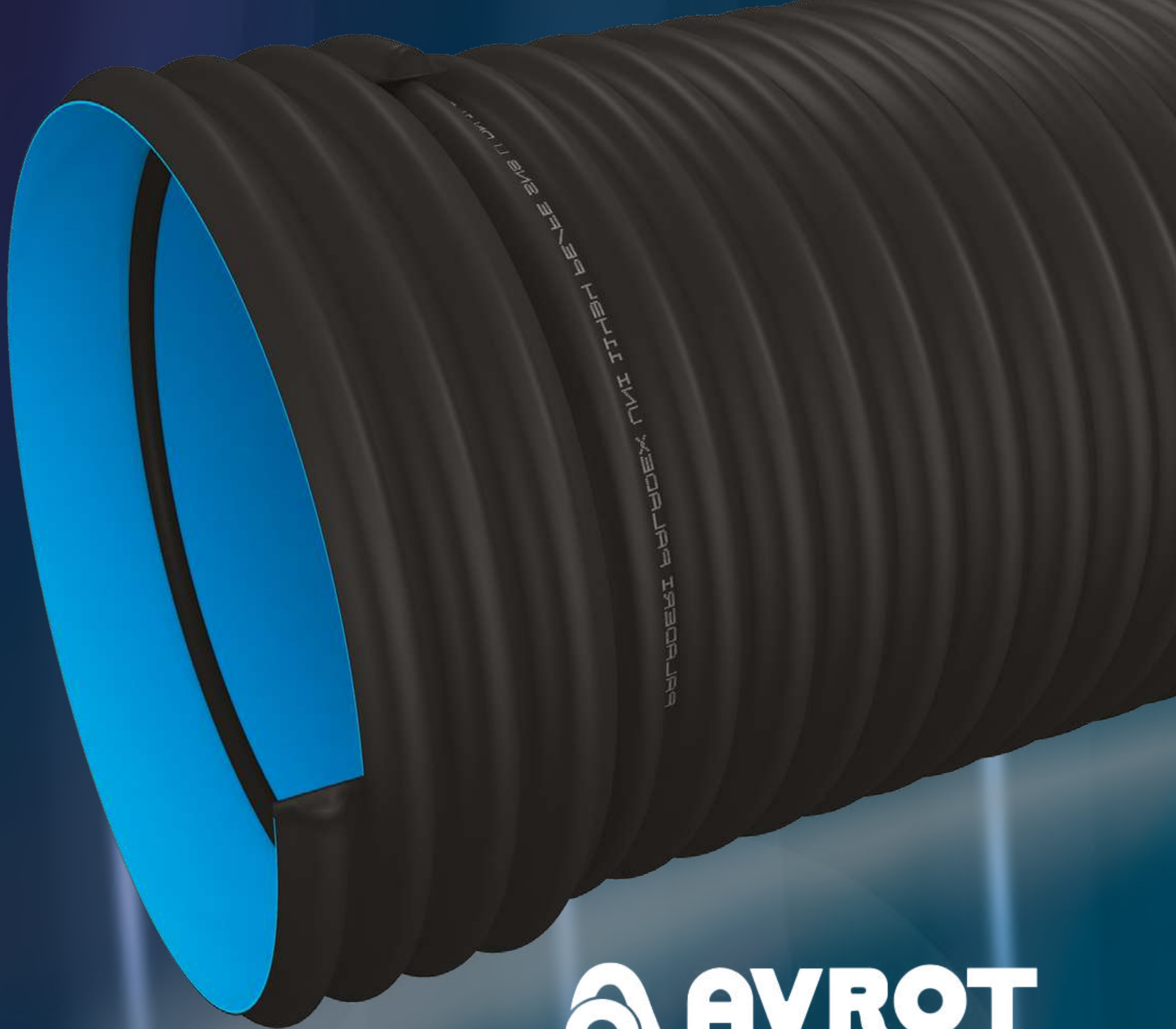
Drainage and Sewage Piping



AVROT INDUSTRIES LTD.

Paladu Paladex

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About the Company

Avrot is committed to innovation, product development, and cutting-edge technologies.

Paladex part of the **Avrot Industries Group** is a trailblazer in the field of piping systems for drainage, stormwater management, and sewerage applications. The company manufactures and markets a unique line of pipes offering numerous advantages.

Over the years, **Paladex** has developed reliable solutions to meet a wide range of needs for planners and installation contractors in both the local and international markets, including:

- HDPE piping with steel-reinforced structural walls, structural PP piping with a helically wound design, and perforated and slotted **Casaflex** piping for drainage
- Piping systems with ring stiffness ratings of SN8, SN12 and SN16 including complete system solutions with manholes and connections to concrete and plastic manholes
- Production of both standard and custom-designed fittings

Standards and Certifications

Avrot's Quality Management System is certified and supervised by the Standards Institution of Israel (SII) and complies with ISO 9001:2015. All piping products conform to applicable standards and are approved by certification bodies in both Israel and Europe.

This technical specification is intended for planners, project managers, inspectors and contractors. It describes the product and calculation methods for the correct use of Paladex piping.

General Characteristics

1. General Characteristics

1.1 Gravity Flow Systems

In recent decades, there has been a trend of constant increase in the market share of plastic piping infrastructure compared to rigid piping. Corrugated plastic piping offers unique advantages that make it the preferred choice for drainage, stormwater management, and sewerage purposes.
The following are key characteristics of importance to planners and end users.

The main requirements for gravity piping systems include:

- Complete sealing at the joints.
- Short and long-term hydraulic properties.
- Resistance to internal hydrostatic pressure during temporary pressure increases.
- Resistance to external environmental pressures (soil loads and dynamic loads).
- Resistance to external pressure in the presence of groundwater.
- Chemical resistance.
- Abrasion resistance.
- Ease of cleaning.
- Quick and simple placement and installation.
- Competitive price.

1. General Characteristics

Paladex Piping vs. Rigid Piping

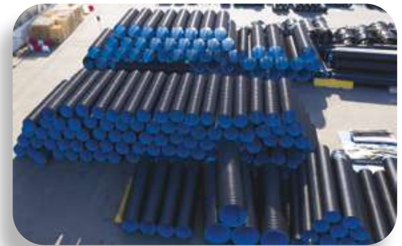
When dealing with gravity piping systems, it is important to distinguish between rigid pipes and flexible pipes (such as **Paladex**.)
A rigid pipe with a circular cross-section cannot accommodate horizontal or vertical pipe deformation.

Any deformation in a rigid pipe may cause damage, whereas **Paladex** pipes feature a structural wall that can withstand significantly greater deformation — both short-term and long-term — without compromising the pipe's hydraulic or mechanical properties. The key characteristic of **Paladex** piping is its ring stiffness (SN), which depends on both the pipe profile (moment of inertia) and the material properties (modulus of elasticity.)

Paladex Pipe Applications

Paladex piping is designed for gravity-based stormwater and wastewater drainage under atmospheric pressure conditions, and is used in a wide range of applications, including:

- Road, highway and culvert drainage
- Conveyance of domestic and industrial wastewater
- Urban and agricultural surface drainage and stormwater systems
- Conveyance of seawater and brine
- Conveyance of chemically reactive wastewater
- **Casaflex** perforated infiltration pipes
- "Protective well radius" systems



Paladex piping is backed by many years of experience.
Thousands of kilometers of **Paladex** pipes have been successfully installed in a wide range of projects in Israel and around the world.

1. General Characteristics

Paladex Pipe An Eco-Friendly Product That Protects the Environment

The **Paladex** pipe introduces green technology to Israel's water and infrastructure sector.

The mechanical strength of steel with the advantages of polyethylene

- **Complete sealing** - preserves water resources and protects groundwater from leakage.
- **High chemical resistance** across a wide range of temperatures and pH ranges.
- **High resistance to biological hazards** (bacterial build-up, root intrusion, rodents)
- **Pipe length** - available in lengths of 6, 7 or 12 m.
- **Cost-effective production process** in terms of energy and raw material consumption.
- Zero environmental pollution.
- **Does not release toxic substances** during production regular use.
- **Very lightweight** - fieldwork can be performed without heavy machinery.
- Nesting capability allows **efficient transport and significant savings in logistics**.
- Made from **100% polypropylene**.
- **High ring stiffness** SN8, SN12, SN16.

1.2 Water Reservoirs

The tanks are based on **Paladex** piping and are exported in any volume required by the customer.
The tanks are installed underground, saving valuable surface area. The tanks are available in diameters ranging from 1 meter to 2.5 meters. Design and construction are carried out according to the planner's specification and in coordination with **Avrot**'s engineering department. The tanks are characterized by ease of assembly and design flexibility, and the system is sealed and pressure-tested at 0.75 bar hydrostatic pressure.

Stormwater Retention Tanks

- **Paladex** tanks are used for storing liquids and solids with high resistance to chemicals.
- Regulate water flow into municipal infrastructure by temporarily storing stormwater and releasing it into the systems gradually, over time.
- **Paladex** tanks are suitable for underground installation, with a load capacity of 60 tons with minimal soil coverage.
- Produced in volumes ranging from 10 to 10,000 cubic meters; for larger capacities, clusters of individual tanks can be manufactured.
- The geometric structure and materials of the tanks provide resistance to soil movement.
- Stormwater tanks can be perforated or slotted to allow gradual infiltration of strormwater into the ground.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1.3 Paladex Conveyance Pipelines

Paladex large-diameter pipes are used to construct water conveyance lines, serving as an alternative to concrete conduits.

Paladex pipelines feature a Manning roughness coefficient of 0.009, compared to 0.12 for concrete, allowing for installation at shallower slopes – reducing excavation depth and enabling faster installation.

Relevant hydraulic calculations to support flow rate and velocity planning can be found in the technical appendices.

Advantages of using Paladex conveyance pipelines:

- Faster installation time.
- Shallower excavation depth.
- Pipe weight is significantly lower compared to concrete (approx. 1:30), eliminating the need for heavy mechanical equipment.
- Suitable for vibration-prone areas, such as near railways.
- Complete watertight sealing.
- It is recommended to install a sediment trap at the pipeline inlet to prevent large debris from entering.
- Easy connection to catch basins.

1.4 Pump Stations

Pump stations for sewage systems / lifting chambers are manufactured using **Paladex** piping (polyethylene pipes reinforced with steel, featuring a smooth interior and corrugated exterior), which gives the pump station high mechanical strength. The pump stations consist of multiple chambers installed side by side. These chambers are produced in diameters ranging from 1,800 mm to 3,000 mm, and typically include:

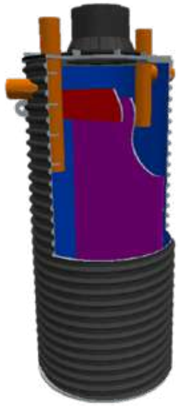
- Pump compartment
- Retention chamber
- Separation chamber

Advantages

- High mechanical strength
- Fully sealed – produced as a single unit
- Chemical resistance
- High resistance to ground movement
- Modular and flexible design
- Lightweight
- Smooth inner wall prevents buildup of debris

Pump Chamber

- The pump chamber is an integral sealed unit supplied with pump pipelines
- Inlet and outlet connections are welded
- Supplied with integral steps or a platform (for chambers taller than 5 meters, per standard) and a suction pipe for tanker connection
- Sloped bottom to prevent debris accumulation
- No height limitation for the wet area in the chamber



Retention chamber

- Retention chamber made of **Paladex** pipe in diameters ranging from 3,000 to 1,800 mm
- Supplied with integral steps
- Welded inlet and outlet connections ensure complete sealing

Separation chamber

- Used for grease separation – volume required by planner between 3,800 liters and 5,300 liters

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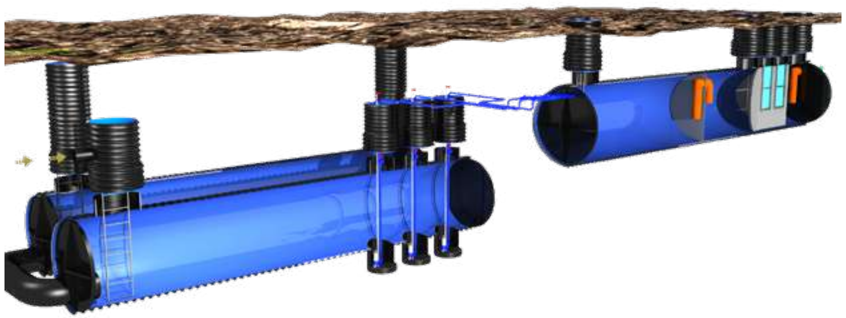
1.5 Sludge/Grease Separators

Sludge and grease separators prevent heavy or floating solids from entering sanitary or industrial wastewater systems.

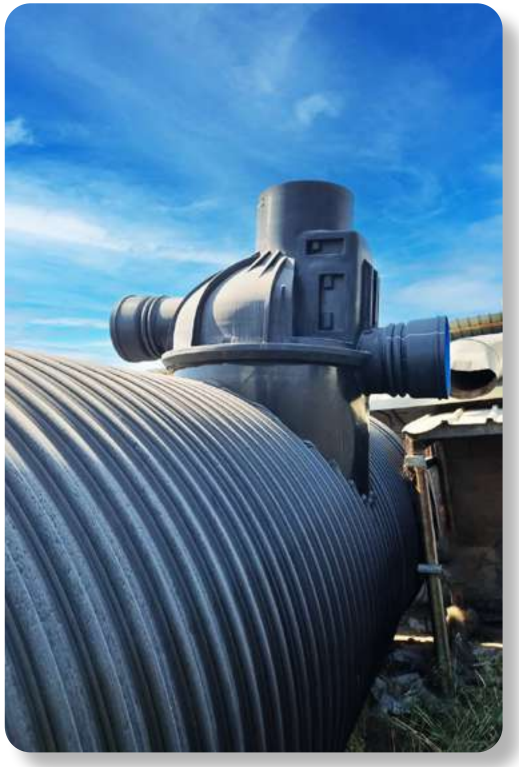
- Separators reduce damage to treatment systems by pre-filtering solids and preventing pump system shutdowns.
- The systems are designed for above-ground or underground installation and are available in capacities ranging from 5,000 to 50,000 liters.
- Sludge and grease removal is performed by pumping or mechanical collection.
- The separators are custom-designed and built according to site requirements and the planner’s instructions.
- The wall structure is engineered for high resistance to ground movement.
- Multi-chamber and dual-chamber designs are available upon request.



1.6 Integral Manholes

Paladex Integral Manholes

Integral trenches are a combination of **Paladex** piping (in the required diameter) with manholes in 630 mm or 1,000 mm diameters, with integrated steps.
The combination of low weight and high mechanical strength enables quick and easy installation.

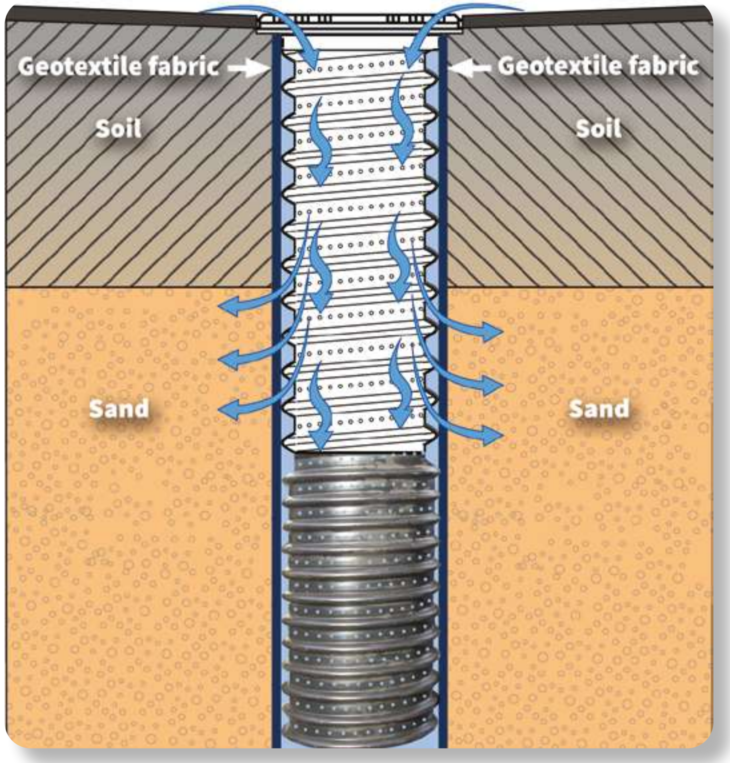


Advantages

The benefits of using this product include:

- Hydraulic advantage – continuous, uninterrupted flow. There is no break in the flow; thus, the Manning roughness coefficient of 0.09 is maintained.
- Watertightness – socket-and-spigot connection with hydraulic sealing gasket.
- Resistance to high loads.
- Allows for the construction of branches.
- Customizable angles available upon request.

1.7 Casaflex Perforated Drainage Pipe – Large Diameters



Corrugated perforated pipes available in diameters from 300 to 3,000 mm.

Perforation options:

- The entire circumference of the pipe
- Upper two-thirds of the pipe
- The perforation is made in the recessed (valley) portion of the pipe. The number of perforations according to design requirements.

Filter wrap options:

- Geotextile fabric filter
- Gravel (aggregate) filter
- The filter type is selected based on soil conditions.

Functions of the filter wrap:

- Prevents clogging of drain perforations
- Increases contact surface area with the pipe
- Provides mechanical protection for the pipe

Uses:

- Groundwater and stormwater drainage
- Drainage of agricultural areas
- Tunnel drainage
- Roadside drainage
- Drainage for infiltration pits
- Pipes are manufactured in lengths of 6 to 12 meters

1.8 Quality and Standards

Avrot has made product and manufacturing quality a core company value.
The **Avrot** plant and the **Paladex** pipe production line comply with all quality requirements under the ISO 9001:2015 standard.



The production line includes an internal quality assurance and control department that performs inspections in accordance with strict criteria defined by various standards, in addition to monitoring various parameters throughout the pipe manufacturing process.

SI 21138 – ISO 21138-3		(Israel)	SI 5302 (ASTM F2435)		(Israel)
UNI 11434	IIP	(Italy)	DT/380/0316	WRc	(England)

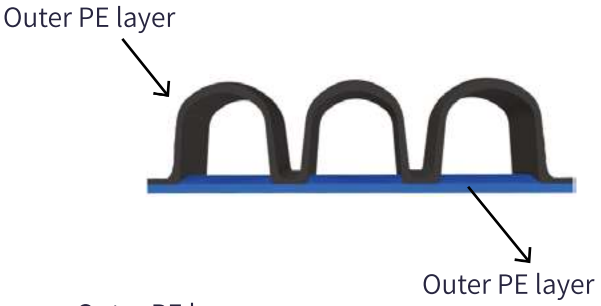
Materials and Structure

Pipe Structure

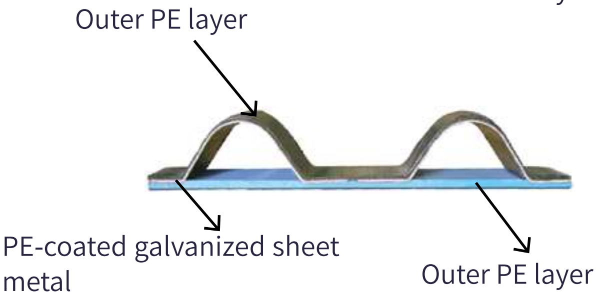
A spiral/corrugated pipe with a hollow structural wall is characterized by high structural strength and low weight. The pipe's design provides high ring stiffness relative to its weight. The structural wall forms a system of ribs and a pipe body (skeleton), where the ribs provide the pipe with both stiffness and flexibility.

- Outer polyethylene layer – Black, with full protection against UV radiation.
- Inner polyethylene layer – Light blue, allowing for clear and easy inspection (e.g., via camera) of the inside of the pipe.

Structural Wall Cross-section



Paladu



Paladex

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2. Materials and Structure

2.1 Paladu Pipe

The pipe is corrugated with a structural wall and includes a bell-end connection. It is made entirely of polyethylene and offers numerous advantages, such as: a high modulus of elasticity, which provides a high ring stiffness relative to its weight; resistance to extreme temperature ranges; high chemical resistance; and more. The pipe has an annular cross-section that allows for on-site cutting and length adjustment as needed.

2.2 Paladex Pipe

The pipe is manufactured from a combination of galvanized steel and polyethylene coating. It is spiral-wound with a hollow structural wall, characterized by high structural strength and low weight. The pipe consists of a continuous spiral of galvanized steel ribs, fully encased in a
dual-layer HDPE coating. The steel ribs provide rigidity and flexibility, while the polyethylene coating offers full protection against chemical and biological hazards, as well as corrosion development.

Paladex Pipe Components

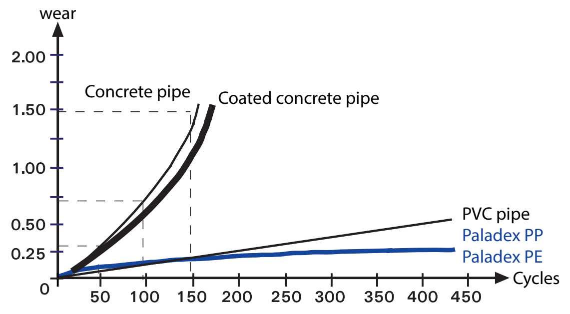
Polyethylene (HDPE) belongs to the group of thermoplastic materials, and is characterized by its light weight. Increasing the density of polyethylene enhances its mechanical strength, abrasion and scratch resistance, tensile strength, thermal resistance, elastic modulus, and chemical resistance. PE is one of the most widely used plastic materials, with over 60 million tons of polyethylene produced worldwide each year.

Galvanized steel strip – The steel in **Paladex** piping provides mechanical strength, the ability to withstand loads, and long-term resistance to creep. The zinc coating on the steel protects it against corrosion. The steel is embedded within the pipe and coated with two layers of polyethylene.

2. Materials and Structure

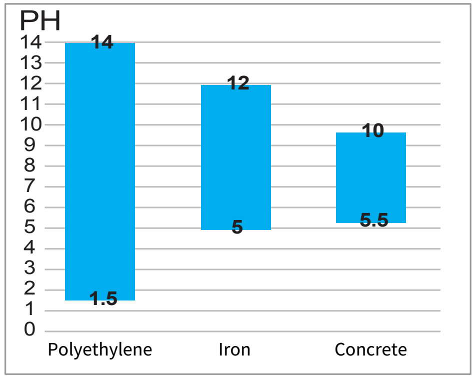
2.3 Abrasion Resistance

Abrasion in drainage and sewer pipes is caused by high flow velocities and the presence of abrasive materials such as sand and stones. Abrasion resistance depends on the material properties and the smoothness of the inner surface. Comparative abrasion tests for different types of piping are performed using the Darmstadt method, which measures abrasion depth versus abrasion cycles. **Paladex** piping is characterized by high abrasion resistance compared to any other pipe. The pipe is suitable for conveying drainage and wastewater at flow velocities exceeding approximately 10 m/s.



2.4 Chemical Resistance

Paladex piping is made from advanced plastic materials that are highly resistant to chemical aggression across a wide range of substances and operating conditions. **Paladex** piping can withstand extremely acidic and basic environments: pH 1.5-14.
List of substances to which **Paladex** piping is resistant is provided in the Appendices chapter.



2.5 Temperature Resistance

HDPE is resistant across a wide temperature range (min: -60˚c; max: -140˚c) and is therefore suitable for a wide variety of unique operating conditions in both civil and industrial applications. As a result of its high temperature resistance, the operating range of the **Paladex** piping exceeds that of any other flexible piping system.

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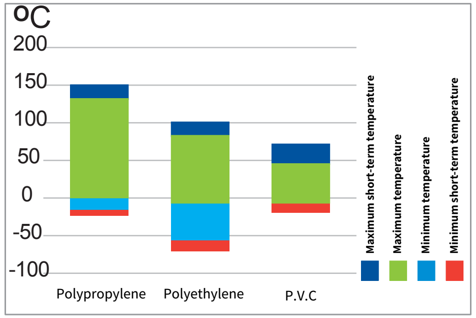

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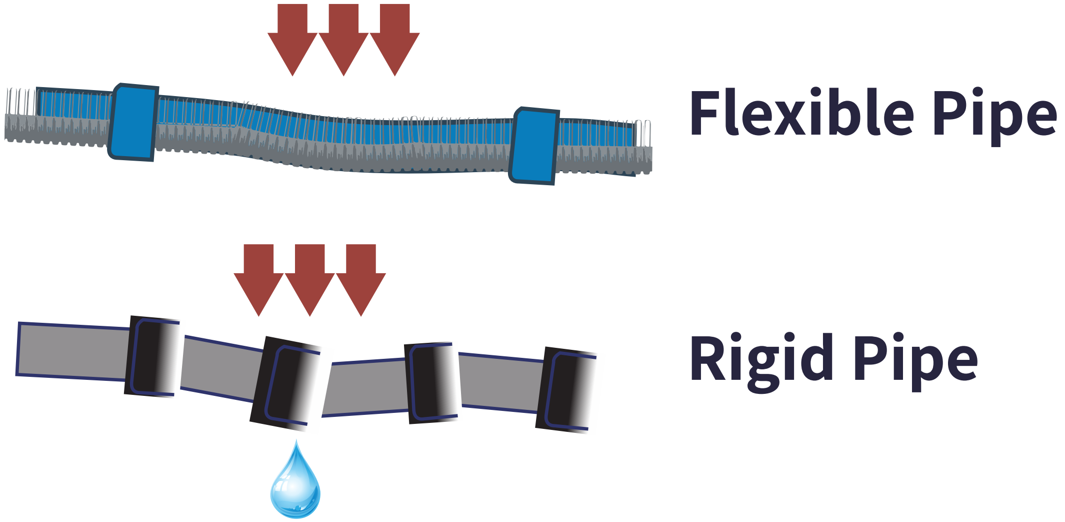
2.6 Flexibility

The ability of **Paladex** piping to avoid the development of cracks and fractures through deformation due to cyclic pressures—and to return to its original shape—is a key property for long-term durability under soil conditions. This capability makes **Paladex** piping the natural choice for long-term infrastructure planning. In addition to its ability to distribute soil loads, the flexibility of **Paladex** piping provides enhanced resistance to earthquakes and seasonal soil pressures.

Paladex pipes do not crack, thus preventing damage from root intrusion into the piping system.

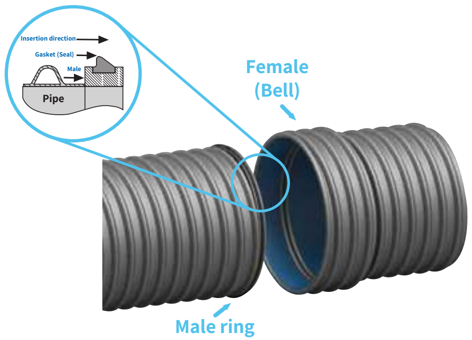


2.7 Paladex Pipe Dimensions and Connections

Paladex is manufactured in stiffness classes SN16, SN12, SN8, combining high mechanical strength with the benefits of polyethylene.

Socket-Spigot Connection Between Pipes
The seal of the connector is of great importance. The lighter the pipes, the easier and more durable the connection between them. **Paladex** piping has an advantage over rigid and heavy pipes, as its connection is based on a male-female joint with an external gasket.

Paladex pipe is produced with an integral bell (female) and a male ring over which an EPDM gasket is fitted. The method allows for quick and easy installation, and the connection is pressure-resistant to 0.7 bar, while maintaining sealing under diameter deformation of up to 5% and angular deflection of up to 1° in accordance with SI ISO 21138-3 / EN I 3476-3 / Israeli Standard 5302.



Nominal Diameter (mm)	**Outer Diameter** (mm)	**Outer Diameter of the Bell** (mm)
852	772	700
900	820	750
950	870	800
1034	972	900
1170	1090	1000
1220	1140	1050
1280	1190	1100
1433	1366	1250
1570	1490	1400
1690	1590	1500
1750	1690	1600
1950	1890	1800
2150	2090	2000
2350	2290	2200
2550	2490	2400
2650	2590	2500

Standard length 7 m * Can be supplied in lengths of 6 and 12 m upon request * Standard: the piping is manufactured according to Israeli Standard SI 5302, which has adopted the international standard ASTM F2435

2.8 UV Resistance

oth layers contain an additive that provides resistance to UV radiation. The outer layer of the **Paladex** pipe contains a carbon-based additive that filters UV rays and protects the pipe from sun damage during storage.

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2.9 Dimensions and Connections of Paladu Pipes

Paladu is a corrugated pipe with a structural wall, manufactured from polyethylene, providing a high ring stiffness relative to its weight, resistance to extreme temperatures, high chemical resistance, and more. Polyethylene is a thermoplastic polymer used for a wide range of applications and, in recent years, has increasingly prominent in the field of liquid conveyance. **Paladu** has an annular cross-section, allowing it to be shortened at any point along the length of the pipe, making it easier to install in the field and connect to manholes.

- Its light weight is another factor that improves installation performance
- **Paladu** pipes are marked with a purple identification stripe along their entire length.
- The piping is manufactured, tested and certified according to the international standard ISO 21138, which is adopted by SII 21138 and defined by internal diameter
- **Paladu** piping is produced with ring stiffness classes SN8–SN12.

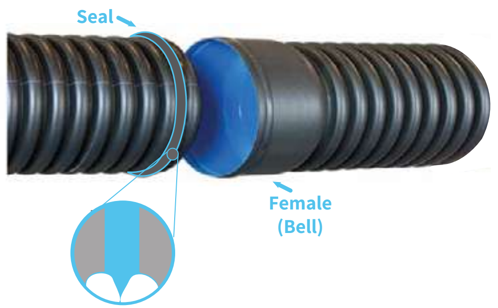
Socket-Spigot Connection Between Pipes

The seal of the joint is of great importance. The lighter the pipes, the easier and more durable the connection between them. **Paladu** piping has an advantage over rigid and heavy pipes, as its connection is based on a male-female joint with an external gasket. **Paladu** pipe is produced with an integral bell (female end) and a male ring fitted with an EPDM gasket. This method allows for quick and easy installation, and the connection is pressure-resistant to 0.7 bar, while maintaining sealing under diameter deformation of up to 5% and angular deflection of up to 1°, in accordance with SI ISO 21138-3 / EN I 3476-3 / Israeli Standard 5302.

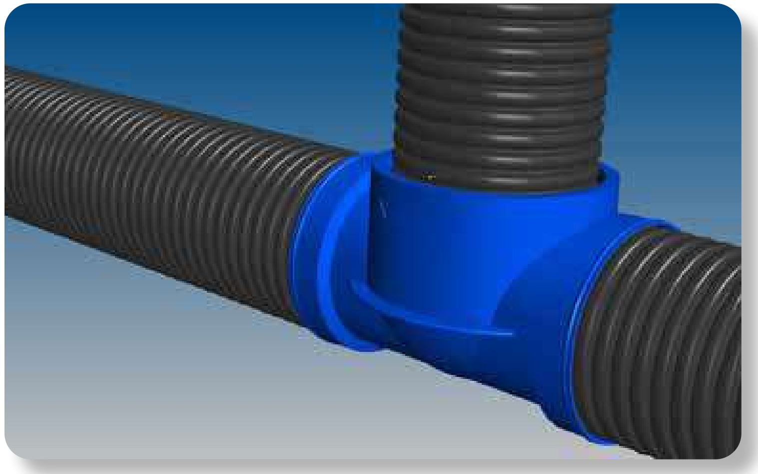
Avrot Inspection Chambers

Avrot has developed a chamber system for **Paladu** piping that meets the applicable standard requirements. The **PALASystem** is a 180˚ through-flow chamber used as an inspection point or a point for transitioning between pipe diameters. The chamber base incorporates integrated connectors for **Paladu** pipes in diameters ranging from 300 mm to 800 mm. The chamber riser has a diameter of 630/800 mm up to ground level and includes ladder rungs.

Dimensions: pipes are supplied in a standard length of 6 meters.



Inner Diameter (mm)	**Outer Diameter** (mm)	**Outer Diameter of the Bell** (mm)
300	338.0	377
400	455.4	495
500	575.7	623
600	686.0	741
800	907.7	961



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PALADEX Innovative Pipe Systems

2.10 Connection to Concrete Manholes

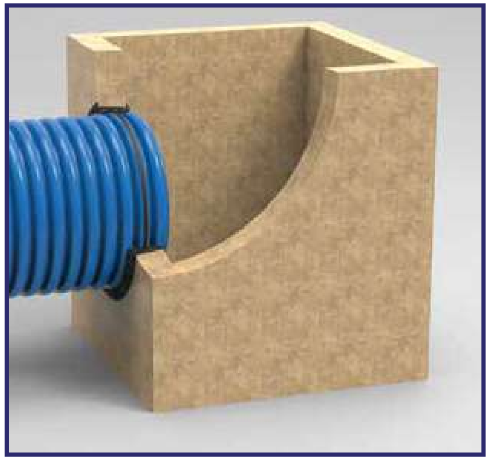
When connecting to inspection chambers, several methods may be used. The type of connector shall be determined by the designer and will be characterized in the technical specification according to the diameter and type of pipe defined in it.

Connection Using Concrete

The most common method for connecting **Paladex** piping to concrete inspection chambers it by using a non-shrink concrete mixed with a sealing additive. The combination of the concrete and the pipe's annular structure creates a water-stopping effect. The size and location of the openings in the inspection chambers shall be determined according to the design plans and agreed specifications.

Manhole Bore Diameter (mm)	**Inner Pipe Diameter** (mm)
400	500
500	600
600	700
700	760
800	870
1000	1120
1250	1370
1400	1600

Manhole Bore Diameter (mm)	**Inner Pipe Diameter** (mm)
1500	1700
1600	1800
1800	2000
2000	2200
2200	2400
2500	2700

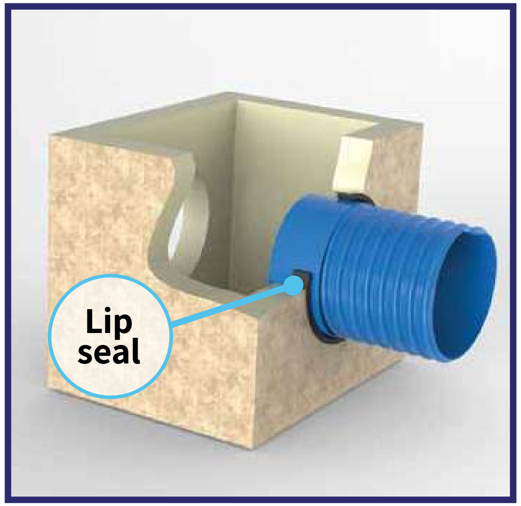


2.11 Connection to Concrete Manholes

Lip seal gasket
A unique EPDM gasket developed for **Paladex** pipes.

- When connecting with a lip seal gasket, manholes must be ordered with openings according to the dimensions defined in the table.
- Place the gasket on the manhole opening in an inverted heart shape.
- Press the gasket into the opening contour until it reaches its designated position.
- Make sure that the outer shoulder of the gasket is positioned on the outer wall.
- Insert the pipe through the gasket using an approved lubricant supplied by the manufacturer.

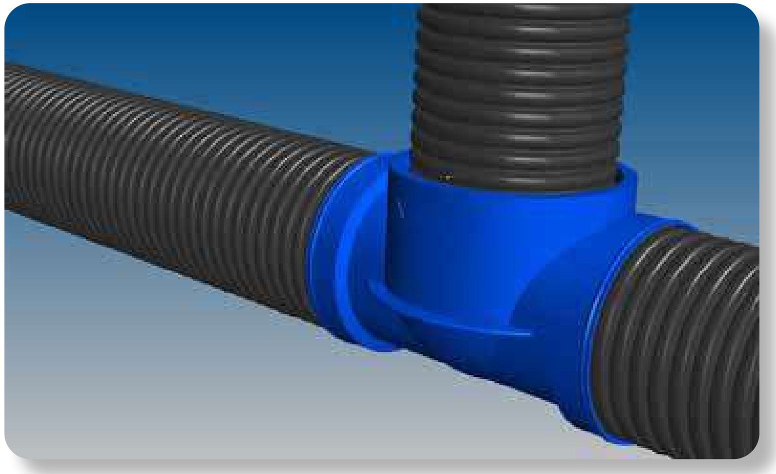
Inner Pipe Diameter (mm)	**Manhole Bore Diameter** (mm)
400	560
500	660
600	760
700	760
800	1060
1000	1150
1250	1400
1500	1650
1800	1950
2000	2150
2200	2350
2500	2650



2.12 Accessories

Polyethylene Manholes and Integral Manholes

The use of plastic manholes is approved by the Standards Institution of Israel.
Load rating: D-400.
Sealing: 0.75 atmospheres using a hydraulic gasket.



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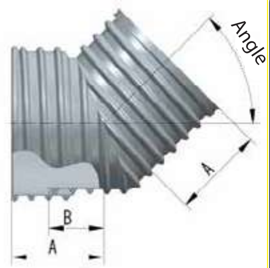
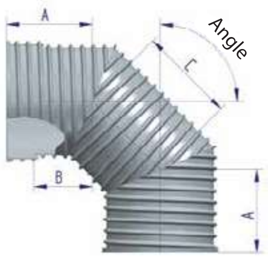
2. Materials and Structure

2.12 Fittings

Paladex Elbows

- Elbow fittings are made from the **Paladex** pipe itself.
- The fittings have the same strength, tightness, and chemical resistance properties.
- Fittings are available in all diameters upon request.





Catalog Number	Pipe Diameter*	Elbow	A	B	C
1240060	400	60	499	259	450
1250060	500	60	520	280	490
1260060	600	60	536	296	520
1280060	800	60	577	337	600
1210060	1000	60	613	373	670
1212560	1250	60	659	419	760
1214060	1400	60	685	445	810
1215060	1500	60	706	466	850
1240090	400	90	552	312	540
1250090	500	90	578	338	590
1260090	600	90	609	369	650
1280090	800	90	670	430	770
1210090	1000	90	726	486	880
1212590	1250	90	802	562	1030
1214090	1400	90	843	603	1110
1215090	1500	90	874	634	1170

* For diameters above 1500 mm up to 2500 mm, please contact the factory.

Catalog Number	Pipe Diameter*	Elbow	A	B
1240015	400	15	430	190
1250015	500	15	436	196
1260015	600	15	442	202
1280015	800	15	458	218
1210015	1000	15	474	234
1212515	1250	15	490	250
1214015	1400	15	501	261
1215015	1500	15	507	267
1240030	400	30	463	223
1250030	500	30	479	239
1260030	600	30	495	255
1280030	800	30	521	281
1210030	1000	30	547	307
1212530	1250	30	583	343
1214030	1400	30	604	364
1215030	1500	30	620	380
1240045	400	45	501	261
1250045	500	45	522	282
1260045	600	45	543	303
1280045	800	45	589	349
1210045	1000	45	630	390
1212545	1250	45	681	441
1214045	1400	45	712	472
1215045	1500	45	738	498

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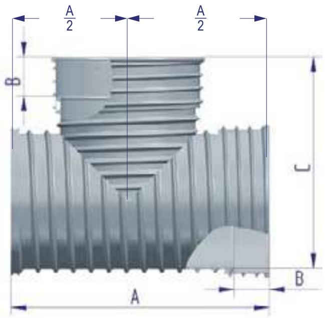
PALADEX Innovative Pipe Systems

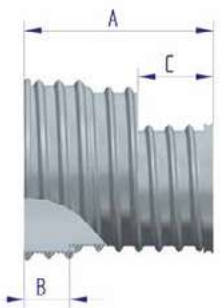
2.12 Fittings

Various fittings for Paladex pipes

T-junction manhole



Reducer



Coupling

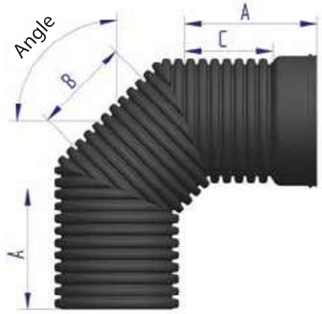
Pipe Diameter	Catalog Number	A	B	C
15400	400	1500	216	900
15500	500	1600	210	1000
15600	600	1700	275	1100
15800	800	1900	320	1300
15100	1000	2100	240	1500
15125	1250	2350	240	1750
15140	1400	2500	240	1900
15150	1500	2600	240	2000

Pipe Diameter	Catalog Number	A	B	C
17400	400	750	216	400
17500	500	750	210	400
17600	600	800	275	400
17800	800	850	320	400
17100	1000	750	240	400
17125	1250	750	240	400
17140	1400	750	240	400
17150	1500	750	240	400

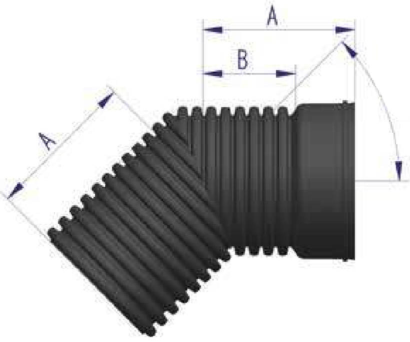
Pipe Diameter	Catalog Number	A	B
19400	400	500	216
19500	500	650	210
19600	600	810	275
19800	800	990	320
19100	1000	1200	240
19125	1250	1350	240
19140	1400	1600	240
19150	1500	1700	240

2.12 Fittings

Paladu Elbows



Catalog Number	Pipe Diameter	Angle	A	B	C
2230060	300	60	455	332	410
2240060	400	60	476	260	450
2250060	500	60	497	287	490
2260060	600	60	513	238	520
2280060	800	60	554	234	600
2230090	300	90	490	367	480
2240090	400	90	521	305	540
2250090	500	90	547	337	590
2260090	600	90	578	303	650
2280090	800	90	639	319	770
1260090	600	90	609	369	650
1280090	800	90	670	430	770



Catalog Number	Pipe Diameter	זווית	A	B
2230015	300	15	420	297
2240015	400	15	431	215
2250015	500	15	437	227
2260015	600	15	443	168
2280015	800	15	459	139
2230030	300	30	445	322
2240030	400	30	456	240
2250030	500	30	472	262
2260030	600	30	488	213
2280030	800	30	514	194
2230045	300	45	465	342
2240045	400	45	486	270
2250045	500	45	507	297
2260045	600	45	528	253
2280045	800	45	574	254

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2.13 Casaflex

Perforation Percentage in Casaflex Piping

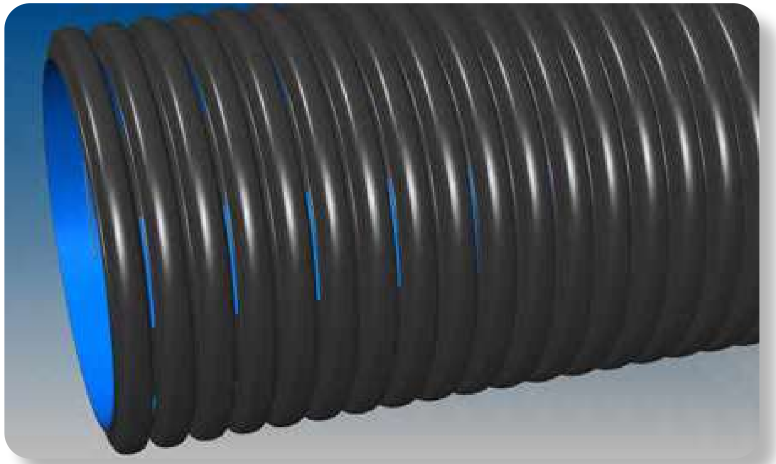
The following table describes the percentage of perforation in **Casaflex** piping per meter of pipe length, as well as the perforated area per square meter of pipe surface area. The perforation percentage can be increased by reducing the spacing between holes up to approximately three times the standard value.

Pipe diameter*	1500	1400	1250	1000	900	800	700	600	500	400
Drilled diameter	12	12	12	12	12	8	8	8	8	8
Spacing between holes	10	10	10	10	10	10	10	10	10	10
Perforation percentage per meter of pipe (%)	0.89	0.89	0.89	0.89	0.07	0.47	0.47	0.59	0.64	0.74
Perforated area per meter of pipe (mm2)	419	391	350	280	302	119	104	111	100	93
Number of holes per meter of pipe	372	347	310	248	267	238	208	222	199	185

*For diameters above 1500 mm and up to 2500 mm – please contact the factory.

Circumferential Slotted Perforation in Corrugated Pipes

Corrugated pipes can be manufactured with either full or partial circumferential slotted perforation for diameters ranging from 300 mm to 600 mm. The following table presents the perforation percentage in both optimal and maximum configurations.



Pipe Diameter	Max.	Opt.	Max.	Opt.	Max.	Opt.	Max.	Opt.
Pipe Diameter (units)	300		400		500		600	
Slot width (mm)	3.2		3.2		3.2		3.2	
Slot length (mm)	50	90	90	140	120	150	140	160
Slotting area per meter of pipe (cm2)	76.8	535.7	86.4	510.7	115.2	547.2	107.5	491.5
Slotting percentage per meter of length (%)	0.8	5.7	0.7	4.1	0.7	3.5	0.6	2.6

Additional configurations are available upon request but may require adjustments for non-standard products.

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Calculations

3.1 Hydraulic Calculations

Paladex pipes are characterized by high fluid conveyance capacity, thanks to their smooth inner wall made of polypropylene/polyethylene, which provides superior flow performance compared to any other drainage pipe on the market (concrete, steel, asbestos). The pipe is also resistant to abrasion from stones and debris due to its smooth surface. This excellent smoothness allows for the design of sewage and drainage lines with minimal longitudinal slopes, while still maintaining effective flow velocity.

The calculation of the pipe's conveyance capacity begins with determining the flow velocity using the Manning equation:

$$V = \frac{R_h^{\frac{2}{3}} \cdot \sqrt{i}}{n}$$

Where:

Value	Description	Units
V	Flow velocity	m/s
R_h	Hydraulic radius	m
i	Pipe slope (invert slope)	m/m
n	Manning roughness coefficient of pipe	$s/m^{1/3}$

PALADEX Innovative Pipe Systems

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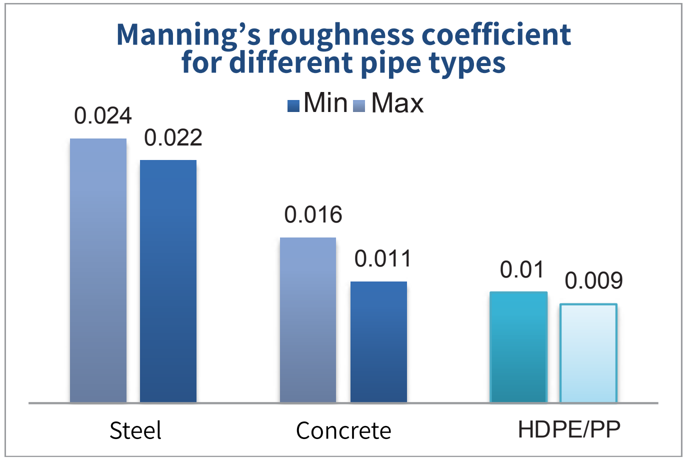
3. Calculations

Manning roughness coefficient of pipe (n)

The inherent smoothness and high resistance of **Paladex** piping to chemical and mechanical abrasion provide it with a significant hydraulic advantage over other types of pipes. **Paladex** have a low Manning roughness coefficient, and this advantage is maintained throughout the pipe's lifespan, whereas other pipes tend to suffer from increased flow surface roughness due to chemical, mechanical and biological wear.



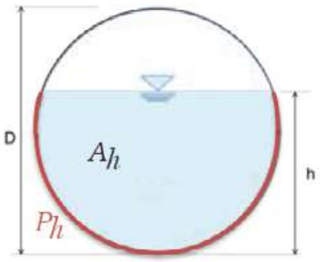
When using **Paladex** pipe, the Manning roughness coefficient should be set to the value of:

$$n = 0.009 \left[\frac{s}{m^{1/3}}\right]$$

Calculation of Manning Equation Parameters:

For a partially filled flow section, the hydraulic radius is calculated by determining the flow area and the wetted perimeter, as described above:

Value	Description	Units
P_h	Wetted perimeter (excluding free surface)	m
D	Inner diameter of the pipe	m
R	Inner radius of the pipe	m
R_h	Hydraulic radius of the flow	m
h	Flow depth	m
A	Cross-sectional area of the pipe	m^2
A_h	Cross-sectional area of the flowing liquid	m^2



Partially full pipe

After calculating the hydraulic radius, we return to the velocity equation (see section 3.1). Using that, we can calculate the flow rate by substituting into the following equation:

$$R_h = \frac{A_h}{P_h}$$

$$A_h = \frac{1}{2} \cdot R^2 \cdot \left\{ \left[\frac{\pi}{90^\circ} \cdot \cos^{1} \left(1 - \frac{h}{R} \right) \right] - \sin \left[2 \cdot \cos^{-1} \left(1 - \frac{h}{R} \right) \right] \right\}$$

$$P_h = R \cdot \left[\frac{\pi}{90^\circ} \cdot \cos^{-1} \left(1 - \frac{h}{R} \right) \right]$$

$$Q = V \cdot A_h$$

(Standard tables by pipe diameter, slope, and flow depth can be found on the following pages).

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Graphical Determination of Flow Velocity and Discharge in a Pipe:

The graph at the bottom of the page (also found in the Appendices section) can be used to determine the flow velocity and discharge as follows:

First, calculate the hydraulic radius and flow area for the full cross section (h=D):

$$A_h = A = \frac{\pi \cdot D^2}{4} \quad ; \quad P_h = \pi * D$$

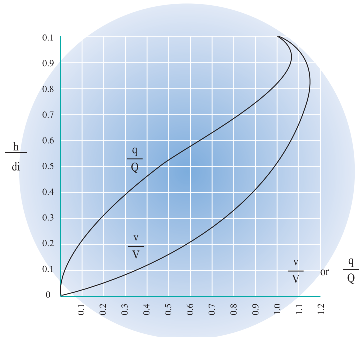
$$R_h = \frac{A_h}{P_h} = \frac{D}{4}$$

Next, calculate the velocity and discharge for the full-flow condition:

$$V = \frac{R_h^{\frac{2}{3}} \cdot \sqrt{i}}{n}$$

$$Q = V \cdot A_h$$

Then, refer to the graph to find the relative flow velocity and discharge for the partially full section, based on the ratio between the flow depth and the pipe diameter.



Velocity and Discharge vs. Flow Depth – Graph in Appendix 4.4

3. Calculations

Example Calculation:

Given:

$$D = 1250\,[mm] = 1.25\,[m]$$

$$h = 0.5 \;\; m$$

$$i = 0.5\% \;\; =)$$

First, calculate the flow velocity and discharge for the fully filled cross-section as follows:

Flowing cross-sectional area

$$A_h = \frac{\pi \cdot D^2}{4} = \frac{\pi \cdot 125^2}{4} = 1.23\,[m^2] \;\; =)$$

Hydraulic radius of the flow

$$R_h = \frac{D}{4} = \frac{1.25}{4} = 0.3125\,[\mathrm{m}] =)$$

Flow velocity

$$V = \frac{R_h^{\frac{2}{3}} \cdot \sqrt{i}}{n} = \frac{0.3125^{\frac{2}{3}} \cdot \sqrt{0.005}}{0.009} = 3.62\,[{}^{m}/_{sec}] =)$$

Discharge

$$Q = V \cdot A_h = 3.62 \cdot 1.23 = 4.45\,[{}^{m^3}/_{sec}] \;\; =)$$

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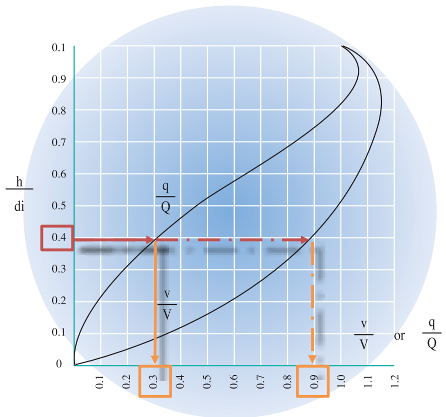
3. Calculations

Now, refer to the graph to determine the velocity and discharge ratios based on the ratio between the pipe diameter (full cross-section) and the flow depth (h) as follows:

$$\frac{h}{D} = \frac{0.5}{1.25} = 0.4$$

From the graph, we can see that for a height ratio of 0.4, the discharge ratio is 0.3 and the velocity ratio is 0.9.



Now, multiply these ratios by the full-flow discharge and velocity to obtain the corresponding values for a flow depth of 0.5 m.

$$Q_h = 4.45 \cdot 0.33 = 1.47 \left[{}^{m^3}/_{sec}\right]$$

$$V_h = 3.62 \cdot 0.9 = 3.26 \left[{}^{m}/_{sec}\right]$$

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3. Calculations

Flow Rate (m^3/s) and Velocity (m/s) Tables for **Paladex** pipes at various slopes according to standard flow cross sections:

Velocity, flow rate and slope for a quarter of a flow section in a pipe:

$h = \frac{1}{4}D$

/ Pipe diameter Φ / "Gradient	*		1500		1400		1250		1000		800		700		600		500		400	
	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q
10%	13.37	5 25	12.80	4 42	12.23	3.68	11.34	2.72	9.77	1.50	8.42	0.83	7.70	0.58	6.95	0.38	6.15	0.24	5.30	0.13
9%	12.68	4 98	12.15	4.20	11.60	3 49	10.76	2.58	9.27	1.42	7.99	0.78	7.31	0.55	6.59	0.36	5.84	0.22	5.03	0.12
8%	11.95	4 70	11.45	3 96	10.94	3 29	10.14	2.43	8.74	1.34	7.53	0.74	6.89	0.52	6.22	0.34	5.50	0.21	4.74	0.12
7%	11.18	4 40	10.71	3 70	10.23	3.08	9.49	2.28	8.17	1.26	7.04	0.69	6.44	0.48	5.81	0.32	5.15	0.20	4.44	0.11
6%	10.35	4 07	9.92	3.43	9.47	2.85	8.78	2.11	7.57	1.16	6.52	0.64	5.97	0.45	5.38	0.30	4.77	0.18	4.11	0.10
5%	9.45	3.71	9.05	3.13	8.65	2.60	8.02	1.92	6.91	1.06	5.95	0.59	5.45	0.41	4.91	0.27	4.35	0.17	3.75	0.09
4%	8.45	3.32	8.10	2.80	7.73	2.33	7.17	1.72	6.18	0 95	5.33	0.52	4.87	0.37	4.40	0.24	3.89	0.15	3.35	0.08
3%	7.32	2.88	7.01	2.42	6.70	2.02	6.21	1.49	5.35	0.82	4.61	0.45	4.22	0.32	3.81	0.21	3.37	0.13	2.91	0.07
2%	.5.98	2.35	5.73	1.98	5.47	1.65	5.07	1.22	4.37	0.67	3.77	0.37	3.44	0.26	3.11	0.17	2.75	0.11	2.37	0.06
1%	4.23	1.66	4.05	1.40	3.87	1.16	3.59	0.86	3.09	0.47	2.66	0.26	2.44	0.18	2.20	0.12	1.95	0.07	1.68	0.04
0.9%	4.01	1.58	3.84	1.33	3.67	1.10	3.40	0.82	2.93	0.45	2.53	0.25	2.31	0.17	2.09	0.12	1.85	0.07	1.59	0.04
0.8%	3.78	1.49	3.62	1.25	3.46	1.04	3.21	0.77	2.76	0.42	2.38	0.23	2.18	0.16	1.97	0.11	1.74	0.07	1.50	0.04
0.7%	3.54	1.39	3.39	1.17	3.23	0.97	3.00	0.72	2.58	0.40	2.23	0.22	2.04	0.15	1.84	0.10	1.63	0.06	1.40	0.03
0.6%	3.27	1.29	3.14	1 08	2.99	0 90	2.78	0.67	2.39	0.37	2.06	0.20	1.89	0.14	1.70	0.09	1.51	0.06	1.30	0.03
0.5%	2.99	1.17	2.86	0.99	2.73	0.82	2.54	0.61	2.18	0.34	1.88	0.19	1.72	0.13	1.55	0.09	1.38	0.05	1.19	0.03
0.4%	2.67	1.05	2.56	0.88	2.45	0.74	2.27	0.54	1.95	0.30	1.68	0.17	1.54	0.12	1.39	0 08	1.23	0.05	1.06	0.03
0.3%	2.31	0.91	2.22	0.77	2.12	0.64	1.96	0.47	1.69	0.26	1.46	0.14	1.33	0.10	1.20	0.07	1.07	0.04	0.92	0.02
0.2%	1.89	0.74	1.81	0.63	1.73	0.52	1.60	0.38	1.38	0.21	1.19	0.12	1 09	0.08	0.98	0.05	0.87	0.03	0.75	0.02
0.1%	1.34	0.53	1.28	0.44	1.22	0.37	1.13	0.27	0.98	0.15	0.84	0.08	0.77	0.06	0.70	0.04	0.62	0.02	0.53	0.01

הערות:
* For velocity and flow rate data for diameters above 1,600 mm, please contact the factory.

$Q \ [m^3/sec]$

$V \ [m/sec]$

Notes:
1. Values marked in blue are not recommended for design purposes.
2. At velocities of 10 m/s or more, anchoring of pipe ends is required.

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3. Calculations

Velocity, Flow Rate and Slope for a Half-Full Pipe Section

$h = \frac{1}{2} D$

/ Pipe diameter Φ * Slope	1600*		1500		1400		1250		1000		800		700		600		500		400	
	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q
10%	19.07	19.18	18.27	16.14	17.45	13.43	16.18	9.93	13.94	5.48	12.02	3.02	10.99	212	9.92	1.40	8.78	0.86	7.57	0.48
9%	18.10	18.19	17.33	15 32	16.55	12 74	15 35	9.42	13.23	5.19	11.40	2 87	10.43	2 01	9.41	1.33	8.33	0.82	7.18	0.45
8%	17.06	17.15	16.34	14 44	15.61	12.01	14 47	8.88	12.47	4.90	10.75	2 70	9.83	1.89	8.87	1.25	7.86	0.77	6.77	0.43
7%	15.96	16.04	15.29	13.51	14.60	11.24	13 54	8.31	11.67	4.58	10.05	2.53	9.20	1.77	8.30	1.17	7.35	0 72	6.33	0 40
6%	14.78	14.85	14.15	12.51	13.52	10.40	12 53	7.69	10.80	4.24	9.31	2.34	8.52	1.64	7.68	1.09	6.80	0.67	5.86	0.37
5%	13.49	13 56	12.92	11.42	12.34	9.50	11.44	7.02	9.86	3.87	8.50	2.14	7.77	1.50	7.01	0.99	6.21	0.61	5.35	0.34
4%	12.06	12.13	11.56	10.21	11.04	8.49	10.23	6.28	8.82	3.46	7.60	1.91	6.95	1.34	6.27	0.89	5.56	0.55	4.79	0.30
3%	10.45	10.50	10.01	8.84	9.56	7.36	8.86	5.44	7.64	3.00	6.58	1.65	6.02	1.16	5.43	0.77	4.81	0.47	4.15	0.26
2%	8.53	8.58	8.17	7.22	7.80	6.01	7.24	4.44	6.24	245	5.37	1.35	4.92	0.95	4.44	0.63	3.93	0.39	3.39	0.21
1%	6.03	6.06	5.78	5.11	5.52	4.25	5.12	3.14	4.41	1.73	3.80	0.96	3.48	0.67	3.14	0.44	2.78	0.27	2.39	0.15
0.9%	5.72	5.75	5.48	4.84	5.24	4.03	4.85	2.98	4.18	1.64	3.60	0 91	3.30	0.63	2.98	0.42	2.64	0.26	2.27	0.14
0.8%	5.40	5.42	5.17	4.57	4.94	3.80	4.58	2 81	3.94	1.55	3.40	0.85	3.11	0.60	2.81	0.40	2.48	0.24	2.14	0.13
0.7%	5.05	5.07	4.83	4.27	4.62	3 55	4.28	2.63	3.69	1.45	3.18	0 80	2.91	0.56	2.62	0.37	2.32	0.23	2.00	0.13
0.6%	4.67	4.70	4.48	3.95	4.27	3.29	3.96	2.43	3.42	1.34	2.94	0.74	2.69	0.52	2.43	0.34	2.15	0.21	1.85	0.12
0.5%	4.27	4.29	4.09	3.61	3.90	3.00	3.62	2.22	3.12	1.22	2.69	0.68	2.46	0.47	2.22	0.31	1.96	0.19	1.69	0.11
0.4%	3.81	3.84	3.65	3.23	3.49	2.69	3.24	1.99	2.79	1.10	2.40	0 60	2.20	0.42	1.98	0.28	1.76	0.17	1.51	0.10
0.3%	3.30	3.32	3.16	2.80	3.02	2.33	2.80	1.72	2.42	0.95	2.08	0.52	1.90	0.37	1.72	0.24	1.52	0.15	1.31	0.08
0.2%	2.70	2.71	2.58	2.28	2.47	1.90	2.29	1.40	1.97	0.77	1.70	0.43	1.55	0.30	1.40	0.20	1.24	0.12	1.07	0.07
0.1%	1.91	1.92	1.83	1.61	1.75	1.34	1.62	0.99	1.39	0.55	1.20	0 30	1.10	0.21	0.99	0.14	0.88	0.09	0.76	0.05

* For velocity and flow rate data for diameters above 1,600 mm, please contact the factory.

Notes:
1. Values marked in blue are not recommended for design purposes.
2. At velocities of 10 m/s or more, anchoring of pipe ends is required.

$Q \quad [m^3/sec]$

$V \quad [m/sec]$

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PALADEX Innovative Pipe Systems

Velocity, Flow Rate and Slope for Three-Quarter-Full Pipe Section

$h = \frac{3}{4} D$

/ Pipe diameter Φ * Slope	1600*		1500		1400		1250		1000		800		700		600		500		400	
	V	Q	V		V	Q	V		V	Q	V	Q	V	Q	V	Q	V	Q	V	Q
10%	21 62	34 97	20.71	29 44	19.78	24 50	18.34	18.11	15.81	9.99	13.62	5 51	12.46	3 86	**11.24**	2 56	9.96	1.57	8.58	0.87
9%	20.51	33 18	19.65	27 93	18.76	23 24	17.40	17.18	14.99	9.47	12.92	5 23	11.82	3 66	10.67	2 43	9.45	1.49	8.14	0.82
8%	19.34	31 28	18.52	26 33	17.69	21.91	16.40	16 20	14.14	8.93	12.18	4 93	11.14	3 45	10 06	2.29	8.91	1.41	7.67	0.78
7%	18.09	29 26	17.33	24 63	16.55	20 49	15.34	15.15	13 22	8.36	11.40	4 61	10.43	3 23	9.41	2.14	8.33	1.32	7.18	0.73
6%	16 75	27 09	16.04	22 81	15.32	18.97	14.21	14 03	12 24	7.74	10.55	4 27	9.65	2.99	**8.71**	1.98	7.71	1.22	6.65	0.67
5%	15.29	24 73	14.64	20 82	13.99	17 32	12.97	12.80	11 18	7.06	9.63	3.89	8 81	2.73	7.95	1.81	7.04	1.11	6.07	0.61
4%	13 67	22 12	13.10	18 62	12.51	15 49	11.60	11.45	10.00	6.32	8.61	3.48	7.88	2.44	7.11	1.62	6.30	0.99	5.43	0.55
3%	11.84	19.16	11.34	16.13	10.83	13 42	10.05	9.92	8.66	5.47	7.46	3.02	6.82	2.11	6.16	1.40	5.45	0.86	4.70	048
2%	9.67	15.64	9.26	13.17	8.85	10.95	8.20	8.10	7.07	4.47	6.09	2.46	5.57	1.73	5.03	1.14	4.45	0.70	3.84	0.39
1%	6.84	11.06	6.55	9.31	6.25	7.75	5.80	5.73	5.00	3.16	4.31	1.74	3.94	1.22	3.56	0.81	3.15	0.50	2.71	0.27
0.9%	6.49	10.49	6.21	8.83	5.93	7.35	5.50	5.43	4.74	3.00	4.09	1.65	3.74	1.16	3.37	0.77	2.99	0.47	2.57	0.26
0.8%	6.12	9.89	5.86	8.33	5.59	6.93	5.19	5.12	4.47	2.82	3.85	1.56	3.52	1.09	3.18	0.72	2.82	0.44	2.43	0.25
0.7%	5.72	9.25	5.48	7.79	5.23	6.48	4.85	4.79	4.18	2.64	3.60	1.46	3.30	1.02	2.97	0.68	2.63	0.42	2.27	0.23
0.6%	5.30	8.57	5.07	7.21	4.84	6.00	4.49	4.44	3.87	2.45	3.34	1.35	3.05	0.94	2.75	0.63	2.44	0.39	2.10	0.21
0 5%	4.83	7.82	4.63	6.58	4.42	5.48	4.10	4.05	3.53	2.23	3.05	1.23	2.79	0.86	**2.51**	0.57	2.23	0.35	1.92	0.19
0 4%	4.32	6.99	4.14	5.89	3.96	4.90	3.67	3.62	3.16	2.00	2.72	1.10	2.49	0.77	2.25	0.51	1.99	0.31	1.72	0.17
0.3%	3.74	6.06	3.59	5.10	3.43	4.24	3.18	3.14	2.74	1.73	2.36	0.95	2.16	0.67	1.95	0.44	1.72	0.27	1.49	0.15
0.2%	3.06	4.95	2.93	4.16	2.80	3.46	2.59	2.56	2.24	1.41	1.93	0.78	1.76	0.55	1.59	0.36	1.41	0.22	1.21	0.12
0 1%	2.16	3.50	2.07	2.94	1.98	2.45	1.83	1.81	1.58	1.00	1.36	0 55	1.25	0.39	1.12	0.26	1.00	0.16	0.86	0.09

* For data on velocities and flow rates above diameter 1,600 mm, please contact the factory.

Notes:
1. Values marked in blue are not recommended for design purposes.
2. At velocities of 10 m/s or more, anchoring of pipe ends is required.

$Q \;\; [m^3/sec]$

$V \;\; [m/sec]$

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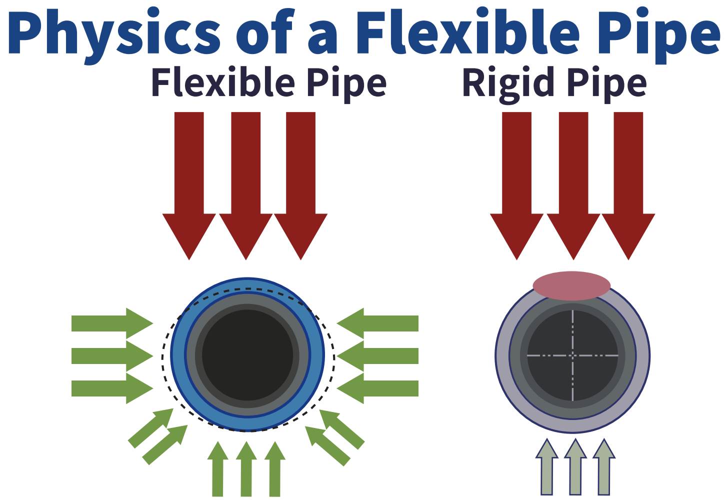
3.2 Loads

PALADEX Piping vs. Rigid Pipes

When comparing different types of piping for gravity flow, one must distinguish flexible **Paladex** pipes and rigid piping (such as concrete or cast iron). There are fundamental differences in the physics and mechanics of these pipe types and in how they respond to external soil loads. The great advantage of **Paladex** piping lies in its ability to distribute the loads applied to it through the surrounding soil, thus avoiding failures and collapses in the piping system while maintaining a fully sealed system over time.

The physics of flexible piping is based on the tolerance and flexibility of the pipe structure which enables support from the surrounding soil above the pipe's circumference. The flexible structure of the **Paladex** pipe transfers vertical stress into radial forces, that are supported by the soil envelope. This provides the pipe wiith mechanical strength and the ability to withstand high external loads.



3. Calculations

Rigid piping with an annular cross-section cannot accommodate horizontal or vertical deformation.

A deformation of just 0.1% of the diameter along either axis may result in cracking or irreversible structural failure. In contrast, **Paladex** piping benefits from mechanical flexibility, allowing it to absorb significant deformation and effectively distribute external loads into the surrounding soil. The flexible structure of the **Paladex** pipe allows it to withstand deformations of approximately 5% of its diameter without damage — both in the short term and over time — and without compromising the pipe's hydraulic performance.

This property enables the pipe to withstand high external loads over time.

The load-bearing capacity of the **Paladex** piping is affected by its **ring stiffness (SN)**. Ring stiffness depends on both the material properties (such as the modulus of elasticity) and the profile geometry of the pipe (moment of inertia). **Paladex** pipes are manufactured in various ring stiffness classes — SN-8, SN-12, and SN-16 — and can be produced with higher stiffness upon request.

The modulus of elasticity of a material is an important parameter for understanding its "flexibility".

Cement mortar	$25x10^3$MPa
Concrete	$30x10^3$MPa
Steel	m $17x10^3$MPa
PVC	$3.6x10^3$MPa
PALADEX	**$1.0x10^3$MPa**

In most cases, a high modulus of elasticity indicates lower elasticity and lower flexibility of the material.

The modulus of elasticity (E) in rigid pipes is greater than in **Paladex** pipes, as shown in the following:
Moment of Inertia (I): The higher the moment of inertia, the greater the structural strength of the pipe. In order to achieve high ring stiffness in pipes made of materials with a low modulus of elasticity, while still maintaining low weight and cost, it is necessary to design a ribbed structural profile. This profile significantly increases the moment of inertia, thereby improving ring stiffness.

3. Calculations

The ring stiffness of pipes with a structural wall is evaluated according to ISO-9969, using the formula as follows:

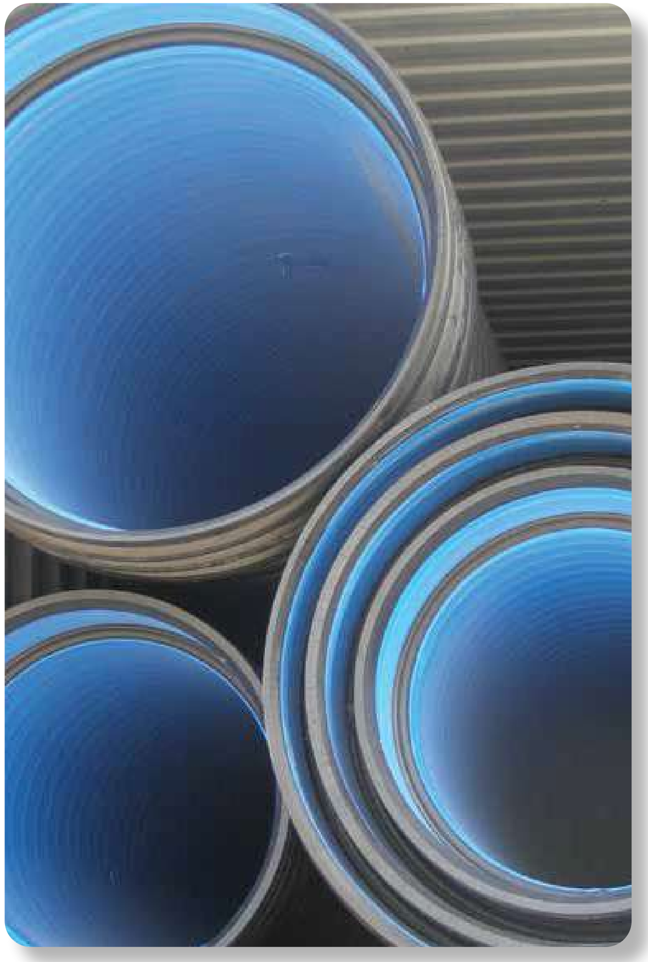
$$Sn = \left(0.0186 + 0.025 \cdot \frac{y}{D_i}\right) \cdot \frac{F}{L \cdot y} \left[\frac{KN}{m^2}\right]$$

Units	Description	Value
S_n	Ring stiffness	$KN/_{m^2}$
F	Force required to produce the permissible distortion	N
L	The length of the test sample	m
Υ	Pipe diameter deformation*	m
D_L	Inner diameter of the pipe	m

* Υ corresponds to a permissible deformation of 3% for the inner diameter, such that:

$$\frac{y}{D_i} = 0.03$$

The advantage of **Paladex** piping lies in its ability to withstand long-term soil loads and ground movement, due to the pipe's capacity to absorb point loads and transfer them to the surrounding soil envelope, thus avoiding pipe failure. Its flexibility and ability to accommodate minor deformations constitute a significant mechanical advantage for infrastructure designed for operational durability over decades.

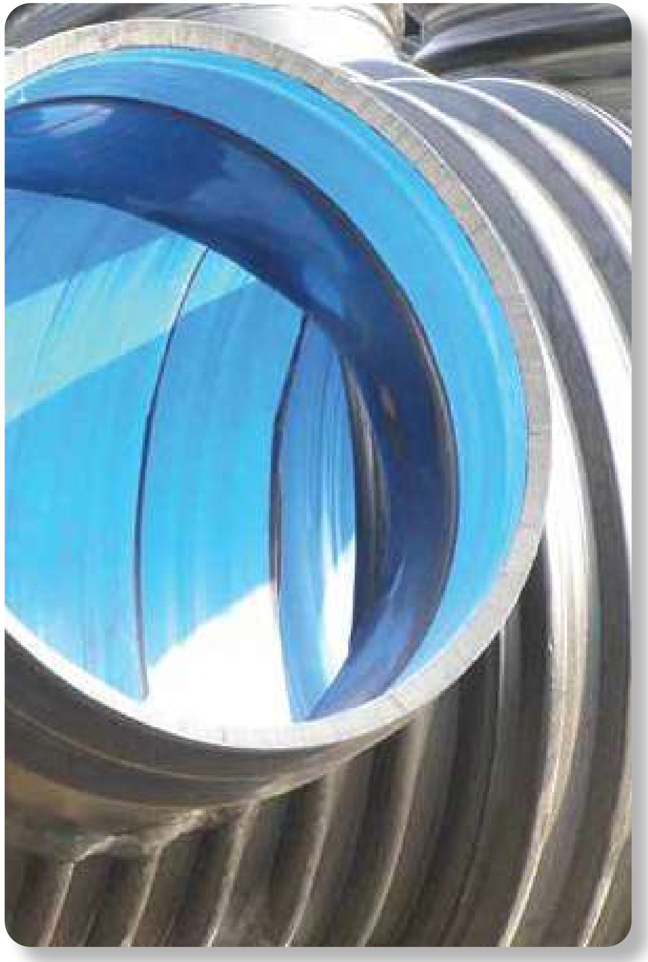


Calculation of Deformation in Flexible Pipes:
The deformation in flexible pipes is calculated as the change in the vertical diameter of the pipe resulting from external loads.

The standard defines a maximum vertical deformation of approximately 5% in **Paladex** pipes as the permissible distortion.

The most widely used equation for calculating deformation in flexible piping is the Spangler Formula (Iowa Formula). This formula appears in various forms in most international standards currently used worldwide. The formula is based on various parameters related to the pipe properties, soil characteristics, the degree of compaction, and external loads acting on the pipe.

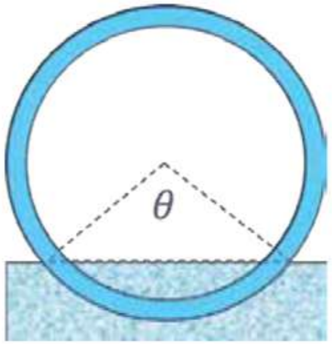
$$\Delta y = \frac{K \cdot (D_L \cdot W_C + W_L + W_F)}{8 \cdot SN + 0.061 \cdot E}$$



3. Calculations

Bedding Constant (K):

Inner Pipe Diameter (mm)	K
Straight bedding, light compaction in the pipe bedding Proctor < 35%, Relative Density > 40%	0.11
Shaped bedding, medium compaction in the pipe bedding Proctor 85%–95%, Relative Density 40%–70% Relative Density selected sand, granular material Type A or B, or fine gravel	0.103
Shaped bedding, high compaction in bedding and pipe sides Proctor > 95%, Relative Density 70%–100% Selected sand, granular material Type A or B, or fine gravel	0.083



Note: Proctor percentage values are estimates of compaction for non-cohesive soils and are based on the maximum compaction laboratory test according to ASTM D698. For cohesionless (frictional) soils, use relative density values per ASTM D4253 and ASTM D4254.

DL – Deflection Lag Factor

The deflection lag factor (DL) represents the long-term settlement of the pipe-soil system. This factor expresses the ratio between the volume of the soil envelope at the time of installation and its volume after long-term compaction. The higher the compression ratio, the greater the load transferred to the pipe surface.
The DL factor depends on the degree of soil compaction around the pipe and the stiffness of the pipe.
The higher the soil density, the lower the deflection lag factor.

Typical DL values:

Light compaction > 85% Proctor > 40% relative density	**Light compaction > 85%-95% Proctor > 40%-70% relative density**	**Light compaction > 85% Proctor > 70% relative density**
DL = 1.5	DL = 1.3	DL = 1.2

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WC - Constant (Static) Load

The standard model for calculating the static earth load acting on a pipe is based on
the research of Professor Marston from the University of Iowa, USA.
The model takes into account the specific installation conditions of the pipe, the unit weight of the soil, the trench width, the fill height, and the outer diameter of the pipe.

For the trench width, two conditions are considered:
A. Narrow trench: When the following conditions apply: 2B < H ; 3DO≤ B
B. Wide trench: When the following conditions occur: 2B ≤ H ; 3DO < B

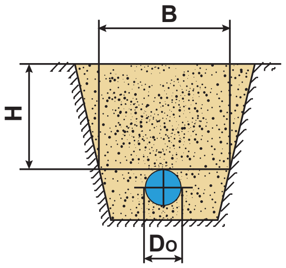
The constant load is evaluated under two conditions: extreme condition (maximum load); design condition (Marston load).

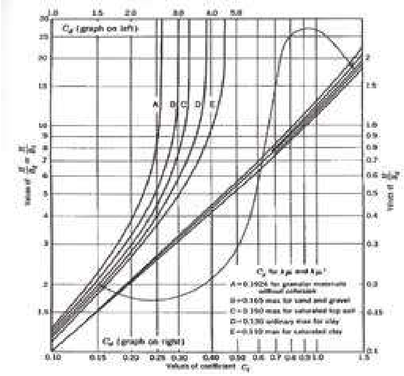
A. Marston Load Calculation Formula:

$W_C = C \cdot \gamma \cdot D_O \cdot B \; [\frac{N}{m}]$

Where:

Units	Description	Value
W_C	Constant earth load	$^{N}/_{m}$
C	Soil condition coefficient	-
γ	Unit weight of soil; if unknown, use 103 15.6	$^{N}/_{m^3}$
D_O	Outer diameter of the pipe	m
B	Trench width	m





The C coefficient is determined using the graph depicted above (also found in Appendix 4.5) where:

- H is the height of fill above the pipe
- A, B, C, D, E refer to the soil type, according to the legend in the graph

3. Calculations

B. Formula for calculating maximum load:

$P = \gamma \cdot D_O \cdot H\ [\frac{N}{m}]$

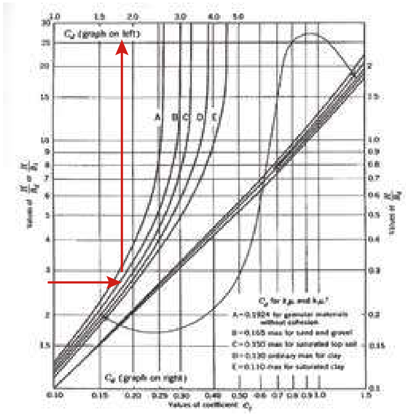
Where:

Units	Description	Value
P	Maximum constant load	N/m
γ	Unit weight of soil; if unknown, use 103 15.6	N/m^3
H	Fill height	m
D_O	Outer diameter of the pipe	m

We will compare the two using an example: a pipe with an outer diameter of 1.33 m (i.e., 1250 mm) is installed in a trench with a width of 2.25 m and a fill height of 6 m above the pipe crown. The fill material is clayey soil. What is the static load in each of the two cases?

A. For Marston load:

$$D_o = 1.33[m]$$
$$B = 2.25[m]$$
$$H = 6[m]$$
$$\frac{H}{B} \cong 2.5$$
$$\Rightarrow C = 1.9$$
$$W_c = 1.9 \cdot (15.6 \cdot 10^3) \cdot 1.33 \cdot 2.25 = 88.7 \cdot 10^3\,[\frac{N}{m}]$$



B. For maximum load:

$$P = (15.6 \cdot 10^3) \cdot 1.33 \cdot 6 = 125 \cdot 10^3\,[\frac{N}{m}]$$

WL – Live Load

The calculation of live load on the pipe envelope is based on Boussinesq's equations and includes all dynamic loads acting on the pipe, for three distinct scenarios: vehicular traffic, trains, and airfields. The live load is calculated using the following formula:
Where:

Units	Description	Value
W_L	Live load	N/m
C_L	Live load coefficient per unit length* (according to the tables below)	-
P	Wheel load***	N
I_f	Outer diameter of the pipe	-

$$W_L = C_L \cdot P \cdot I_f \ \left[\frac{N}{m}\right]$$

Pipe diameter [mm]	PDepth of Cover (above pipe crown) [m]***																				
	0.6	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5
400	0.285	0.223	0.139	0.094	0.069	0.053	0.042	0.035	0.029	0.024	0.021	0.018	0.016	0.014	0.012	0.011	0.010	0.009	0.008	0.007	0.007
500	0.356	0.278	0.173	0.117	0.086	0.066	0.053	0.043	0.036	0.030	0.026	0.022	0.020	0.017	0.015	0.014	0.012	0.011	0.010	0.009	0.008
600	0.428	0.334	0.208	0.141	0.103	0.079	0.064	0.052	0.043	0.037	0.031	0.027	0.023	0.021	0.018	0.016	0.015	0.013	0.012	0.011	0.010
700	0.499	0.389	0.243	0.164	0.120	0.093	0.074	0.061	0.050	0.043	0.036	0.031	0.027	0.024	0.021	0.019	0.017	0.015	0.014	0.013	0.011
800	0.570	0.445	0.277	0.187	0.137	0.106	0.085	0.069	0.058	0.049	0.042	0.036	0.031	0.027	0.024	0.022	0.019	0.017	0.016	0.014	0.013
1000	0.713	0.556	0.347	0.234	0.172	0.132	0.106	0.087	0.072	0.061	0.052	0.045	0.039	0.034	0.030	0.027	0.024	0.022	0.020	0.018	0.016
1250	0.891	0.695	0.433	0.293	0.214	0.166	0.132	0.108	0.090	0.076	0.065	0.056	0.049	0.043	0.038	0.034	0.030	0.027	0.025	0.022	0.020
1400	0.998	0.779	0.485	0.328	0.240	0.185	0.148	0.121	0.101	0.085	0.073	0.063	0.055	0.048	0.042	0.038	0.034	0.030	0.028	0.025	0.023
1500	1.069	0.834	0.520	0.351	0.257	0.199	0.159	0.130	0.108	0.091	0.078	0.067	0.059	0.051	0.046	0.041	0.036	0.033	0.030	0.027	0.024
1600	1.140	0.890	0.555	0.375	0.274	0.212	0.169	0.139	0.115	0.097	0.083	0.072	0.063	0.055	0.049	0.043	0.039	0.035	0.031	0.029	0.026

* Table of the live load coefficients for a single wheel crossing (assuming an effective pipe length of 1.0 m)
**According to AASHTO standards, the effective load for a single wheel is 71.4 KN
*** For diameters over 1600 mm, please contact the factory.

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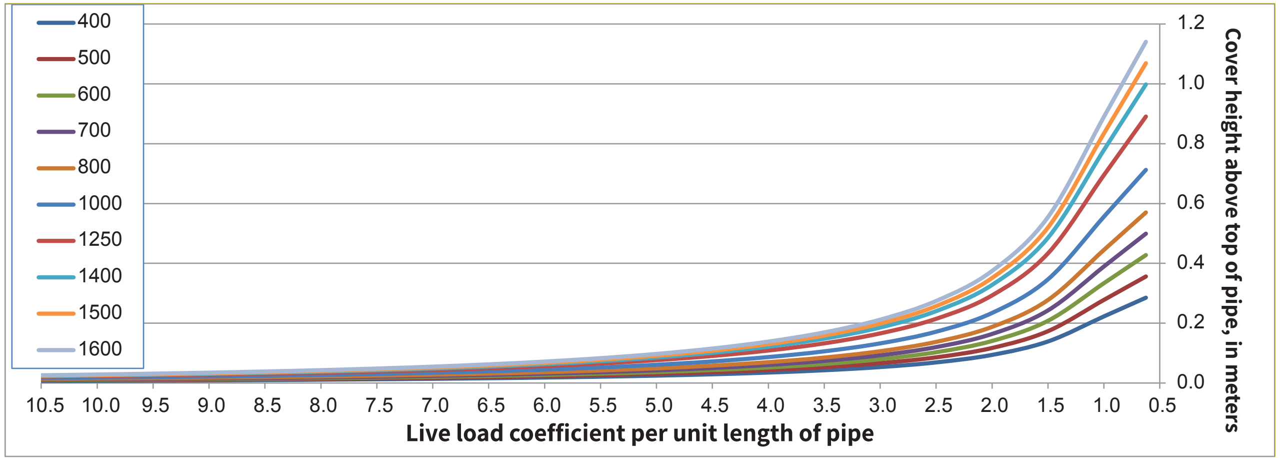
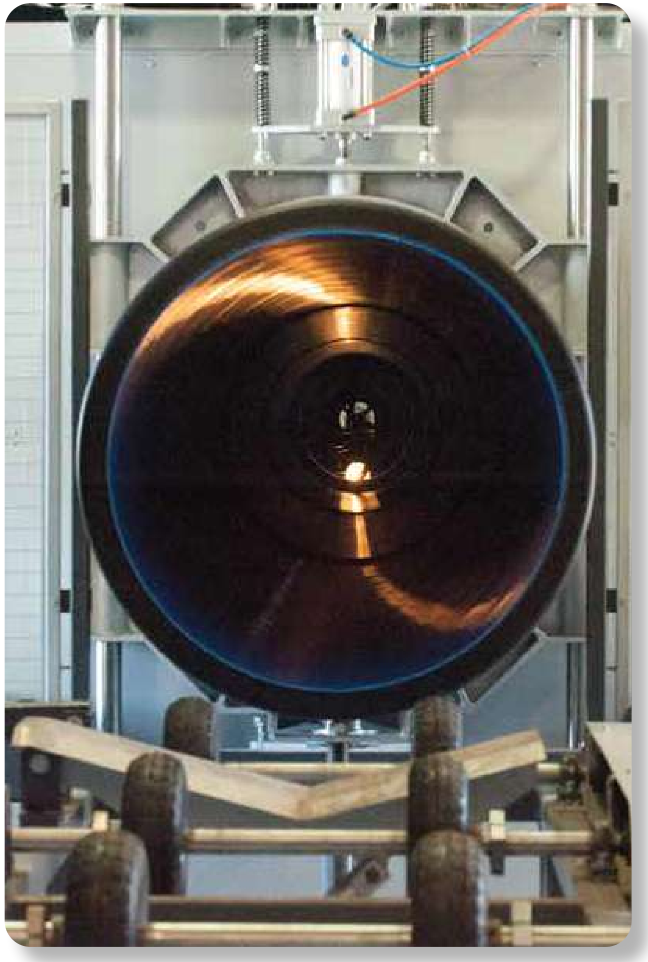
The following graph illustrates the behavior of the live load coefficient as a function of pipe diameter (in mm) and depth of cover (in m):



The following table provides the Impact Factor (IF), based on the depth of cover and the type of dynamic load acting on the pipe:

Taxiway, aircraft parking apron, holding area, engine run-up area	Airport runway	Railway tracks	Main road	Depth of cover [m]
0.3 to 0	1.5	1.75	1.0	1.5
0.6 to 0.3	1.35	1.5	1.0	1.35
1 to 0.6	1.15	1.5	1.0	1.35
Above 1	1.0	1.35	1.0	1.15



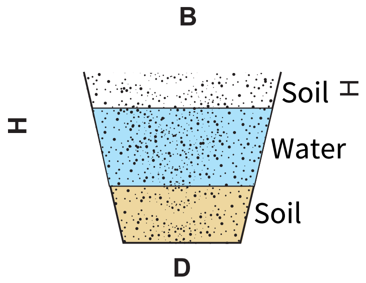
WF – Hydraulic Load from Groundwater

In certain cases, the pipe may be installed in soil located near the groundwater table. If the pipe is laid at a depth equal to or greater than the groundwater level, the groundwater exerts a load that affects the deflection of the pipe. This load should be taken into account only when the groundwater level (upper surface) reaches half the height of the pipe or higher (after installation), as illustrated in the diagram.

When there is no groundwater present, the value of this load in Spangler's equation is considered zero.

The following is the formula for calculating the hydraulic load from groundwater:

$$W_F = \delta_W \cdot [(H - H_1) + \frac{D}{2000}] \quad [\frac{N}{m}]$$



Where:

Units	Description	Value
W_F	Buoyant force per unit	N/m
δ_W	Unit weight of water, which is 9,800	N/m^3
H	Total filling height	m
H_1	Dry backfill height	m
H_2	Groundwater level	m
D	Outer diameter of the pipe	m

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Load Design – E' – Soil Reaction Modulus

The E' value represents the soil's ability to support the pipe. The following table provides soil reaction modulus values (E') used for calculating deformation in flexible pipes, based on Howard (14) and commonly used in engineering practice.

Table of E' values by soil type and degree of compaction:

Soil type, fill material (according to Israeli Standard SI 253* and SI 3**)	High compaction	Medium compaction	Light compaction
	< 95% Proctor	< 85%-95% Proctor	< 85% Proctor
	70% relative density	40%-70% density	40% relative density
Fat plastic soils (clays or silts): MH, CH, CH-MH	Do not use as pipe bedding	Do not use as pipe bedding	Do not use as pipe bedding
Low or non-plastic clayey/silty soils (CL, CL-ML, ML-CL, CH, ML-MH) containing more than 25% cobbles	1,400	2,800	6,900
Cobbles and sand containing more than 15% fines. GM SC, SM, GC, GM	2,800	6,900	13,800
Cobbles, well-graded and poorly graded sand, and cobbles with little silt or clay, containing less than 15% fines. GM-GC SP' SW, GP, GW,	6,900	13,800	20,700
Well-graded coarse aggregate up to 37.5 mm: (SC, GM, GC-SC, GC)	20,700	20,700	20,700

Note: For planning purposes according to Standard Design Specification No. 458, only the soils and E' values marked in the dark sections of the table may be used. The recommendations in the table refer to installation of flexible pipes at a depth of less than 15 meters. When the cover height above the crown of the pipe exceeds 15 meters, use 75% of the E' values listed in the table. When the cover height above the crown of the pipe is less than or equal to 5 meters, the E' values in the table should be used, and the following values should be added to the calculated relative deflection, according to the degree of compaction, as detailed below:

Additional random deviation to be added to calculated pipe diameter deflection, according to the level of soil compaction			
High compaction	Medium compaction	Light compaction	Without compaction
2%	2%	1%	0.5%

* SI 253 – Soil Classification for Civil Engineering Purposes – Laboratory and Visual Classification (Unified Method)
** SI 3 – mineral Aggregates from Natural Sources.

Note – Standards referenced: ASTM D3839-94a [16], ASTM D2321-89 [15]
These standards offer a different approach to soil classification, but recommend that,
through appropriate compaction of all types of backfill materials, a soil reaction modulus (E') of:
6,900 kN/m^2 (1,000 psi) be achieved as the minimum soil support for flexible pipe installations.

Load Design – Example

The following table provides the parameters for the pipe and its installation environment:

Notes	Units	Value	Parameter
Pipe diameter (inner)	1000	mm	Outer diameter: 1,090 mm
Ring stiffness	$SN\text{-}8$	$^{KN}/m^2$	
Cover height above pipe crown	2	m	
Trench width	1.2	m	
Expected live load	Main road	-	
Bedding material around pipe	Medium-compacted sand (90% Proctor)	-	
Soil density	2,000	$^{Kg}/m^3$	$20^{KN}/m^3$

Calculate the vertical deflection of the pipe.

Solution:

The calculation will be performed using the Spangler's formula, with the following parameter values:

Units	Value	Details	Parameter
DL	Deflection lag factor	1.3	-
K	Bedding constant	0.103	-
SN	Ring stiffness	8	$^{KN}/m^2$
E'	Soil reaction modulus	6,900	$^{KN}/m^2$

First, we calculate the constant (earth) load acting on the pipe.

$$W_c = C \cdot \gamma \cdot D_o \cdot B = 1.3 \cdot 2 \cdot 10^3 \cdot 1.09 \cdot 1.2 = 34 \cdot 10^3 [\frac{N}{m}]$$

Next, we calculate the live load acting on the pipe.

$$W_L = C_L \cdot P \cdot I_f = 0.234 \cdot 71.4 \cdot 10^3 \cdot 1.0 = 16.7 \cdot 10^3 \; [\frac{N}{m}]$$

We now substitute the values into Spangler's formula (be sure to use correct units!)

$$\Delta y = \frac{K \cdot (D_L \cdot W_C + W_L + W_F)}{8 \cdot S_n + 0.061 \cdot E'} = \frac{0.103 \cdot (1.3 \cdot 34 \cdot 10^3 + 16.7 \cdot 10^3)}{8 \cdot 8 + 0.061 \cdot 6900} \cong 12\,mm$$

$$\frac{\Delta y}{DN} = \frac{12\,\text{mm}}{1000\,\text{mm}} = 1.2\%$$

The expected deflection according to the Spangler model is 1.2%. To this result, we will add a statistical deviation coefficient of 1%, based on the defined installation conditions.

Therefore, the maximum expected long-term vertical deflection of the pipe under these conditions is 22 mm or 2.2% of the pipe's inner diameter.

3. Calculations

Notes: in order to evaluate deflection under site conditions shortly after installation, and for quality control of installation, the maximum short-term deflection values should be used (with DL = 1). To this deflection, a statistical deviation of 2% should be added, as described previously (see table on page xx).

If we take all the defined parameters and substitute them into the formula, we can generate a table showing the possible deflection under various scenarios.

	Clayey soils			Cobbles			Graded sand		Crushed stone	
Cover Depth	High compaction < 95% Proctor 70% rel. density	Medium compaction <85%-95% Proctor 40%-70% rel density	High compaction < 95% Proctor 70% rel. density	Medium compaction < 85%-95% Proctor 40%-70% rel density	High compaction > 95% Proctor 70% rel. density	Medium compaction85%- 95%> Proctor 40%-70% rel. density	Light compaction <85% Proctor 40% rel. density	High compaction < 95% Proctor 70% rel. density	Medium compaction <85%-95% Proctor 40%-70% rel. density	Light compaction <85% Proctor 40% rel. density
0.45	**4.67%**	**3.47%**	**1.64%**	**NA**	**2.93%**	**1.64%**	**3.65%**	**1.92%**	**NA**	**2.62%**
1	**3.18%**	**1.89%**	**1.25%**	**4.21%**	**2.17%**	**1.25%**	**2.88%**	**1.52%**	**4.24%**	**2.21%**
1.5	**2.64%**	**1.59%**	**1.06%**	**3.61%**	**1.84%**	**1.06%**	**2.49%**	**1.31%**	**3.74%**	**1.93%**
2	**2.10%**	**1.32%**	**0.93%**	**3.13%**	**1.59%**	**0.93%**	**2.25%**	**1.18%**	**3.54%**	**1.81%**
2.5	**2.08%**	**1.33%**	**0.96%**	**3.23%**	**1.62%**	**0.96%**	**2.35%**	**1.23%**	**3.76%**	**1.92%**
3	**1.95%**	**1.27%**	**0.92%**	**3.15%**	**1.56%**	**0.92%**	**2.31%**	**1.20%**	**3.75%**	**1.89%**
3.5	**2.05%**	**1.38%**	**1.05%**	**3.50%**	**1.74%**	**1.05%**	**2.65%**	**1.38%**	**4.41%**	**2.23%**
4	**2.05%**	**1.42%**	**1.10%**	**3.66%**	**1.82%**	**1.10%**	**2.83%**	**1.47%**	**4.78%**	**2.41%**
4.5	**2.07%**	**1.47%**	**1.17%**	**3.86%**	**1.91%**	**1.17%**	**3.03%**	**1.58%**	**NA**	**2.61%**
5	**2.15%**	**1.55%**	**1.25%**	**4.11%**	**2.03%**	**1.25%**	**3.26%**	**1.70%**	**NA**	**2.83%**
6	**2.26%**	**1.69%**	**1.41%**	**4.59%**	**2.27%**	**1.41%**	**3.72%**	**1.94%**	**NA**	**3.28%**
7	**2.33%**	**1.82%**	**1.56%**	**NA**	**2.48%**	**1.56%**	**4.16%**	**2.17%**	**NA**	**3.73%**
8	**2.39%**	**1.93%**	**1.70%**	**NA**	**2.69%**	**1.70%**	**4.60%**	**2.40%**	**NA**	**4.17%**

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3.3 Installation Guidelines for Paladex Pipe – Buoyancy Prevention

The light weight of the **Paladex** pipe is one of its main advantages, making the installation process easier. However, for that same reason, the pipe tends to float. It should be noted that almost all types of piping are prone to buoyancy under certain conditions. In fact, if the buoyant force exceeds the weight of the overlying soil anchoring the pipe, pipe displacement may occur. In situations where buoyancy is possible due to the presence of groundwater or another water source, proper installation and anchoring of the pipe are critical. The following calculations provide an analysis of the minimum required cover height needed to prevent pipe from floating. Another solution is, of course, anchoring the pipe to the ground.

3.4 Pipe Buoyancy in the Presence of Groundwater

Buoyancy becomes a concern for buried pipes when groundwater infiltrates the pipe zone. In projects where the groundwater level is high or where water surrounds the pipe, precautionary measures must be taken to prevent the pipe from floating. Under appropriate conditions, increasing the pipe cover height can help prevent buoyancy.

The vertical hydrostatic force (U) causing the pipe to float, due to the water level, can be calculated using the following formula:

$$U = \frac{\pi}{4} \cdot D^2 \cdot \delta_w \; [\frac{Kg}{m}]$$

Where:

Value	Description	Units
Kg/m^3	Buoyant force per unit length	U
m	Outer diameter of the pipe	D
Kg/m^3	Specific weight of water (typically 1000 kg/m^3)	δ_w

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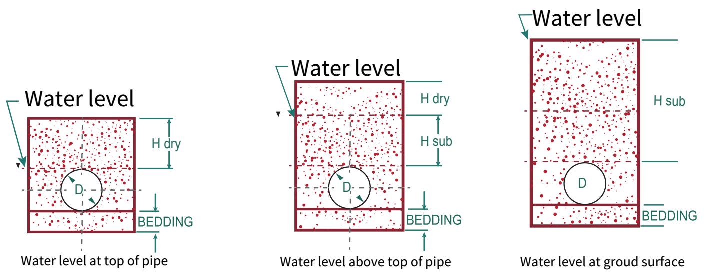
3. Calculations

To ensure that the pipe does not float, the buoyant force must be less than the total load acting on the pipe and the pipe's own weight. The required soil load—depending on various groundwater depths—can be calculated using the following formula, which is applied according to the position of the water level relative to the pipe, as illustrated in the diagram below.

$$W_{soil} = \delta_{dry} \cdot H_{dry} \cdot D + (\delta_{sat} - \delta_{w}) \cdot (H_{sub} + 0.1073D) \cdot D \left[\frac{Kg}{m}\right]$$

Where:

Units	Description	Value
W_{soil}	Soil load acting on the pipe	Kg/m^3
δ_{dry}	Specific weight of dry soil, (typically 1920 kg/m^3)	Kg/m^3
H_{dry}	Depth of dry soil above the pipe	m
H_{sub}	Depth of soil below the groundwater level	m
δ_{sat}	Specific weight of saturated soil, (typically 2280 kg/m^3)	Kg/m^3
δ_{w}	Specific weight of water (typically 1000 kg/m^3)	Kg/m^3
D	Outer diameter of the pipe	m



Configuration of groundwater relative to the pipe

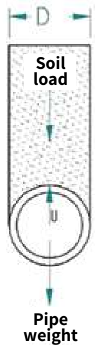
3. Calculations

Below is a table of pipe diameters and their weights:

Weight (kg per meter)	Outer diameter (mm)	Inner diameter (mm)
400	440	10
500	545	14
600	654	18
700	772	21
800	872	27
1000	1082	37
1200	1282	42

Weight (kg per meter)	Outer diameter (mm)	Inner diameter (mm)
1250	1332	51
1400	1462	75
1500	1590	89
1600	1690	90
1800	1890	135
2000	2090	151
2200	2290	161
2500	2590	186

The minimum required cover height to counteract buoyancy can be calculated by comparing the sum of the upward forces acting on the pipe (buoyant forces) with those that resist flotation (soil load). There are many methods for calculating soil load, but the conservative approach is to assume that the soil column directly above the pipe provides the resisting load – as illustrated in the diagram. Accordingly, the required cover height is calculated using the following formulas:



Where:

$$U \leq W_{soil} + W_{pipe} \qquad H = H_{dry} + H_{sub}$$

Units	Description	Value
U	Buoyant force per unit length	Kg/m
W_{soil}	Weight of the overlying soil	Kg/m
W_{pipe}	Weight of the pipe	Kg/m

Units	Description	Value
H_{dry}	Depth of dry soil above the pipe	m
H_{sub}	Depth of soil below the groundwater table	m

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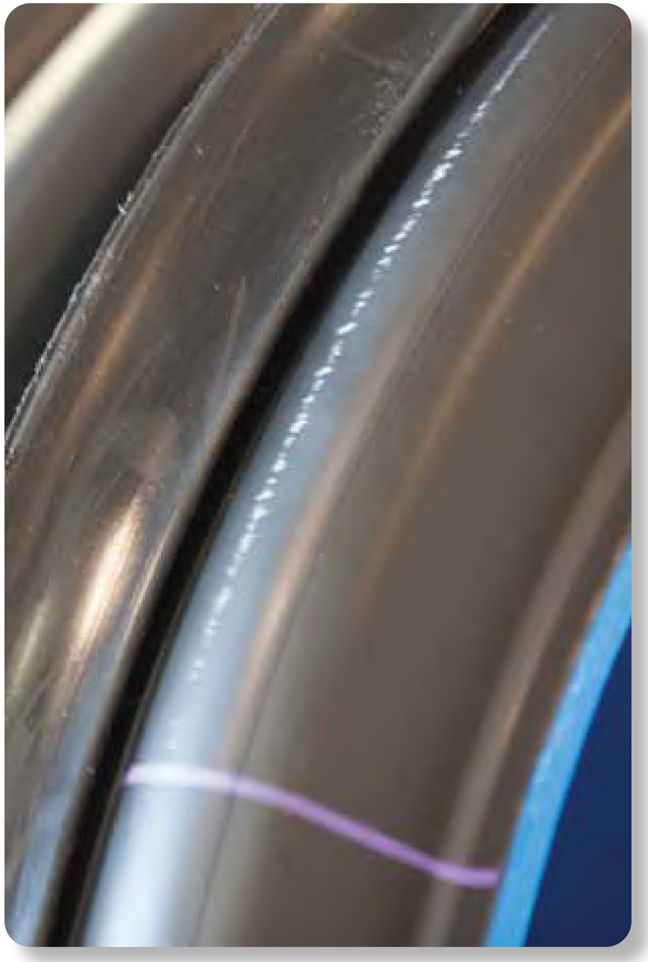
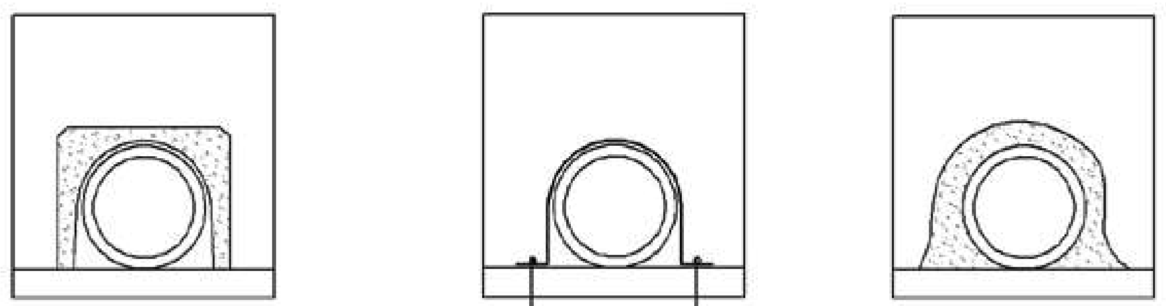
3. Calculations



The following assumptions are used to determine minimum coverage requirements for applications where installation conditions vary. The possibility of pipe flotation must be evaluated according to the defined site conditions.

- The assumption that the pipe is empty – this not only simplifies the calculation, but also represents a condition in which the buoyant force is greater (i.e., more conservative).
- The outer diameter of the corrugated pipe is used to determine the soil load applied to it and contributes to preventing displacement.
- A saturated soil density of approximately 2,280 kg/m^3 is used, which is typical for many soil mixtures. Denser soils will reduce the risk of flotation.
- When the water table is at ground level, as illustrated in the right-hand diagram (see previous page), this represents fully saturated soil. This is considered a worst-case scenario, yielding more conservative design results.

In certain cases, alternative anchoring methods may be used to restrain the pipe and prevent flotation, as shown in the diagram above. The maximum spacing between anchors shall not exceed 3.0 meters. For 7-meter-long pipes, anchors are placed at each joint and at the midpoint of the pipe to ensure stability.



Precast concrete collar | **Securing the pipe using an anchor and bolts** | **Securing the pipe with concrete**

Pipe anchoring methods for buoyancy prevention

3.5 Buoyancy Due to CLSM Backfill

Backfilling with CLSM (Controlled Low Strength Material) facilitates the installation process, but can cause the pipe to float. Buoyancy due to CLSM backfill is calculated using the following equation:

$$U_{CLSM} = \frac{A_{disp} \cdot \delta_{CLSM}}{144} \left[\frac{Kg}{m}\right]$$

Where:

Units	Description	Value
U_{CLMS}	Buoyant force per unit length	$^{Kg}/_{m}$
A_{disp}	Fill area (the space between the trench and the pipe)	m^2
δ_{CLMS}	Specific weight of CLSM (typically 1850–2300 kg/m³)	$^{Kg}/_{m^3}$

Due to the significant difference between the weight of water and the weight of CLSM, the resulting buoyant force can be more than twice that of hydrostatic uplift. Therefore, when using CLSM for backfill, the pipe must remain aligned and stabilized. This can be achieved by anchoring the pipe using steel rods arranged in an X-shape over the top of the pipe and embedded into the trench walls, or by using other commercially available anchoring systems.

3.6 Calculating Paladex Pipe Deflection: Theory vs. Practice

Field Test Summary Led by Dr. Mark Telesnik – GEOTECH Ltd.

This document presents a comparison between measured vertical deformation and applied loads, as observed in a field test conducted on a Paladex pipe. The empirical measurements are compared with the theoretical calculations of pipe deformation and applied load according to the Spangler-Martson model under equivalent installation conditions. Test conditions were as follows:

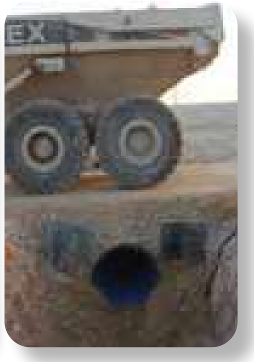
The test included several stages, the essence of which is described below. Sensors were placed in both the pipe and the surrounding soil to measure soil pressure and pipe deformation.

Pipe diameter: 800 mm Cover height: 45 cm

Compaction level: 95% Proctor Backfill material: pipe sand

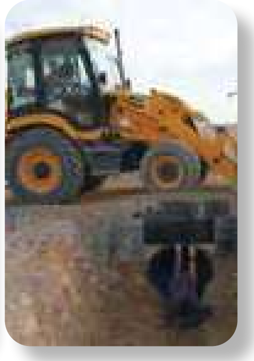
Operating conditions: vehicle traffic with varying loads was applied to simulate different real-world scenarios.

Full articulated 50.4 tons



Empty articulated 22.4 tons

Large roller 13.4 tons



Backhoe 4 tons

Small roller 2.7 tons

Sensors for measuring vertical and horizontal deformation

Load measurement sensors positioned at the top, bottom and sides of the pipe

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Test Results Graph:

Changes in pipe diameter (in mm) during the passage of a 50.4-ton loaded articulated dump truck with three axles. The X-axis represents the time axis during the passage of the truck over the pipe; the Y-axis shows the change in pipe diameter (in mm) along the vertical and horizontal axes. Each spike in the graph represents the passage of an axle. The red graph represents deformation along the vertical axis; the black graph shows deformation along the horizontal axis. It can be seen that the maximum vertical deformation occurred during the passage of the two rear axles and was less than 3 mm. Furthermore, the pipe returned to its original diameter after each transient load; in other words, no residual deformation occurred.

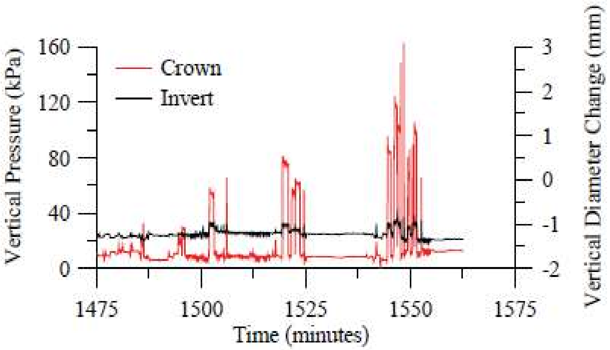
- The maximum deformation measured in the field test was less than 0.375%
- The maximum theoretical deformation, based on calculation, was 1.26% — nearly four times greater than the actual result.
- The Paladex pipe is capable of withstanding significant dynamic loads even under minimal cover height.

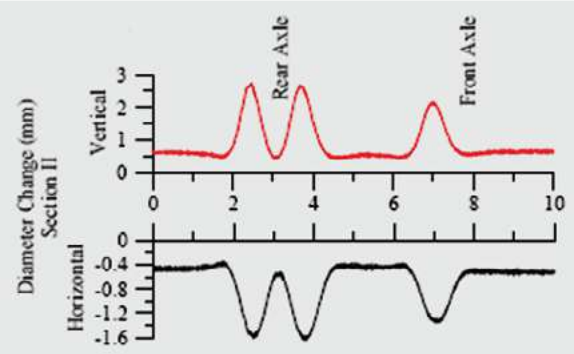
Load Resistance

During the testing phase, load measurements were taken on the pipe.
The following graph shows the loads experienced by the pipe at various points throughout the experiment. It should be noted that even when the articulated dump truck weighing over 50 tons passed over the pipe, the load “felt” by the pipe was approximately 160 kPa.

Test Results Graph (continued):

The actual measured deformation was significantly lower than predicted by the mathematical model based on the Spangler-Marston formula. It is evident that there is a coefficient (or ratio) between the actual deformation and the theoretical model, and thus it can be concluded that reliance on the model yields conservative results and provides a safety margin.





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Appendices

4. Appendices

4.1 Chemical Resistance Table

Material	Resistance
PE = Polyethylene	E = Excellent
	G = Good
	F = Fair
	N = Not Recommended

Paladex piping is made from plastic materials (HDPE), and therefore has high chemical resistance.

This information is based on data published by raw material manufacturers and is provided for the designer's professional consideration.

Below is a list of chemical resistance classifications for **Paladex** piping:

Chemical Resistance Classification:
E - Continuous exposure for 30 days with no damage.
G - Continuous exposure for 30 days with minimal damage.
F - Some effect after 7 days of exposure.
N - Not recommended for prolonged use.

Chemical	PE	PP
Acetaldehyde	G	G
Acetamide	E	E
Acetic Acid, 5%	E	E
Acetic Acid, 50%	E	E
Acetone	E	E
Aluminum Hydroxide	E	E
Ammonia	E	E
Ammonium Hydroxide	E	E
Ammonium Oxalate	E	E
n-Amyl Acetate	E	G
Amyl Chloride	F	N
Aniline	E	G
Benzaldehyde	E	E
Benzene	G	G
Benzoic Acid, Sat.	E	E
Benzyl Acetate	E	E
Boric Acid	E	E
Bromine	F	N

Chemical	PE	PP
Bromobenzene	F	N
n-Butyl Acetate	E	G
sec-Butyl Alcohol	E	E
Butyric Acid	F	N
Calcium Hypochlorite	E	E
Carbazole	E	E
Carbon Disulfide	N	E
Carbon Tetrachloride	G	G
Chlorine	G	G
Chloroacetic Acid	E	E
Chloroform	G	G
Chromic Acid	E	E
Citric Acid	E	E
Cresol	F	E
Cyclohexane	E	G
Decalin	E	G
o-Dichlorobenzene	F	F
p-Dichlorobenzene	G	E
Diethyl Benzene	F	N
Diethyl Ether	F	N
Diethyl Ketone	G	G

Chemical	PE	PP
Diethyl Malonate	E	E
Dimethyl Formamide	E	E
Ether	F	N
Ethyl Acetate	E	E
Ethyl Benzene	G	F
Ethyl Benzoate	G	G
Ethyl Butyrate	G	G
Ethyl Chloride, Liquid	G	F
Ethyl Cyanoacetate	E	E
Ethyl Lactate	E	E
Ethylene Chloride	G	G
Ethylene Glycol	E	E
Ethylene Oxide	G	F
Fluorine	G	G
Formic Acid, 50%	E	E
Formic Acid, 90-100%	E	E
Fuel Oil	G	E
Gasoline	G	E
Glycerine	E	E
n-Heptane	G	E
Hexane	G	E

Chemical	PE	PP
Hydrochloric Acid, 1-5%	E	E
Hydrochloric Acid, 35%	E	E
Hydrofluoric Acid, 4%	E	E
Hydrofluoric Acid, 48%	E	E
Hydrogen	E	E
Hydrogen Peroxide	E	E
Isopropyl Acetate	E	G
Isopropyl Benzene	G	F
Kerosene	G	G
Lactic Acid, 3%	E	E
Lactic Acid, 85%	E	E
Magnesium Salts	E	E
Methoxyethyl Oleate	E	E
Methyl Ethyl Ketone	E	E
Methyl Isobutyl Ketone	E	G
Methyl Propyl Ketone	E	G
Methylene Chloride	G	F
Nitric Acid, 50%	G	G

Chemical	PE	PP
Nitric Acid, 70%	G	G
Nitrobenzene	G	F
n-Octane	E	E
Orange Oil	G	G
Perchloric Acid	G	G
Perchloroethylene	N	N
Phenol, Crystals	G	G
Phosphoric Acid, 1-5%	E	E
Phosphoric Acid, 85%	E	E
Potassium Hydroxide	E	E
Propane Gas	F	N
Propylene Glycol	E	E
Propylene Oxide	E	E
Resorcinol	E	E
Salicylaldehyde	E	E
Sulfuric Acid, 1-6%	E	E
Sulfuric Acid, 20%	E	E
Sulfuric Acid, 60%	E	E

Chemical	PE	PP
Sulfuric Acid, 98%	E	E
Sulfur Dioxide, Liq.	F	F
Sulfur Salts	G	G
Tartaric Acid	E	E
Tetrahydrofuran	G	G
Thionyl Chloride	N	N
Toluene	G	G
Trichloroethane	F	F
Trichloroethylene	F	F
Turpentine	G	G
Vinylidene Chloride	F	F
Xylene	G	G
Zinc Salts/Stearate	E	E

4.2 Installation Instructions for Paladex Pipes

General

1. **Paladex** pipes are approved for Standard Marking under Israeli Standards SI 5302 and SI 21138, with a ring stiffness rating of SN8.
2. The pipes are intended for drainage, stormwater, and underground sewage systems.
3. The pipes are manufactured in 6- or 7-meter lengths, or as specified by the customer.
4. The pipes are supplied with EPDM rubber gaskets matching the pipe diameter.
5. Connections between pipes shall be made using bell-and-spigot couplings.
6. Fittings made from **Paladex** pipe shall be produced according to the designer's specifications and adapted to the bell-and-spigot connection method.

Unloading and handling

- Loading, unloading, and transporting the pipes on the site must be done carefully, using appropriate mechanical equipment in order to avoid damaging the pipe.
- Pipes shall be unloaded and handled using certified lifting straps (with a minimum width of 50 mm).
- Do not use chains or ropes of any kind, nor insert a strap, chain, or rope through the pipe.

Trench Excavation for Pipe Installation

- Trench excavation shall be carried out in accordance with the plans and in compliance with all applicable safety laws and regulations.
- Excavation depth shall be as defined by the designer and adapted to the type of soil.
- Trenching should be performed as close as possible to the time of pipe installation.

≤ 450mm

> 500mm

Trench width
- The trench width must be sufficient for pipe installation and compaction of the surrounding backfill.
- The minimum clearance between the pipe wall and each trench wall must be approximately 30 cm.
- If the native soil at the site cannot provide the required lateral support for the pipe as per the design, the trench shall be widened according to the instructions of the design engineer.

Trench bottom
- The bottom of the trench shall be stable and level. The longitudinal slope will be as designed.
- The trench bottom shall be free of any stones, clumps, roots, or protrusions larger than 5 cm.
- If the pipe is installed beneath a roadway, the trench bottom shall be compacted to match the compaction level of the road subgrade.
- During pipe installatoin, the trench must remain dry.

Trench bedding
- The trench bottom shall be bedded with a stone-free base layer. The bedding material shall be spread evenly along the entire trench and leveled according to the designed pipe slope.
- The bedding layer must provide uniform and stable support along the full length of the pipe.
- The minimum thickness of the bedding layer shall be 15 cm.
- Bedding shall be made of selected sand or compacted granular material, free of debris and organic matter. It shall be compacted to a minimum of 95% Proctor density or 70% relative density, in accordance with Israeli Standard SI 1865.
- A 5 cm thick layer of selected sand should be spread over the compacted bedding to allow for easy leveling of the pipe.

4. Appendices

Pipe installation

- Pipe installation shall be carried out in accordance with a pre-approved plan prepared by a qualified designer.
- Deviation from the approved plan and the designer's instructions requires written approval from the designer.
- Pipes shall be installed only in a properly excavated trench.
- Pipes must not be placed directly on hard surfaces such as rock, concrete, or paved surfaces.

Pipe embedment backfill material

The materials used for trench bedding and backfilling around the pipe shall include:

- Selected sand (SM, SW, SP) in accordance with Israeli Standard SI 3.
- Granular material – Type A or B base (GM, GP)
- Gravel (GW) – in accordance with SI 1885 or SI 1886
- Maximum grain size of backfill material: 20.0 mm

Preliminary inspection

- All pipes and gaskets shall be visually inspected prior to installation to ensure they are in accordance with the design and free of damage or contamination.

Installation procedure

- Pipes hall be laid on a dry and well-drained bedding.
- Pipes will be laid in a straight line and according to the design slope.
- Installation should begin from the lowest point of the line.
- Pipes shall be laid so that direction of flow is from male to female end.
- Do not deviate from the designed slope or alignment. If an obstruction arises during installation that requires adjustment, instructions must be obtained from the designer.
- The invert of the pipe must be fully supported along its entire length by the bedding.

Guidelines for Pipe Installation Under Special Field Conditions

Anchoring pipes on steep slopes

- Pipes installed on a longitudinal slope greater than 12% must be anchored.
- Anchoring shall be done according to the designer’s instructions.

Groundwater

- Pipe installation must be carried out in a dry trench.
- The groundwater level in the trench must be lowered using appropriate means until backfilling is completed.
- The cover height must be sufficient to prevent pipe flotation.

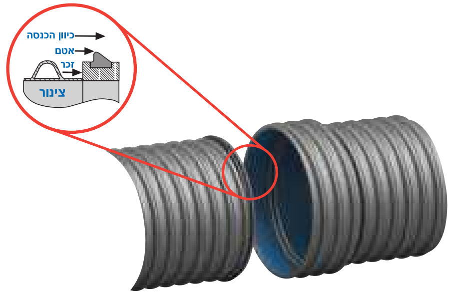
4. Appendices

Pipe connection

- Pipe connections shall be made using a bell-and-spigot joint, with the gasket supplied with the pipes.
- Make sure that the gasket is intact, free of defects, and clean.
- The pipe shall be connected so that the flow direction is from the male end to the female end.
- The pipe ends and gasket must be thoroughly cleaned before assembly.

Gasket installation

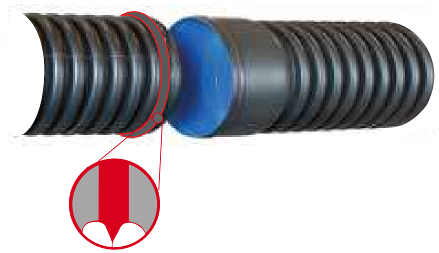
- **Paladex** pipe – install the gasket according to the diagram, on the male ring at the pipe end. Ensure that the orientation of the fin is correct.
- **Paladu** pipe – install the gasket according to the diagram, on the first groove from the pipe end.
- Apply lubricant (supplied by the manufacturer only) to the gasket and inner surface of the bell.
- The pipe connection shall be made by pushing pipe to pipe, using tension straps only.
- Pipe alignment must be done manually.
- Insertion depth will be up to the stop - 240 mm (marked with a white stripe on the outer surface of the pipe of the male end).
- The pipe must not be deflected more than 1°.



Pushing the pipe with any equipment other than tension straps is strictly prohibited.

Backfilling and covering

Backfilling of the trench after pipe installation shall be carried out in two stages:
1. Initial backfill – from the pipe invert up to at least 15 cm above the pipe crown.
2. Final backfill and cover.



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Initial backfill

The initial backfill is intended to provide the pipe with support and stability, prevent displacement, reduce deformation, and protect it from impact by hard objects. The backfill material shall be:

- Selected sand (SM, SW, SP) in accordance with Israeli Standard SI 3.
- Granular material – Type A or B base (GM, GP)
- Gravel (GW) – in accordance with SI 1885 or SI 1886
- Backfill shall be spread across the full width of the trench on both sides of the pipe, in layers of now more
- than 20 cm.
- Each backfill layer shall be compacted on both sides of the pipe using a hand tamper or
- light compacting equipment (up to 1.2 tons) to the degree specified by the designer.
- If wetting of the backfill is required, it shall be done in a controlled manner, to avoid puddling or flotation of the pipe.

Final backfill

- Final backfill shall be carried out up to ground level.
- The material used may be native or imported soil, provided it contains no organic matter or stones larger than 30 mm, or as approved by the designer.
- Heavy compaction equipment may be used only if the total cover above the pipe crown exceeds 40 cm.
- In any case, no heavy vehicles shall be allowed to pass over the trench until final backfill and trench cover are fully completed.

Installation instructions for Paladex piping with CLSM backfill

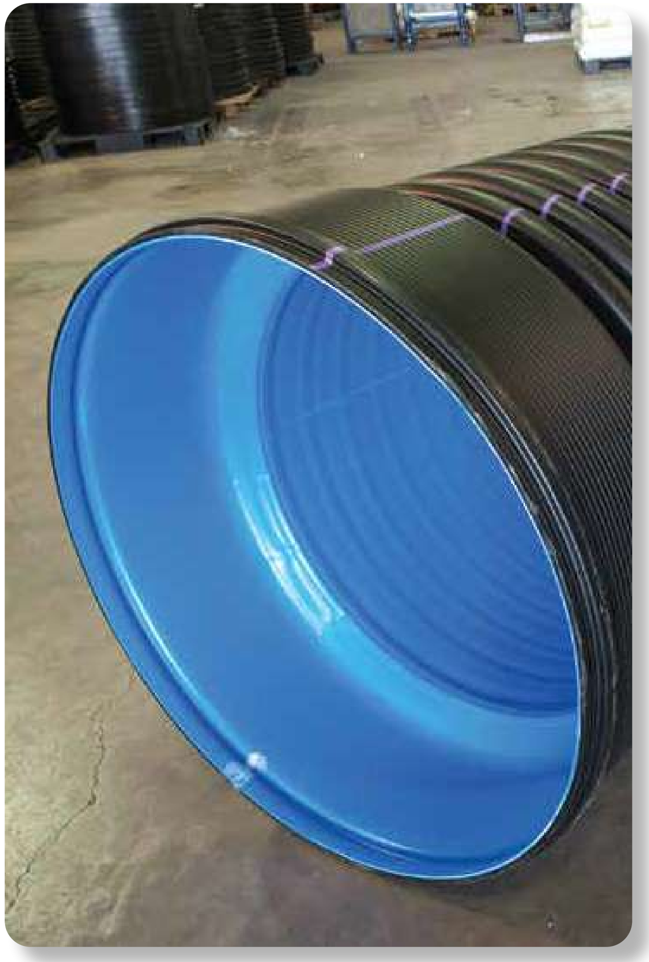
The use of CLSM (Controlled Low Strength Material) is not mandatory. Its use is subject to the designer's specification or based on other needs, such as rapid trench closure in densely populated areas or other relevant considerations.

Preparation for CLSM concrete backfill application

- Pipes shall be placed at the center of the excavated trench, resting on a compacted bedding in accordance with the plans approved by the designer.
- The position, depth, and slope of each pipe shall be measured by a licensed surveyor.
- The contractor must organize site operations so that CLSM concrete discharge is carried out continuously, enabling
- free flow over relatively long distances and ensuring proper filling of the trench void.
- The contractor must carefully plan the casting in advance and place barriers before pouring to prevent the concrete from flowing into unintended areas.
- In locations where the pipeline is installed on steep longitudinal slopes, casting shall be done in stages, with barriers in place to prevent accumulation of concrete in low areas.
- Temperature affects the concrete's setting time, casting process, and results – therefore, the contractor must consult with the concrete supplier regarding environmental conditions.

Pipe anchoring

- Due to its low self-weight, the pipe may shift from its position or even float in the material. Therefore, the contractor must securely anchor the pipes in place before the start of casting (using sandbags or other suitable anchoring methods).



Casting

- To reduce hydrostatic pressure on the pipe walls and trench, the concrete may be poured in stages/ layers. Each layer shall be poured only after the previously poured layer has set/hardened.
- During casting, care must be taken to ensure that the concrete is poured around the center of the pipe to prevent displacement. Avoid pouring directly onto the trench walls to reduce the risk of collapse.
- The casting height should exceed the crown of the pipe by at least 8-10 cm.
- No backfill layers shall be compacted over the concrete until it has reached a minimum strength of 0.35 MPa (typically 48–72 hours).
- Under no circumstances should vehicles be driven over the hardened material before eight (8) hours have passed since casting.

Field service, supervision and training

1. Detailed on-site guidance and supervision should be obtained from **Paladex** representatives regarding pipe installation instructions – through field service and in the presence of the project manager or their representative.
2. This guidance does not release the contractor from overall responsibility for the work and the product.

4.3 Pipeline Integrity Inspection

Introduction

The installation of underground piping requires inspection and quality control. It is important to identify issues and deviations from specifications before the pipeline is put into operation. In most cases, a visual inspection is sufficient to detect faults and issues along the line; however, in some instances, additional tools may be necessary to provide a quick and accurate assessment of the system's condition.

CCTV inspection

The contractor shall perform an internal visual inspection along the installed pipelines (water, sewage) using Closed-Circuit Television (CCTV) equipment. A camera will be inserted into the pipeline and move along its length. This inspection will take place after pipe installation, backfilling, and compaction of the required fill layers. The inspection process will be broadcast in real time on a closed-circuit monitor and recorded on a CD for documentation.

Deformation (deflection) testing

In cases where it is necessary to verify that the pipe deformation does not exceed the limits permitted by the standard, a deflection test may be performed up to approximately 30 days after installation. Since small changes in pipe diameter (a few percent) are difficult to detect visually, the most common and practical solution in such cases is to use a GO/NO-GO gauge.

The deflection test is performed using a GO/NO-GO gauge of the appropriate diameter, which is pulled through the pipe from manhole to manhole. If the gauge passes through the entire length of the pipe without obstruction, it may be concluded that the deflection is within the limits of the standard. The gauge is inserted at the upstream manhole and pulled with a rope to the downstream manhole. An example of a GO/NO-GO gauge can be seen in Figure 2.

Figure 1

Figure 2

4. Appendices

According to the Israeli standard for Paladex piping, the maximum allowable pipe deflection is 5% of the base diameter (i.e., the minimum internal diameter). The recommended maximum deflection is 3%. Table 1 defines recommended gauge diameters for conducting tests according to the standard requirement (5%) as well as according to the recommended limit (3%).

Pipe type (mm)	Minimum diameter	3%	8%
400	383	372	364
500	486	471	462
600	584	566	555
800	766	743	728

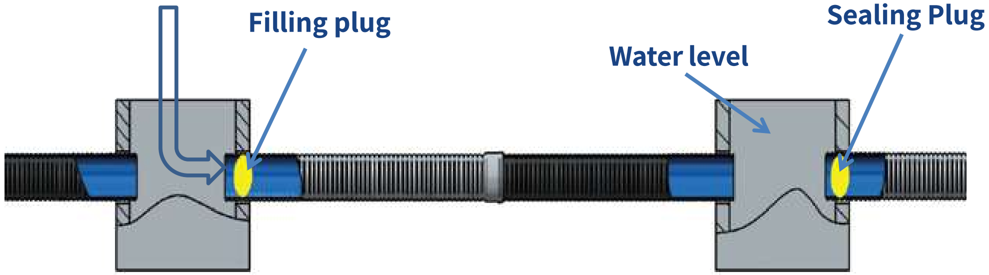
Table 1: Recommended GO/NO-GO Gauge Diameters for Deflection Testing in **Paladex** Piping

If a localized deformation issue is detected in the pipe, it may indicate external damage.
A local repair may be performed in the affected area. For pipe repair, contact Field Service.

Pipe tightness (leakage) test

The pipe section must be sealed at both ends using plugs. At the lower end, sealing is performed with a special plug that allows for filling and draining water. At the upper end, sealing is done at the opposite pipe opening. The section under test is then filled with water through the plug at the lower end until the water reaches the manhole at the upper end to a height of at least 1.5 meters above the bottom of the manhole.

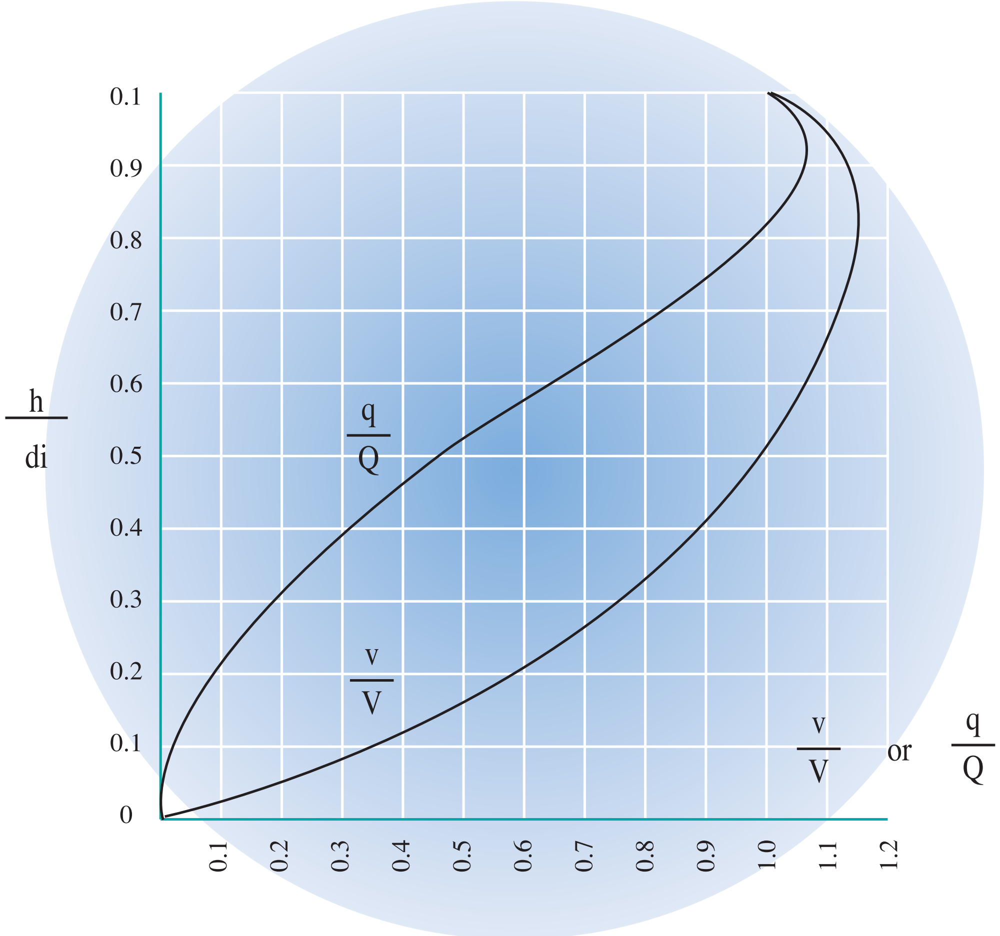
The water is held in the pipeline for 24 hours to allow concrete manholes to absorb water (this step may be skipped for plastic manholes). The line is refilled with the missing water until the level reaches at least 1.5 meters above the bottom of the manhole. This water level must be maintained continuously for at least 24 hours. If the test does not meet the criteria, the line must be repaired in accordance with the manufacturer's Field Service guidelines.



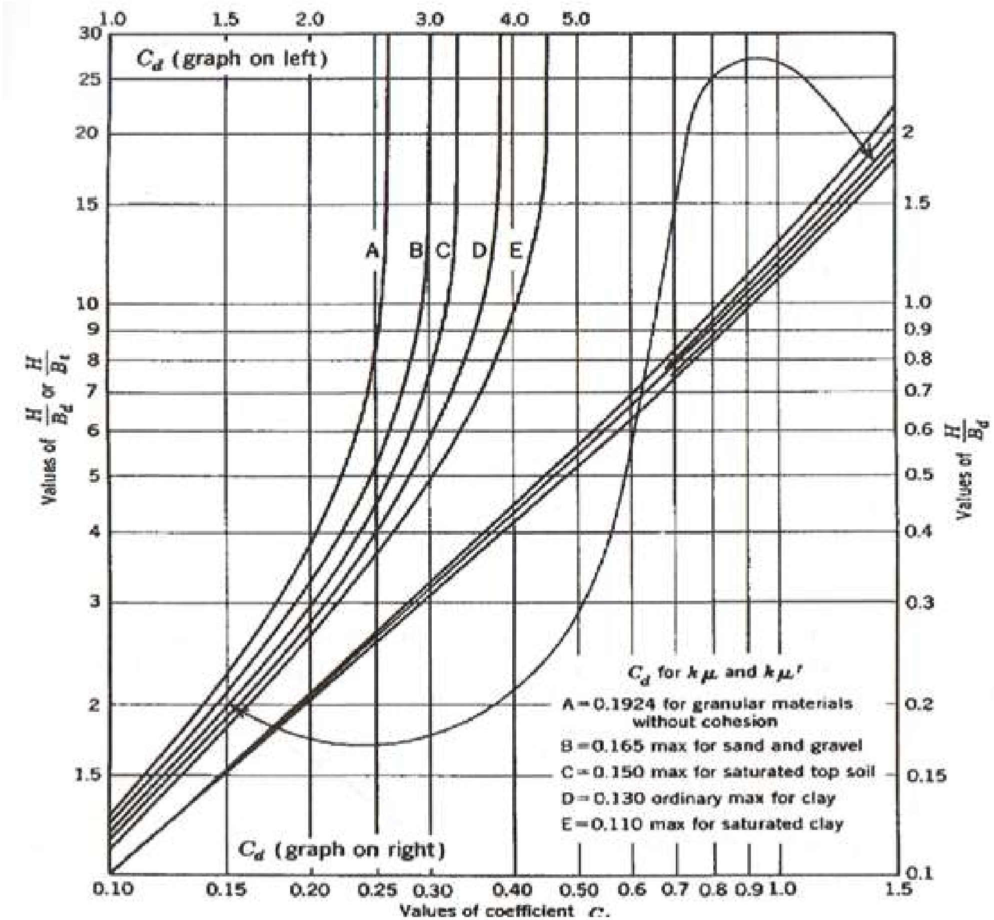
For pipes with diameters of 800 mm and above, joint tightness can be tested using dedicated testing devices.
Source: Installation Recommendations for Corrugated Pipe, CPPA – Plastic Pipe Institute

According to the Israeli standard for structured-wall polyethylene piping.

4.4 Flow Rate and Velocity vs. Fill Height Graph



4.5 Graph for Calculating Soil Loads



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4.6 Data for Sludge Separators

Inspection Diameter [mm]	Inlet/Outlet Diameter [mm]	Outlet Height [mm]	Inlet Height [mm]	Internal Length [mm]	Usable Volume [L]
710	150/150	1080	1100	1459	1940
710	200	1060	1080	1528	1940
710	200	1060	1080	1575	2000
710	250	1320	1340	1648	3000
710	315	1255	1275	2312	4000
710	315	1255	1275	2890	5000
800	315	1815	1835	1940	6500
800	315	1815	1835	2388	8000
800	315	1815	1835	2537	8500
800	315	1815	1835	2687	9000
800	315	1815	1835	2985	10000
800	400	1730	1750	3906	12500
800	400	1730	1750	4688	15000
800	400	1730	1750	5556	18000
800 (x2)	400	1930	1950	5128	20000
800 (x2)	400	1930	1950	6410	25000
800 (x2)	400	1930	1950	7692	30000

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