values are for the opposite situations.

Plastic Pipes in water and wastewater industry

Plastic pipes for potable water and sewage applications have been in use in world since many years ago. Since that time, production techniques and applications have evolved, but essentially plastics have repeatedly shown that they are the superior materials for a great range of installations.

Among different plastic pipes, Polyvinyl chloride, PVC, is one of the most popular plastics used in building and construction. It is used in drinking water and waste water pipes, window frames, flooring and roofing foils, wall coverings, cables and many other applications as it provides a modern alternative to traditional materials such as wood, metal, rubber and glass. These products are often lighter, less expensive and offer many performance advantages.

Corrugated PVC Pipe

plain PVC Pipe

Corrugated PP Pipe

Corrugated PE Pipe

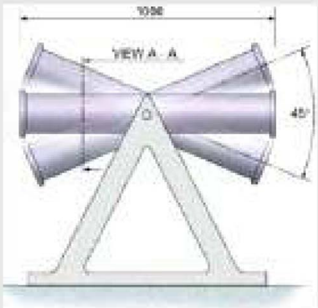
Chemical resistance

The specific waste-water characteristics determine the need for sewage piping to have very good performance regarding the pH of the chemical components present in circulating flows. This is one of the most outstanding characteristics of plastic piping, no matter what material is employed because, in general, it has very high resistance to most products present in waste water. Although PE and especially PP perform better at high temperatures, PVC is more resistant against the effects of acids, mineral oils and fuels that are so frequent in urban run-off water.

Lack of corrosion

In general, plastic piping is inert when referring to corrosion. This leads to a significant advantage because piping material must not oxidize due to aerobic corrosion or suffer anaerobic corrosion produced by components and microorganisms in circulating water and surrounding soil.

Piping must be resistant to electro-chemical action, in other words, against electric corrosion currents that are produced when two points on the piping surface are at a different potential, or when the surrounding soil has different oxygen or salt concentrations throughout the pipeline route, which is a normal occurrence. Electric corrosion currents only pass through piping when its material has less electrical resistance than the soil and they corrode in the same way as stray currents that form in electrical installations. In the case of effluents and especially aggressive soils, materials must be employed that are resistant to such aggression and/or special protection systems or sufficiently thick, stable and resistant coverings. It's been proven that PVC pipes are non-conductors of electricity and immune to electrochemical reactions caused by acids, bases, and salts that cause corrosion in metals. This characteristic exists on both the inside and outside of PVC pipe.



ABvaKHAK PVC-U® twin-wall corrugated pipe which is mainly based on PVC material has shown high performance regarding abrasion, this because of high hydraulic capacities.

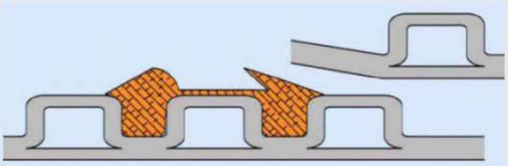
Abrasion resistance

Piping subject to solid particles dragged along by the effluent must be abrasion resistant. This is especially important in piping used in unitary sewage systems and in the rain water sewage network in separate systems. The lower internal rugosity values of plastic piping have favorable effects on the performance against abrasion. In fact, the internal surface abrasion of all plastic piping progresses very slowly. It can be guaranteed that abrasion wear at normal speeds is insignificant and that, because of this, piping duration is practically unlimited.

Joint sealing

A fundamental requirement nowadays is that a sewage system does not have any leaks that could lead to environmental contamination. Furthermore, subsoil water must not be allowed to infiltrate the piping because if this is significant, it would increase energy consumption and purification costs in general and may even affect normal network and purification plant operation. All this means that excellent piping sealing is required, especially where joints, connections and manholes etc. are concerned, which are the critical aspects for compliance with this basic requirement.

ABvaKHAK PVC-U® piping is made employing the elastomer joint and does not require any welding which will decrease the time needed for installation. It also eliminates welding difficulties e.g. misalignment, cracks in welding and lack of penetration.



Diameter rating	Standardised maximum angle	Abvakhak piping maximum angle
160	6°	9°
200	5°	7°
250	4°	6°
315	3°	5°
400	1°	3°
500	1°	3°

MAXIMUM ANGULAR JOINT DEVIATION BETWEEN PIPES.

Welding process also generates weld beads both inside and outside the pipe which makes non-level pipes inside and leads to later blockages.

In the **ABvaKHAK PVC-U®** piping, this joint is bi-lobed up to diameter DN500, with a profile that, on the one hand, prevents joint movement during piping installation and, on the other ensures greater sealing.

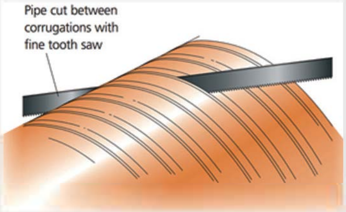
ABvaKHAK PVC-U® twin-wall corrugated pipe gasketed joints have consistently out-performed those of traditional pipe products in actual service. They are simple and easy to assemble and can be filled, tested, and placed in service immediately after assembly.

In this respect, prefabricated union systems based on elastic joints, in which the sealing is guaranteed by the manufacturer's quality assurance, are especially recommended in comparison with onsite executed joints that require very strict controls making them very .difficult to achieve in practice

In ABvaKHAK PVC-U® piping sealing is greater than in any other pipes, this because of flexible piping deformation collaborating in better elastic joint sealing.

Lastly, it is mentioned that, in addition to piping, there are other elements in the network where water infiltrations may occur, with the most obvious one being inspection manholes. These infiltrations are produced when the sewage installation is below the groundwater level.

Consequently, the sealing requirements must be extended to all network elements, especially where groundwater is concerned and even more so in inspection manholes, where collector and mains supply connections are frequent sources of leaks and water entry.



Field modifications with PVC-U are quick and easy. The annular (vs. spiral) corrugated exterior creates a cutting "guide" to provide even, square pipe cuts every time. PVC-U can be easily cut with a hand or power saw. No spigot end chamfering or beveling is required. No gaskets are wasted because they are easily removed and attached on the pipe spigot

Comparison of three main plastic pipes (PVC, PE, PP)

Three main plastic pipes have mutual characteristics which have made them suitable to be employed in water and wastewater systems. In other hand there are some dissimilarities made each type to meet specific requirements.

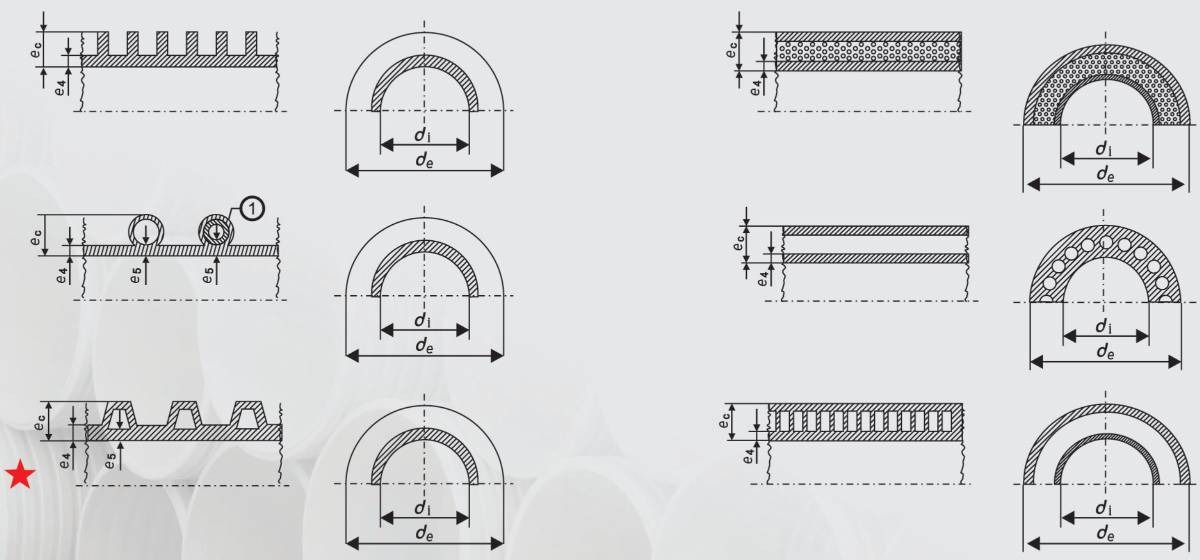
It should be mentioned that sewage piping, usually buried and supporting traffic loads which requires high rigidity, but it should also possess certain flexibility to transmit forces to the trench fill-in material and to absorb possible settling of both ground and pipe.

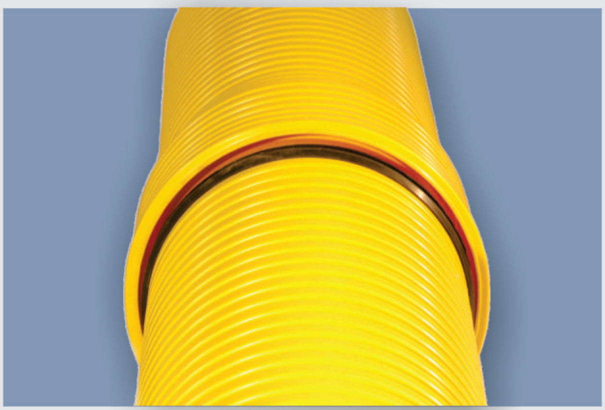
Due to wall thickness, high pressure water pipes can undergo external loads once buried while in sewage or low-pressure water systems the absence of internal pressure eliminates the need for additional thickness instead requires higher stability under external loads.

High wall thickness of pressure pipes will make higher costs and therefore most well-known European companies started to redesign pipes' wall structures which can support higher external loads while eliminating useless extra wall thickness.

There are different double-wall pipe structures which each one designed to have maximum stability under external loads while decreasing project costs.

Among different structures, consulting engineers have selected the most effective design in low-pressure and or gravity flow water and sewage system which is currently has the highest consumption in mentioned systems (★)

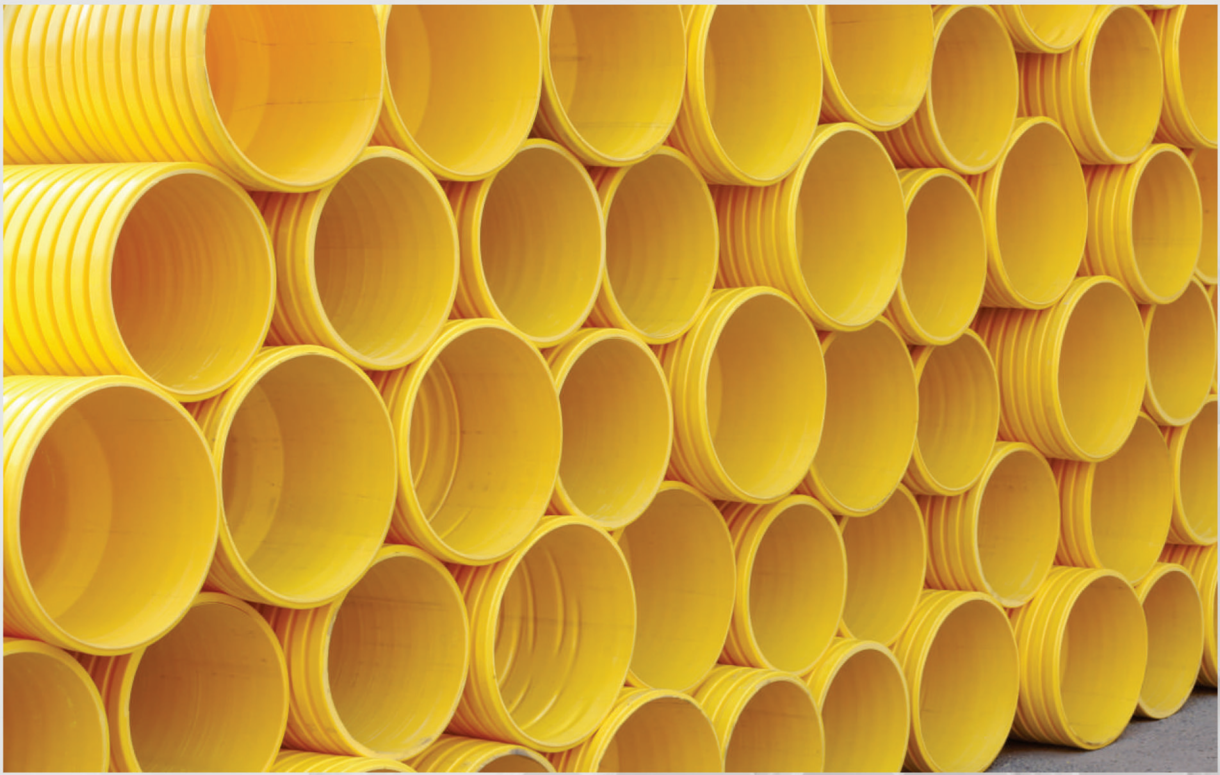




Performance and installation costs
Safety during installation

In general, plastic piping is very light and, in the case of the structured type, even more so. This characteristic leads to very low handling and installation costs because significant savings are obtained in the machinery and personnel required during installation.

In addition to the above, the weight also significantly increases works performance, which reduces deadlines and therefore fixed costs that can be a determining factor for project economic feasibility.



Lastly, but no less important, another basic advantage of piping lightness is the increased safety for installation personnel. For deep piping that requires trench wall shoring, the less time spent in the trench means increased works safety.

Piping flexibility

Frequently, network piping is subject to forces and deformation produced by differential soil settling, which must not cause any fracturing or leaks. This requires piping flexibility that enables it to adapt to deformation and minimizing local forces that are produced. Plastic piping with elastic joints adapts to settling and easily absorbs the produced stresses, whereas in a rigid-element system, which is incapable of adapting to the same deformation, enormous forces appear that can cause fracture and subsequent leaks.

PVC is a polar polymer with strong intermolecular forces, therefore in room temperature it comes in a molded form. On the other hand, when plasticizer is added upon fabrication, flexible PVC products are obtainable. This is a major advantage of PVC. PVC products without any plasticizers are called

rigid PVC products, while PVC products that include plasticizers are called flexible PVC products. The softness of the flexible PVC products is obtained as a result of plasticizers coming between molecules to separate them, reducing intermolecular forces.

ABvaKHAK PVC-U® pipe is designed and manufactured specifically for gravity sewer applications based on special formula supporting both rigidity and flexibility characteristics.

Energy consumption

According to a study (*) carried out by the Environmental Modelling Laboratory belonging to the Engineering Project Department at the Catalonian Poly-technical University, the energy consumption and

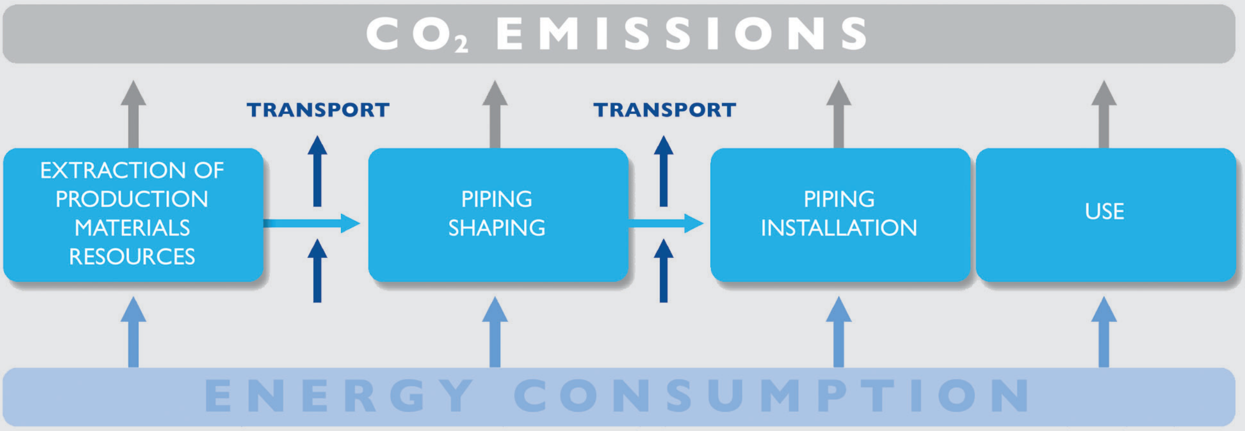
CO2 emission into the atmosphere throughout the life cycle of these products, are very low when comparedto reinforced concrete piping.

(*) "Energy consumption and CO2 emission estimates associated with the production, use and final arrangement of PVC, PEHD, PP, cast iron and concrete piping" (December.2005). Authors: Dr. José María Baldasano Recio, Dr. Pedro Jiménez Guerrero, María Gonçalves Ageitos and Dr. René Parra Narváez.

This life cycle contemplates all product stages during its useful life-time:

- Extraction of raw material for manufacturing the piping.
- Transporting the raw material to the production plant.
- Piping manufacture.
- Transporting the piping to the installation worksite.
- Piping installation.
- Piping usage: maintenance and repair jobs.

(*) "Energy consumption and CO_2 emissionestimates associated with the production, use and final arrangement of PVC,PEHD,PP,cast iron and concrete piping (December.2005). Authors: Dr.Jose Mana Baldasano Recio, Dr.Pedro Jimenez Guerrero,Maria Goncalves Agetos and Dr.Rene Parra Narvez.



LIFE CYCLE SCHEMATIC FOR BURIED PIPING (WITHOUT RECYCLING STAGE).

Sewage piping - Energy consumption and CO_2 emission for three metres of piping

	Energy consumption (kW/h)	CO_2 emission (kg de CO_2)
SN8 corrugated PVC (0% recycled) DN315	121.3	36.1
SN8 corrugated PE (0% recycled) DN400	211.0	58.6
SN8 corrugated PP (0% recycled) DN400	191.0	61.5
DN400 concrete	345.0	129.4

The findings of this study are summarized in the above table. As can be seen, the plastic material values are lower than those for concrete because of the lower weight and raw material content of the former with respect to the latter. This difference is much higher if recycled plastic materials are used.

This deformation is a percentage of the piping diameter and is a direct function of the vertical loads, Qvt, that are opposed by two factors:

- Es = surrounding soil modulus of elasticity that depends on the trench, fill-in type and compaction with is installation quality.
- RCE = piping specific circumferential rigidity, defined as:

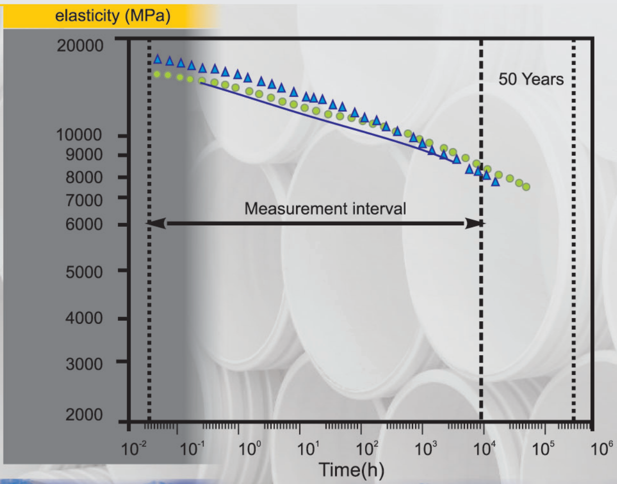
$$RCE = \frac{E_c.I}{D_m{}^3}$$

where:

- Ec = piping material modulus of elasticity.
- I = moment of inertia per unit length, which depends on piping thickness.
- Dm = piping mean diameter

The deformation formula shows that if the soil component is sufficiently high (Es high value), the piping rigidity does not require high values. If, on the other hand, the soil modulus of elasticity Es is not sufficiently high, piping deformation will largely depend on its own rigidity.

However, when using plastic piping, the more standard technical documentation, limit plastic piping deformation to 5% its diameter over fifty years. This time limit is linked to the known characteristic of plastic materials and of polymers in general, to undergo modulus of elasticity losses over time when such elements are subject to mechanical stresses. This loss is called "creep" and is due to deformation of the polymer macromolecules and is very strong at the beginning, but falls over time and is asymptotic for the fifty-year horizon. Creep is usually represented as



Maximum short and long-term rigidity

As previously seen, plastic piping flexibility is a significant factor in adapting to soil settlement. However, this has to be balanced by the even more important requirement for the piping to have sufficient short and long-term rigidity and be able to withstand all external loads throughout its useful lifetime.

Such loads not only affect the piping, but also the surrounding soil so that correct installation is essential.

However, can the installation be adequately controlled?

Usually, it cannot. Nevertheless, piping quality is easily ensured because its specifications, such as rigidity, are subject to standardized tests.

In practice, depending on surrounding soil conditions, the capacity to withstand external loads will have greater or lesser relevance. To a large extent, these conditions will depend on how the installation was carried out, namely trench dimensions, fill-in type and compaction.

The above may be quantified using the buried piping deformation formula:

$$\frac{\Delta Y}{D} = \frac{K_1.Q_{vt}}{K_2.E_s + K_3.RCE}$$

When piping has to withstand interior pressure, the corresponding product standards require that the piping be able to withstand the expected working pressure for fifty years after being put into operation. The manufacturers have to design piping to initially withstand pressures that are much higher than required so that they maintain the expected pressures in the long term.

In non-pressurized buried piping, the operating loads are due to external factors only, such as the weight of the overlying soil, dynamic vehicle traffic forces and the static forces of any surface loads etc. As previously seen, the forces of such loads are opposed by the various resistant values in the soil and piping rigidity.

If it is expected that soil conditions will not be sufficiently good to attain high Es values, or it is not possible to guarantee correct installation, then it will be necessary to guarantee a sufficiently high initial piping rigidity RCE0 so that the long-term rigidity RCE50 is maintained at acceptable values.

Cf = Ep0 / Ept

$$Cf=Ep_0/Ep_t$$

In other words, as the ration of the modulus of elasticity p and the modulus of the same plastic p after time t. The creep coefficient for time t that is considered (two or fifty years etc.) will determine the initial plastic piping rigidity value. As will be seen later, the creep coefficients may vary greatly depending on the plastic type under consideration.

Taking into account the significance of these concepts because of their influence on plastic piping durability, it will be shown how to optimize piping type selection from among the usual options. This defines the initial moduli of elasticity for the three considered materials according to the following values:

- PVC-U (non-plastified PVC):

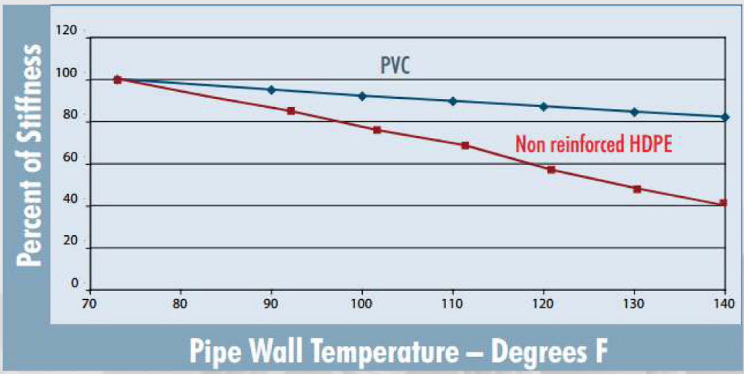
E0 = 3,600 MPa

- PEAD (high-density polyethylene):

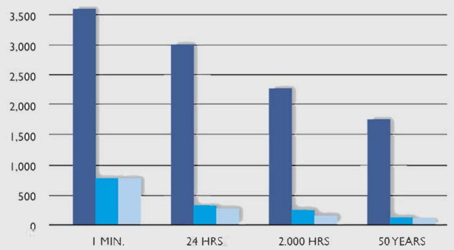
E0 = 800 MPa

- PP (polypropylene copolymer block

E0 = 800 MPa

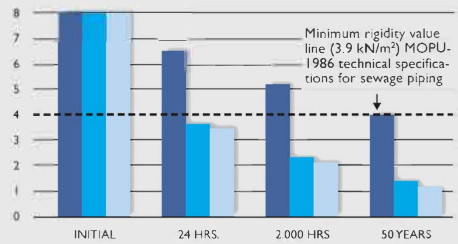


If these values are entered into the previous rigidity formula, it is clear that in order to achieve a certain initial rigidity, corrugated PE and PP piping must have their moment of inertia I and therefore thickness considerably increased in relation to PVC piping since the latter has a much higher E0 value.
Moreover, due to creep effects, the mentioned standard defines a series of decreasing modulus of elasticity values over time for each material when the piping is subject to forces, as in the case of piping buried under vehicle traffic. The first of the two graphs shows the fall in modulus Et and the second, starting with SN8 piping, the corresponding fall in rigidity by the same proportion since the I and Dm values remain invariable over time in the formula for the latter.



	1 MIN.	24 HRS	2.000 HRS	50 YEARS
PVC	3,600	3,000	2,350	2,350
PE	800	800	250	250
PP	800	360	210	120

COMPARISON OF THE MODULES OF ELASTICITY OVER TIME ACCORDING TO DIN 16961.



	INITIAL	24 HRS.	2.000 HRS	50 YEARS
PVC SN8	8.0	2.3	8.0	8.0
PE SN8	8.0	3.8	2.3	2.3
PP SN8	8.0	3.6	2.1	1.2

DEVELOPMENT OF RIGIDITY RCE = (ExI)D_m^3 OVER TIME ACCORDING TO DIN 16961.

The Et values are employed to provide the creep coefficients for the three considered materials. So, for the E50 values at fifty years:

- CPVC 50 = 2.06
- CPE 50 = 5.33
- CPP 50 =6.67

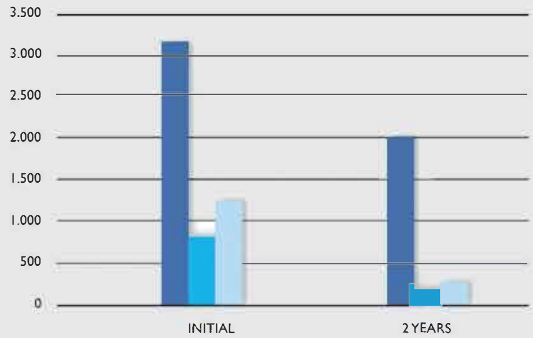
These same coefficients are those corresponding to the rigidity losses if the loads applied to the piping were of the order of magnitude contemplated in this standard. In SN8 PVC piping, which includes ABvaKHAK PVC-U ® piping, the rigidity fall at fifty years is half the initial value because the original design sought rigidity of 3.9 kN/m2 at fifty years, which coincided with the initial value marked by the MOPU-1986 technical specifications for sewage piping.
With the same requirements as PE and PP piping, the designs for this piping would have included minimum initial rigidities of 21 kN/m2 and 26 kN/m2, respectively.
It is quite clear that the SN8 rigidity is totally insufficient when the piping installation is not correctly executed, which is why the use of such piping in sewage networks produced significant general piping ovalisation. Despite this, low prices mean its use is widely extended. Low prices are due to this piping being very light with very low raw material costs.

The European UNE-EN 13476 from 2008:

Plastic piping systems for sewage and non-pressurized underground sewage - Structured wall piping systems of non-plasticized polyvinyl chloride (PVCU), polypropylene (PP) and polyethylene (PE).
This standard, the most recent, defines maximum creep coefficients at two years and initial moduli of elasticity for the three considered materials, which are:

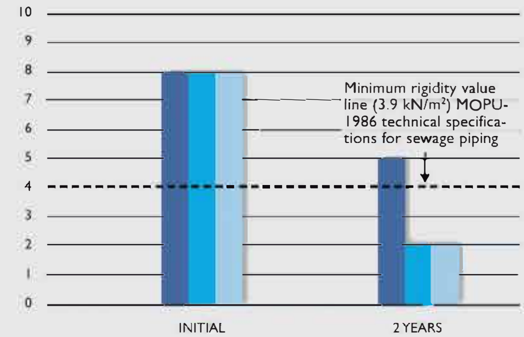
- CfPVC ≤ 2.5 E0, PVC = 3,200 MPa
- CfPE ≤ 4 E0, PE = 800 MPa
- CfPP ≤ 4 E0, PP = 1,250 MPa

This standard only contemplates coefficients at two years because, after this period, rigidity falls are now small and this facilitates the creep test which, for two years, requires an accelerated test of only two months (the fifty-year test requires fourteen months).
Furthermore, some of the initial moduli of elasticity defined by this standard varied because certain additives were employed to guarantee higher quality of the materials used in these piping types.



	INITIAL	2 YEARS
PVC Sanecor	3.200	2.000
PE	800	200
PP	1.250	312

MODULES OF ELASTICITY OVER TIME ACCORDING TO UNE-EN 13476.



	INITIAL	2 YEARS
PVC SN8 Sanecor	8.0	5.0
PE SN8	8.0	2.0
PP SN8	8.0	2.0

RIGIDITY DEVELOPMENT OVER TIME ACCORDING TO UNE-EN 13476.

In this case it can be seen that after two years of being buried, piping under loads that produce modulus of elasticity losses of the considered magnitudes, the ABvaKHAK PVC-U ® piping still has a rigidity of some 5 kN/m2, while the PE and PP corrugated piping maintains a value of only 2 kN/m2, which is insufficient to prevent significant deformation in this time period.

The above allows the conclusion that ABvaKHAK PVC-U ® SN8 PVC piping is among the habitual, cost-competitive piping types that has the best short and long-term performance regarding external loads.

Maximum hydraulic capacity

The hydraulic capacity of a gravity-red sewage pipeline is determined by two factors, the friction coefficient between the water and the piping and the piping inside diameter. As already stated, the friction coefficient in plastic piping is K = 0.10 in the Prandtl-Colebrook formula for waste water, which is ten times lower than that for concrete piping.

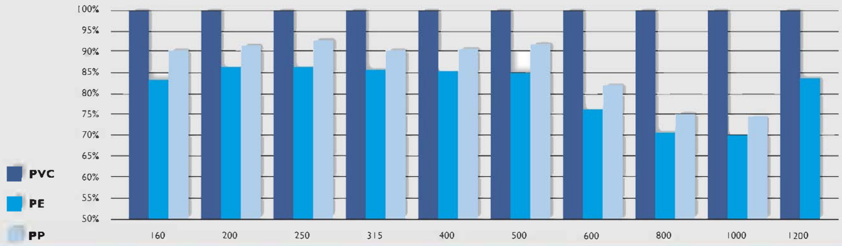
Regarding the inside diameter, most plastic piping follows the criterion DN = Dexterior, so that the inside diameter depends on piping thickness and the manufacturer. This provides different flow rates, given the same slope and internal rugosity for the same diameter rating. ABvaKHAK PVC-U ® piping follows this criterion only to diameter DN 500 for the necessity that all piping must be compatible with the standard fittings and accessories on the market.

Furthermore, for a specific piping (RCE) rigidity, the thickness depends on the corresponding material type which, on having a determined modulus of elasticity Ec requires a moment of inertia value of I in the formula:

$$RCE = \frac{E_c . I}{D_{m3}}$$

Since I is a function of thickness (in plain piping $I = 1/12\ e^3$), in PE and PP corrugated piping (small Ec value), the thickness will have to be higher than for corrugated PVC-U (high Ec) in order to achieve the same rigidity. Therefore, in ABvaKHAK PVC-U ® piping, the hydraulic capacity is always greater than in other thermoplastic materials.

The following graph shows percentages of means flow rates at full section corresponding to the various materials employed in corrugated piping for the same slope values (1.5%) and internal rugosity (k=0.10).



DIFFERENCES IN MEAN FLOW RATE AS PERCENTAGE OF SN8 CORRUGATED PIPING (BASE 100% FOR A8VAKHAK SHAHRA8 GOSTAR PIPING).

ABvaKHAK PVC-U®, the most sustainable solution

A product is sustainable when it satisfies the requirements of current generations without compromising the possibilities of future ones to take care of their own needs. Along these lines, it is important for the product to have a long life cycle, to be long-lasting, but, at the same time, resource consumption during this lifetime must be a minimum, as should be its social and environmental impacts.
In the case of ABvaKHAK PVC-U ® sewage piping, the previous points contain a series of characteristics that contribute to product sustainability.

The following table summarizes the repercussions of the properties of this product on the factors contributing to greater sustainability.

CHARACTERISTIC	DURABILITY	ENERGY SAVING	ENVIRONMENTAL RESPECT
Raw material	-	↑	↑
Piping weight	-	↑	-
Material recyclability	-	↑	↑
Chemical resistance	↑	-	↑
Lack of corrosion	↑	-	↑
Abrasion resistance	↑	-	-
Deposits/Incrustation	↑	-	↑
Long-term rigidity	↑	-	-
Material flexibility	↑	-	-
Hydraulic capacity	-	↑	-
Installation costs	-	↑	-
Workplace safety	-	-	↑
Sealing	-	↑	↑
Maintenance costs	-	↑	-

PROPERTIES OF ABVAKHAK SHAHRAB PIPING THAT INCREASE PRODUCT SUSTAINABILITY.

piping range dimensions (ABVAKHAK SHAHRAB)

DN	PIPING INSIDE DIAMETER	PIPING OUTSIDE DIAMETER	MAXIMUM OUTSIDE CUP DIAMETER	MEAN MOUTH LENGTH
160	146	160	182	105
200	182	200	228	122
250	228	250	284	165
315	285	315	358	190
400	364	400	448	199
500	452	500	563	230

Thus, special fittings are manufactured in all diameters with the same material, being plain fittings of SN4

Maximum versatility in the ABvaKHAK PVC-U® system

ABvaKHAK PVC-U® piping possesses one of the widest ranges in plastic sewage piping. The table below contains the main dimensions of the various diameters.

ABvaKHAK PVC-U® is manufactured according to BS EN 13476-3 :2007 to ensure joint performance and system compatibility and to fulfill general and specific requirements for pips, fittings and the system based on unplasticized poly (vinyl chloride) (PVC-U) structured –wall piping system that are to be used for non-pressure underground drainage and sewerage systems.

ABvaKHAK PVC-U® PIPING TECHNICAL SHEET

The following table summarizes the technical specifications for ABvaKHAK PVC-U® piping.

PHYSICAL AND CHEMICAL FEATURES	
Density	1,350 ÷ 1,520 kg/m^3
Linear dilation coefficient	8 x 10^{-5} m/m. °C
Thermal conductivity	0.13 kcal/m.h. °C
Specific heat	0.2 ÷ 0.3 cal/g.°C
Vicat softening temperature	≥ 79 °C, according to UNE-EN 727:1997
pH limits	Between 3 and 9 at 20 °C
Dichloromethane resistance	At 15 °C, during 30 min, according to UNE-EN 580:2003
Oven test	According to ISO 12091:1995

MECHANICAL FEATURES	
Annular Rigidity (also called SCR = Specific Circumferential Rigidity)	RCE ≥ 8 kN/m^2, according to UNE-EN ISO 9969:2008
Creep coefficient at 2 years	≤ 2.5, according to UNE-EN ISO 9967:2008 The actual value varies between 1.6 and 1.8
Impact strength	According to UNE-EN 744:1996 (Clock sphere method)
Annular flexibility	30% deformation in DN160 to D315 and 20% in DN400 à DN1200, according to UNE-EN ISO 13968:2009

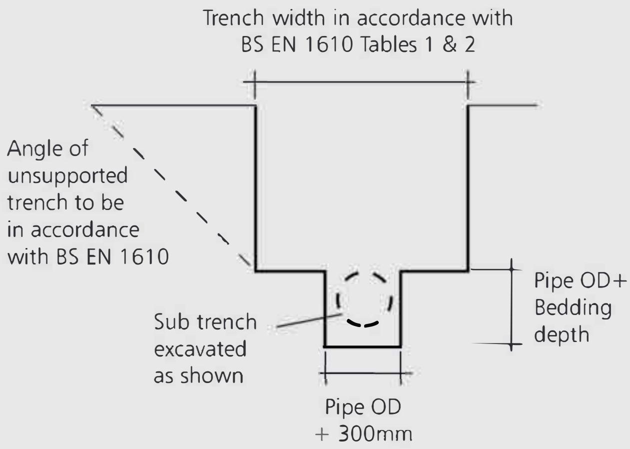
HYDRAULIC SPECIFICATIONS	
Sealing with internally pressurised elastomer joint	Tests at 0.05 MPa with angular deviation and diametral deflection, according to UNE-EN1277:2004
Sealing with joint in internal depression	Tests at -0.03 MPa with angular deviation and diametral deflection, according to UNE-EN1277:2004
Equivalent rugosity (Prandtl-Colebrook)	K= 0.01 mm (for clean water) K= 0.10 ÷ 0,25 mm (for waste water)

Installation data: Pipe laying

The following information is based on the recommendations in BS 5955: Part 6 and BS EN 1610 (Construction and testing of drains and sewers)

Excavation

Trenches should not be open for extended periods in advance of pipe laying and should be backfilled as soon as possible. It is essential that the sides of the trench are adequately supported during pipe laying. Trench widths should be as narrow as is practicable but not less than the pipe diameter plus 300mm to allow adequate sidefill to be placed. Deeper excavations should ideally incorporate a sub-trench in accordance with the diagram opposite.



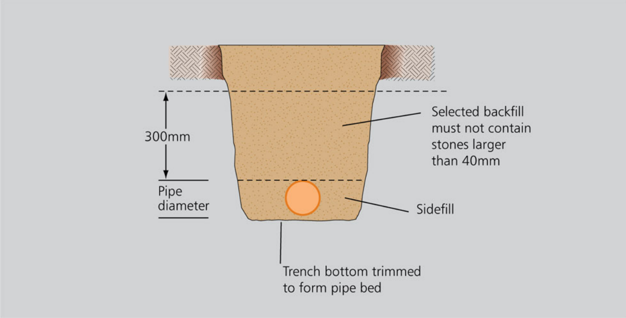
Granular material for bed & surround of PVCu drains and sewers

Suitable imported granular material for bedding and surrounding PVC-U twin wall corrugated pipe for private and adoptable sewer applications is detailed in the table right: Grading complying with the requirements of BS EN 1610. Granular material also includes aggregates for concrete to BS EN 12620.

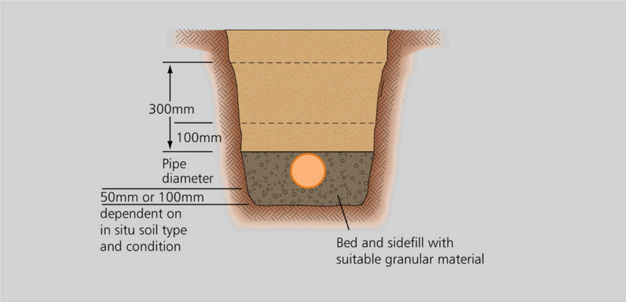
Nominal pipe size	Granular material size
100/110mm	10mm nominal single-size 14 to 5mm course graded
150/160mm	10 or 14mm nominal single-size 14 to 5mm course graded
150/225mm and over	10,14 or 20mm nominal single-size 14 or 20 to 5mm course graded

Bedding & backfill

Where the as-dug material is suitable*, the bottom of the trench may be trimmed to form the pipe bed and the as-dug soil used as sidefill and backfill in accordance with BS EN 1610 bedding construction type B (see drawing opposite).
*Suitable material is defined as material in accordance with the recommendations of BS 5955: Part 6: 1980 Appendix A, having a maximum particle size not exceeding 20mm.

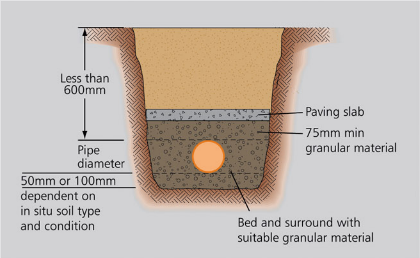


Where the as-dug material is unsuitable as bed and surround installation should be carried out in accordance with BS EN 1610 bedding construction type 1, as shown opposite. Trenches should be excavated to allow for the depth of bedding material.



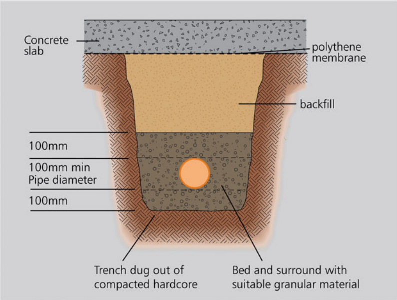
Before any pipework is installed the bedding material should be laid evenly along the bottom of the trench. The sidefill material must be the same as the bedding material and extended to the crown of the pipe and be thoroughly compacted. Where the backfill above the pipe contains stones larger than 40mm or where the pipework is deeper than 2m in poor ground, the granular material must extend at least 100mm above the pipe crown. Alternatively, backfill material can be graded to eliminate stones exceeding 40mm and this selected material used for the first 300mm above the pipe.
When the pipes are to be laid in rock, compacted sand or gravel, or in very soft or wet ground requiring mechanical means of trimming, the bedding should be a minimum of 100mm.

Installation data: Pipe laying



Shallow domestic drains

Pipes laid at depths less than 600mm and which are not under a road should, where necessary, be protected against damage by placing over them a layer of concrete, paving slabs or similar. A minimum 75mm cushioning layer of granular material must be laid between pipes and the slabs or concrete. Where drains are laid in fields, additional protection may be required from heavy vehicles and equipment. It is recommended that the installation is carried out with a concrete slab spanning the trench as shown for drains under private roads (right).



Drains under solid ground floors

Drains often have to be laid under buildings in order to connec t sanitary pipework which has been positioned some distance from the outer walls. Where this occurs, deep hardcore within the foundation boundaries should be compacted first. The trench for the pipe should then be excavated and suitable material employed for the bedding and backfilling operation. If trenches are dug from original ground, pipes may be laid and surrounded as necessary before the top layer of hardcore is formed. Where a pipe passes through a wall or foundation of a building, a lintel or sleeve should be built-in to provide clearance around the pipe