Guidelines for usage in roadway

Sewage pipes
Road drainage
Chambers ø 630

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We wish You an enjoyable and fruitful work with our catalogue.

Sławomir A. Stodólski

Prezes Zarządu
Pipelifi Polska S.A.

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GUIDELINES FOR USAGE OF PLASTIC SEWAGE PIPES IN ROADWAY

CERTIFIKAT JAKODGI
ISO 9001
LLOYD'S REGISTER

PIPELIFE
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1. INTRODUCTION

1.1 SCOPE

These guidelines focus on typical applications of PIPELIFE Polska plastics pipes for sanitary sewer and storm sewer systems laid under roads (in a road’s right-of-way).

The sequence chapters present the rules concerning the horizontal and the vertical alignments of sewers controlled by their purpose and related to the maintenance, the methods of pipe strength and deflection calculation, as well as requirements for earthworks, pipeline installation and workmanship.

The presented guidelines complement the PIPELIFE Polska general catalogue about applications of plastics sewer pipes in highway engineering.

These guidelines do not include detailed hydraulic dimensioning of sewers (diagrams) which are presented in the general PIPELIFE Polska Technical Catalogue, as well as in the professional literature. Besides, the guidelines do not include such subjects like, properties of plastic material, chemical, physical and mechanical characteristics of products, laboratory tests and control, as well as handling, storage, assembling of pipe, as all these problems are presented in international [EN] and Polish [PN] Standards.

1.2 DEFINITION OF TERMS

<table>
<thead>
<tr>
<th>No</th>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Accidental parking strip (emergency strip)</td>
<td>The side strip of the highway for stopping and parking technically immobilized vehicles</td>
</tr>
<tr>
<td>2</td>
<td>Carriageway (trafficway)</td>
<td>Part of road crown, usually paved that serves vehicles passing.</td>
</tr>
<tr>
<td>3</td>
<td>Category of mining area</td>
<td>Area of mining damage and deformation according to Polish Standard [15].</td>
</tr>
<tr>
<td>4</td>
<td>Culvert</td>
<td>This term is used to designate a facility for cross drainage to carry water beneath the roadway.</td>
</tr>
<tr>
<td>5</td>
<td>Gully, waste water inlet</td>
<td>The compact storm water inlet facility with openings to catch gutter flow and connected to storm sewer.</td>
</tr>
<tr>
<td>6</td>
<td>Gutter</td>
<td>Drainage providing slightly depressed area of paved bottom that collects and carry surface water to gully.</td>
</tr>
<tr>
<td>7</td>
<td>Lateral sewer</td>
<td>Sewer that collects discharges from houses or gullies and carries it to another branch sewer, or main sewer.</td>
</tr>
<tr>
<td>8</td>
<td>Main sewer (trunk sewer)</td>
<td>Sewer that carries the discharge from large area to the point of disposal.</td>
</tr>
<tr>
<td>9</td>
<td>Manhole (inspection chamber)</td>
<td>The structures of different sizes and material applied for sewers inspection and cleaning.</td>
</tr>
<tr>
<td>10</td>
<td>Median strip (dividing strip)</td>
<td>The part of road crown between carriageways (roadways) of opposite directions.</td>
</tr>
<tr>
<td>11</td>
<td>Pipe ring stiffness (SN)</td>
<td>Parameter used to classify sewer pipe which represents pipe operating capacity to external load, expressed in kPa, and is dependent on pipe diameter, pipe wall thickness and relaxation modulus of pipe material.</td>
</tr>
<tr>
<td>12</td>
<td>Rational method</td>
<td>Method used for storm sewer sizing based on assumption that period of rainfall is equal to the time concentration and intensity duration - frequency relationships.</td>
</tr>
</tbody>
</table>
PIPELIFE Polska offers a wide variety of plastics pipe systems which can be used for all types of sewers including road surface-water drainage. Sewer pipe system area manufactured from: polypropylene (PP), polyethylene (PE - HD), rigid polyvinyl chloride (PVC-U).

The PIPELIFE Polska products spectrum covers:
- sewer pipes made from PVC, PE, PP with nominal diameters from 50 to 3400 mm;
- branches 45° and 90° - equal and unequal;
- bends 15°, 30°, 45°, 67°, 87°;
- connectors, reducers, double sockets couplings, caps and plugs, access caps, flap gates, adoptors PP/PVC, PVC/PP and to cast-iron, concrete and stoneware pipes, sleeves, and in-situ manhole entries;
- inspection chambers ø 200, 315, 400, 630, 710 and 800 mm;
- manholes ø 1000 : 2000 mm;
- gully chambers ø 400 ÷ 630 mm;
- land and civil engineering perforated drainage pipes and fittings;
- culverts;

The detailed information on the assortment of PIPELIFE Polska products are included in the main PIPELIFE Polska technical catalogue, which is edited by the Producer and actualized as the products are introduced into the market.

Pipes, fittings and coupling elements made from PVC for the outdoor sewer systems are manufactured according to the Polish Standard PN-EN 1401-1.

Pipe systems made from polypropylene (PP) with structural pipe walls for sewers and drainage pipelines as well as for culverts laid under embankments have got Technical Approvals:
- AT/98-04-0506 of Highways and Bridges Research Institute, Warsaw and;
- AT/99-02-0752 of COBRTI - INSTAL

Besides inspection chambers for sewerage and drainage systems have obtained technical Approvals:
- AT/2000-02-0875 of COBRTI - INSTAL and;
- AT/97-03-0096 of Highways and Bridges Research Institute, Warsaw.
Design and installation requirements for sewer pipelines in the road right-of-way besides the ascertainment of the pipe bearing capacity to the imposed external loads, shall be coordinated with all Statutory Authorities having any interest in any part of the sewer installation, and in the case of a mining areas of categories II-IV (see: Polish Standard [15]) also with the Regional Mining Office.

As repairs of buried sewer pipe is a very hard task, which requires excavation and temporary shut-down of a road lane or even a section of a roadway, the location of sewers under roadways and in the right-of-way should conform to the obligatory acts and standards, especially in relation to motorways, expressways and highways of categories KR5 and KR6. All designed sewer pipelines layouts must be agreed with authorities and especially with highway authorities. The example location of a main storm sewer in the median strip of the motorway is shown in figure.

Requirements and standard recommendations concerning location of sewer pipelines are based on obligatory Acts, Decrees, Standard Codes of Practice in different fields of engineering, presented in Chapter 4. However, some regulations are not consistent. In the presented guidelines in the case of different recommendations as the obligatory the recommendations concerning highway engineering are accepted.
2.3.1 DISTANCES BETWEEN DIFFERENT UNDERGROUND UTILITIES AND SERVICES

Sewer pipelines laid along roadside have to be set at the distances not less than:
- 15.0 m - from monuments of nature;
- 2.5 m - from trees;
- 2.5 m - from the edge of road pavement;
- 2.0 m - from other sewer pipelines;
- 1.5 m - from water supply pipes;
- 1.5 m - from property borders and fencing;
- 1.0 ÷ 1.25 m from electricity high tension cables (HI) of 132 kV to 400 kV;
- 1.0 m - from overhead transmission line supports and telecommunication poles;
- 1.0 m - from pipes of heating systems;
- 1.0 m - from buried telecommunication cables;
- 0.75 ÷ 1.0 m - from electricity low and mean tension cables of 20 ÷ 132 kV;
- 0.5 m - from other electricity and telecommunication cables.

All the above distances ought to be treated as a minimal, measured to the outline of the pipes, chambers and other objects.

According to the Polish Decree [1], storm water inlets and sewer can be laid only in a range of ground shoulders verges or in median strips of motorways, in any case sewer can be placed in the emergency lane or in the road side band. The distances of sewers from gas piping are specified in the Polish Decree [4] and Polish Standard [21]. When the sewer pipeline is not related to the road function should be place at the longer distances. The Polish Act [2] specifies the distances from roads depending on the type of land development and the classes of roads. These distances are given in Table 3.

Table 3

<table>
<thead>
<tr>
<th>Class of road</th>
<th>Urban area</th>
<th>Sparsely settled area</th>
</tr>
</thead>
<tbody>
<tr>
<td>motorway</td>
<td>30m</td>
<td>50m</td>
</tr>
<tr>
<td>express way</td>
<td>20m</td>
<td>40m</td>
</tr>
<tr>
<td>national highway</td>
<td>10m</td>
<td>25m</td>
</tr>
<tr>
<td>provincial highway</td>
<td>8m</td>
<td>20m</td>
</tr>
<tr>
<td>local highway</td>
<td>6m</td>
<td>15m</td>
</tr>
</tbody>
</table>

2.3.2 DEPTHS OF SEWERS

Vertical alignment of sewers is guided by a number of rules. According to the Polish Regulation [5] the minimum cover of a pipe sewer under roads is 1.4 m, unless the pipe is protected with a special structure. Where the sewer is to be laid at the shallower depth, the checking calculations are necessary to prove the pipe bearing capacity. The protection structure can be accomplished with a properly compacted sandy-gravel backfill.

According to the Polish Decree [1], storm water inlets and sewer can be laid only in a range of ground shoulders verges or in median strips of motorways, in any case sewer can be placed in the emergency lane or in the road side band. The distances of sewers from gas piping are specified in the Polish Decree [4] and Polish Standard [21]. When the sewer pipeline is not related to the road function should be place at the longer distances. The Polish Act [2] specifies the distances from roads depending on the type of land development and the classes of roads. These distances are given in Table 3.

The Approval [45] of the Highways and Bridges Research Institute allow to use plastic pipes of structural walls as a culvert structures under roads, at the minimum required depth of cover 1.0 m over the crown of pipe.

Besides, to prevent frost damage, the minimum depth of sewer pipes cover shall to be not less than:
- 1.0 m - for the depth of frost penetration 0.8 m;
- 1.2 m - from the depth of frost penetration 1.0 m;
- 1.3 m - from the depth of frost penetration 1.2 m;

The map shows zones of frost penetration depths at the territory of Poland given in the Polish Standard [12].

Polish Standard [16] requires that the cover above the sewer to be 20 cm deeper than the depth of frost penetration given in the Standard [12].
The minimum recommended inside diameters of the storm sewers according to the Polish Regulation [3] and the Polish Standard [18] are as follows:

- 200 mm at sparsly settled area;
- 250 mm at urban area;

Besides, in the case of toll-expressway, the Polish Regulation [3] defines that the minimum recommended diameter of storm sewer is 300 mm.

The minimal slopes of storm sewers designated as surface drainage in the highway engineering are given in the Polish Standard [18].

The slopes given in Table 4 depend on the size of sewer, however at the depths of flow lower than 50% of full flow depth (half of diameter) the Standard [18] requires to check the slope of sewer for self-cleansing to avoid deposition of solids and clogging. The criterion is the value of shearing stresses \( t = 2.5 \) N/m², which require to provide large slopes of sewers.

The requirements regarding maximal values of slopes for sewers are different. The Polish Standard [11] concerning sewerage systems, states the following maximum slopes for various nominal diameters of plastic pipe sewers:

- 15% for \( d_n \leq 150 \) mm
- 10% for \( d_n = 200 \) mm
- 8% for \( d_n \geq 250 \) mm

Whereas, the Polish Guidelines [32] related to highways design states the following maximum slopes of sewers:

- 3% for \( d_n = 400 \) mm
- 2.5% for \( d_n = 500 \) mm
- 2% for \( d_n = 600 \) mm
- 1.5% for \( d_n = 800 \) mm
- 1% for \( d_n \geq 1000 \) mm

The most rational approach is presented in the Polish Standard [18], on surface water drainage on roads, which requires that flowing full velocities used in design of storm sewers were below 7 m/s, to prevent erosion of the pipe by grit transported in the water.
2.3.4 SEWER SERVICE CONNECTIONS AND GULLIES

For sanitary sewers service connections, the minimum required diameter is 150 mm, and the maximum length of line is 12.0 m. When the service connection is longer the required pipe diameter is 200 mm. In no case the run of service connection can exceed 20.0 m. The connection pipes can be placed at angles of 450 to 900, but the recommended angle is 600.

Whereas, the Polish Regulation [5] for sewer service connections, gives the following values of the minimum slopes:
- 1.5 % for \( d_n = 150 \) mm
- 1.0 % for \( d_n = 200 \) mm
and the Standard [11], the following values of minimum slopes:
- 0.8 % for \( d_n = 150 \) mm
- 0.5 % for \( d_n = 200 \) mm

The requirements related to the maximum slopes are the same as for sewers, presented in Section 2.3.3.

The Polish Standard [11] requires the sewer service connection flowing at the depth lower than a half of pipe diameter.

The Polish Guidelines [31, 32, 34, 61] referred to the design of storm-water inlets for road drainage are not the same.

The Guidelines [31] referred to the design of motorways and expressways recommend to calculate the distances between storm water inlets according to the rules from the Guidelines [34] or the manual [61]. These calculations are based on the storm having probability \( p=10\% \). Under such conditions there can be ponding of water on a roadway of a width not exceeding 50 cm, and storm-water inlets should to pick up the total discharge of surface run off.

The Guidelines [32] gives the distances between gullies for the various longitudinal slopes of a roadway gutters, they are listed below:

<table>
<thead>
<tr>
<th>Slope (as % of pipe axis)</th>
<th>Interval</th>
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</thead>
<tbody>
<tr>
<td>&lt;0.3%</td>
<td>40 ± 50m</td>
</tr>
<tr>
<td>0.3 ± 0.5%</td>
<td>50 ± 70m</td>
</tr>
<tr>
<td>0.5 ± 1.0%</td>
<td>70 ± 100m</td>
</tr>
<tr>
<td>&gt;1.0%</td>
<td>≤ 100m</td>
</tr>
</tbody>
</table>

Gully chambers have to be equipped with sediment trap of the depth 80 cm. If a gully is without sediment trap, the manhole with sediment trap should be installed at the sewer to which the gully is connected.

Any storm-water inlet incorporated in combined sewer system must be trapped with sufficient seal depth to prevent syphonage. The minimum depth of water level below the surface in the gully chamber or in the trap should be at least as follows:
- 1.5 m - for the depth of frost penetration 0.8 m;
- 1.6 m - for the depth of frost penetration 1.0 m;
- 1.7 m - for the depth of frost penetration 1.2 m.

2.3.5 OTHER DESIGN CRITERIA.

Sewers should cross the roadway centre line at angles close to 900 and not less then 750. The depth of cover over under road should be at least 1.4 m, if the depth of cover is less, a protection structure should be provided.

Inspection chambers and manholes should be placed: at all changes in sewer grade, pipe size, or alignment; at all intersection, at the end of each line, and on long straight lengths-manholes should be provided at distances:
- 50 m - on sewers of diameters to 1000 mm;
- 60 m - on sewers of diameters to 1400 mm;
- 60 - 80 m - on larger diameter sewers.

The Polish Regulation [1] in respect to the storm water sewers for motorways gives the following distances for manholes:
- 40 m - on sewers of diameters to 600 mm;
- 50 m - on sewers of diameters to 800 mm;
- 60 m - on sewers of diameters to 1000 mm;
- 100 m - on sewers of diameters to 1500 mm.

Usage of inspection chambers and manholes structures, manufactured from plastic materials, of streamlined shapes as well as the modern equipment used for sewerage systems inspection and maintenance enable that shorter distances between chambers can be accepted (of 80 m and even 100 m for the size of 200 mm).

A properly constructed outfall is to be provided wherever a surface water sewer discharges into an open channel. The invert, wherever possible, should be positioned at least 20 cm above the ditch bottom.

2.4 CULVERTS BENEATH ROADS

PP and PE pipes may be used to build culverts under railways, highways, service and access roads, as well as for trenchless reporations of the concrete culverts by the relining method.

PP Pragma® pipes are offered for culverts in sections of standard length of 6 m and 8 m, PE pipes are manufactured in sections of the length 12 m. Whereas, longer sections can be delivered for individual orders. In such a case the pipe for culvert is prepared according to an individual design. The culvert pipe inlet and outlet ends can be cut at right angle or at sloping ends suitable to the fill slopes as well as to the angle of culvert passing through the road embankment. Placing the culvert at the right angle is recommended but generally the deviation angle should not exceed 15°.

Culverts should be capable of accommodating the anticipated design flow. Culverts can operate under different upstream and downstream control conditions as:
- culverts with the inlet end unsubmerged;
- culverts with the inlet end partly submerged and with the outlet end unsubmerged;
- culverts of pressure flow, with the inlet end submerged and outlet end submerged.

At streams and water-courses where during flood flows different object, trees and other large buoyant materials can be transported which
1. Designing of submerged culverts is not recommended because damming up of water at the inlet will require protection lining of ditch slopes and bottom at the upstream end as well as at the downstream end. In the case when the pressure of flow through culvert is unavoidable, the water level at the upstream end of culvert should not exceed 20 cm over the crown of pipe.

Irrespective of hydraulic calculations, mandatory minimum inside diameters of culverts for various lengths are listed in Table 5.

It is recommended to design culverts of slopes 0.5% ÷ 3.5%, and the minimum and maximum permitted culvert slope is 0.2% and 3.5% respectively. If the depth of flow in the culvert is lower than 50% of pipe diameter, the criteria for slopes like for sewers should be used.

Hydraulic calculations of culverts differ from calculations of sanitary or storm water sewers. The detailed description of culverts calculations under various conditions are presented in the Polish Guidelines [35].

When designing culverts attention must be paid to the design loads expected. Pipe strength and bedding must be adequate to withstand these loads. Plastic PP and PE pipes can be used beneath roads with very heavy load (exceeding standard loading), but the strength - stress calculation have to be carried out, and condition of performance defined to:

- earth work technique;
- bedding conditions;
- trench width;
- backfill material and degree of compaction;
- minimum and maximum depth of burial.

The minimum depth of burial of the culvert measured from surface of road crown should be not less than 0.5 m, when the depth of burial is less than 1.0 m it is necessary to perform strength calculation to state whether the bearing capacity limits of pipe are not exceeded.

2.5 HYDRAULIC DESIGN OF SEWER PIPES

Storm water sewers connected with road function involve disposal of water falling on the roadway. Pavements are generally crowned or cambered so as to carry water to lateral gutters (or ditches), which in turn carry water to the point of disposal without damaging or impairing the utility of highway or street.

Before any attempt is made to provide surface drainage, the amount of water that will have to be disposed of must be known. The quantity of water reaching any point during or following a storm is dependent upon the area contributing flow, the type and depth of soil a surface over which flow occurs and the slope and other typographic features of drainage area, as well as the rate at which the water reaches the point of question.

The method extensively used in designing storm sewer systems is the rational method. The algorithm of calculation based on the rational method is described in the Polish Standard [18] related to surface drainage of highways. The peak discharge design storm used in dimensioning of the storm sewer system is calculated on the base of recurrence interval, average rainfall intensity during a period of time equal to the time of concentration and the tributary area. The Standard [18] give also the necessary to calculation dimensionless runoff coefficients proportional to area imperviousness and requirements concerning minimal values of pipeline slopes and diameters.

<table>
<thead>
<tr>
<th>Length of culvert (m)</th>
<th>National and provincial highways</th>
<th>Local highways and unpaved roads</th>
<th>Cycle tracks and sidewalks</th>
<th>Railways</th>
</tr>
</thead>
<tbody>
<tr>
<td>L&lt;10</td>
<td>600</td>
<td>400</td>
<td>300*</td>
<td>800</td>
</tr>
<tr>
<td>10 ≤ L ≤ 20</td>
<td>900</td>
<td>600</td>
<td>400</td>
<td>800</td>
</tr>
<tr>
<td>L&gt;20</td>
<td>1200</td>
<td>800</td>
<td>500</td>
<td>800</td>
</tr>
</tbody>
</table>

* Culverts under exits from local roads can be of 250 mm in diameter.
Actual Polish regulations for buried conduits do not include any strength calculations of flexible pipes, and the method used for rigid pipes are not adequate. The method giving sufficiently accurate results, is the method based on Scandinavian Standard [24] and elaborations [63], this method is referred to as the Scandinavian Method (SM).

Hydraulic design of sewer pipes is a tedious task requiring several trials to obtain the most economical design. Therefore, for convenience of designers PIPELIFE company has prepared nomographs to determine hydraulic parameters of gravity sewer pipes. Those nomographs are included in the general PIPELIFE Polska Technical Catalogue [51].

A difference in design approach between sanitary and storm sewer is that the storm drainage pipes at the design peak discharge are flowing full.

According to Polish Standard [18] sewer slopes should be sufficient to maintain self-cleansing velocities, especially at small depths of flow in pipe. The self-cleansing condition is formulated as the critical shearing stresses ($\tau$). The standard [18] requires that at small depths of flow the shearing stress should be at least 2.5 N/m$^2$. It is a big value which require slopes much higher than the slopes requirement in the Polish Standard [11] and according to the commonly used formula: $I [\%] = 100/D [mm]$.

The standards obligatory in other countries are less restrictive. For example the Danish Standard (DS - 432) concerning sewers, requires that the value of shearing stress should be at least 2.45 N/m$^2$ in the case of sanitary severs and combined sewers, and 1.47 N/m$^2$ for storm sewers.

Besides, this standard permits to reduce the above given shearing stress by 10% for plastic pipe sewers, to the values of 2.21 N/m$^2$ and 1.32 N/m$^2$, respectively.

The basic formulae used for sewer pipe hydraulic calculations are:
- The Colebrook - White formula, for pipes flowing full:
  $$Q_o = -6.95 \times \log\left(\frac{0.74}{D \times \sqrt{1 + 10^{-6} \times \frac{k}{3.71 \times D}}}\right) \times D^{3/2} \times I$$  

- The Bretting formula for pipes flowing partly full:
  $$\frac{Q}{Q_o} = 0.46 - 0.5 \times \cos\left(\pi \times \frac{h}{D}\right) + 0.04 \times \cos\left(2 \times \pi \times \frac{h}{D}\right)$$

### 2.5.2 FLOW RATE IN PIPE

### 2.5.3 SELF-CLEANSING CONDITIONS

### 2.6 STRENGTH ANALYSIS OF BURIED PLASTIC PIPE

Actual Polish regulations for buried conduits do not include any strength calculations of flexible pipes, and the method used for rigid pipes are not adequate. The method giving sufficiently accurate results, is the method based on Scandinavian Standard [24] and elaborations [63], this method is referred to as the Scandinavian Method (SM).

It is recommended to calculate the strength of the conduit in any design conditions. The Standard [24], on the base of the up to the present experience does not require calculation of pipe strain for typical common applications, under following pipe installation conditions:
- maximum depth of burial not exceed 6 m;
- minimum depth of burial is 1 m at traffic load;
- pipe bedding layer, sidefill and initial backfill are made of gravel and sandy material with the patride size of 0.075 mm not exceeding 10%, properly compacted to the 90% of modified Proctor test density;
- pipes show any damages or deformation of cross-section;
- short-term pipe ring stiffness (SN) is not less than 4, and for pipes under roads of heavy traffic SN $\geq 8$;
- maximum permissible initial deflection of pipe after installation does not exceed 8% and 9% for PVC pipes and PP or PE pipes, respectively.
When the above conditions are not fulfilled, the strength checking calculations are required.

The Scandinavian Method is based on the assumption that flexible plastic pipes make use of the horizontally acting soil support ($q_h$) as a result of vertical deflection of pipe ($\delta$) under vertical load ($q$). In the Scandinavian Model the soil pressure distribution is of parabolic shape. The better are soil parameters and soil support the lower is pipe deflection.

The design concept of flexible pipes is described with the Sprangler formula, as:

$$\frac{\delta}{D} = \frac{f(q)}{SN + S_s} \quad (3)$$

The soil stiffness ($S_s$) is determined by the secant modulus of the soil ($E'_s$). For typical soil materials used for fills like gravels and sands of unit weight $\gamma = 19$ kN/ m$^3$ the secant modulus ($E'_s$) depends mainly on the degree of soil compaction and the fill height [$63$], as illustrated in figures.

### Table 7

<table>
<thead>
<tr>
<th>No.</th>
<th>Symbol</th>
<th>Unit</th>
<th>Quantity and application</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$\alpha$</td>
<td>—</td>
<td>coefficient of reduction of buckling stress</td>
</tr>
<tr>
<td>2</td>
<td>$B_s$</td>
<td>%</td>
<td>bedding factor - empirical value referred to quality and supervision of bottom conditions</td>
</tr>
<tr>
<td>3</td>
<td>$C$</td>
<td>—</td>
<td>coefficient of traffic load dependent on road class and load category</td>
</tr>
<tr>
<td>4</td>
<td>$D$</td>
<td>m</td>
<td>outside pipe diameter</td>
</tr>
<tr>
<td>5</td>
<td>$E$</td>
<td>kPa</td>
<td>modulus of elasticity of pipe material</td>
</tr>
<tr>
<td>6</td>
<td>$E'_s$</td>
<td>kPa</td>
<td>secant modulus of the soil</td>
</tr>
<tr>
<td>7</td>
<td>$E_s$</td>
<td>Mpa</td>
<td>secondary modulus of soil</td>
</tr>
<tr>
<td>8</td>
<td>$\phi$</td>
<td>—</td>
<td>factor of safety for traffic load</td>
</tr>
<tr>
<td>9</td>
<td>$h$</td>
<td>m</td>
<td>thickness of soil layer</td>
</tr>
<tr>
<td>10</td>
<td>$H$</td>
<td>m</td>
<td>depth of the cover of the pipe</td>
</tr>
<tr>
<td>11</td>
<td>$h_o$</td>
<td>m</td>
<td>height of the ground water table over pipe</td>
</tr>
</tbody>
</table>
External static loads on a buried pipeline are imposed by the weight of the soil and by any extra loads imposed by structures (bearing directly over the pipe). The vertical load imposed by soil is calculated as follows:

\[ q_z = \sum_{i=1}^{n} \gamma_i \cdot h_i \]  \hspace{1cm} (4)

remembering that below groundwater table water saturated unit weight of the soil (\(\gamma\)) have to be taken. Hydrostatic load imposed on an underground sewer is as follows:

\[ q_w = \gamma_w \cdot h_w \]  \hspace{1cm} (5)

When the ground water table is below the pipe invert level and the differences between unit weights of soil layers are insignificant, the averaged unit weight of soil layers can be used.


2.6.3 TRANSIENT (TRAFFIC) LOADS

Transient loads are imposed by vehicles passing over or close to the pipeline. Standard loading of road surface are treated in different ways in national standards of various countries. Below are listed recommendations based on Polish Standard [20] and Polish Guidelines of Highways Design [31, 32, 33].

According to the above standard and guidelines traffic loads are determined based on the decisive vehicle of three axles and wheel load of 60 kN (front axle) plus 2 x 120 kN (two rear axles) as follows:

- for highways of I and II class - load category A;
- for highways of III, IV and V class - load category B;
- for highways of higher technical classes - load category C;

The one wheel load is evenly distributed over the bearing area of 20 x 60 cm.

For load categories A, B and C the influence of traffic load is calculated by the pressure distribution according to the Boussinesq formula:

\[ q_r = \frac{3P \cdot H^3}{2 \cdot \pi \cdot R^5} \]  \hspace{1cm} (6),

where:
- \( P \) = wheel load on the road surface [kN]
- \( H \) = height of filling over pipe [m]
- \( R \) = horizontal distance of point application of force to the considered point [m]

After transformation of formula (6), the expression for vertical load superimposed by traffic is obtained as

\[ q_z = C \cdot P / H^2 \]  \hspace{1cm} (7)

The traffic load coefficient (C) relationships are presented in the figure.

Besides, the Polish standard [20] demands that for structures where the depth of cover over pipe is less than 1.0 m, the factor of safety for dynamic load should be used, expressed as:

\[ \varphi = 1 + \left( \frac{1 - \sum h}{0.5} \right) \cdot 0.35 \leq 1.325 \]  \hspace{1cm} (8)

The Polish Standard [20] allows that the dynamic load factor of safety may be not used when the depth of cover is over 1.0 m.

<table>
<thead>
<tr>
<th>Load category</th>
<th>Front - ( P_1 )</th>
<th>Rear - ( P_2 )</th>
<th>Rear - ( P_3 )</th>
<th>Lateral distance between vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>60</td>
<td>120</td>
<td>120</td>
<td>1.00</td>
</tr>
<tr>
<td>B</td>
<td>60</td>
<td>120</td>
<td>120</td>
<td>1.25</td>
</tr>
<tr>
<td>C</td>
<td>60</td>
<td>120</td>
<td>120</td>
<td>1.50</td>
</tr>
<tr>
<td>D</td>
<td>80</td>
<td>120</td>
<td>-</td>
<td>1.50</td>
</tr>
<tr>
<td>E</td>
<td>50</td>
<td>100</td>
<td>-</td>
<td>1.50</td>
</tr>
</tbody>
</table>

Table 8
2.6.4 STRAIN OF THE PIPE.

Relative deflection of pipe diameter

When the total vertical load \( q = q_z + q_w + q_r \) (see sections 2.6.2. and 2.6.3) and soil stiffness \( E_s' \) are known, the relative initial deflection of pipe can be determined as follows:

\[
\varepsilon(\%) = \frac{\delta}{D} \times 100\% = \frac{8.3 \times q}{16 \times SN + 0.122 \times E'_s} \tag{9}
\]

The relative deflection of pipe \( \varepsilon(\%) \) is then enlarged with empirical values of the installations and bedding factors \( I_f \) and \( B_f \), respectively. The values of factors \( I_f \) and \( B_f \) listed in Table 9, have to be treated as the approximate because they are adequate only for trenches backfilled with properly compacted gravel or coarse and medium sized sands.

### Table 9

<table>
<thead>
<tr>
<th>Components of installation factor ( I_f )</th>
<th>Components of bedding factor ( B_f )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pipe in stepped trench</strong></td>
<td><strong>No supervision</strong></td>
</tr>
<tr>
<td>- no supervision</td>
<td>- no stones</td>
</tr>
<tr>
<td>- with supervision</td>
<td>- soil with stones or rock</td>
</tr>
<tr>
<td>Heavy construction traffic and ( H&lt;1.5m )</td>
<td>1 ( \div 2% ) With supervision</td>
</tr>
<tr>
<td>Compaction of fill above the pipe</td>
<td>0 ( \div 1% ) - no stones</td>
</tr>
<tr>
<td>with heavy equipment (( Q&gt;0.6\kN ))</td>
<td>- with stones</td>
</tr>
</tbody>
</table>

Initial relative deflection of pipe after installation is:

\[
\varepsilon_d(\%) = \varepsilon(\%) + I_f + B_f \leq 8\%. \tag{10}
\]

Usually this deflection of pipe do not exceed 5% and the allowed short term deflection is:

- 8 % - for PVC pipes;
- 9 % - for PP and PE pipes

As a result of settlement and displacement of the pipe and the surrounding soil, the long term deflection of pipe also increases to the value:

\[
\varepsilon_o(\%) = 2 \times \varepsilon(\%) + I_f + B_f \leq 15\% \tag{11}
\]

The long term maximum deflection should not exceed 15 %.

Buckling

External pressure imposed by the weight of the soil and the ground water, cause compressive ring forces in the pipe wall. When the compressive forces in the pipe are large they can cause failure due to buckling of the pipe wall. For pipes buried in loose soils or in the open, buckling will occur in a shape near the Cassini curve (ellipse of flattened down and up arch). High values of the pipe ring stiffness and soil stiffness prevent buckling of the pipe wall. In properly compacted firm soils buckling will occur in a small wavy pattern on the whole pipe circuit. The permissible buckling stress can be determined from expressions:

a) for not buried pipes

\[
P_{kr} = 24 \times SN \tag{12}
\]

b) for pipes installed in loose granular or cohesive soils of low degree of compaction

\[
P_{kr} = 24 \times SN + 2/3 \times S_s \tag{13}
\]

provided the condition \( SN > 0,025 \times S_s \) is fulfilled

c) for ideally circular pipe

\[
P_{kr} = 5.63 \times \sqrt{SN \times S_s} \tag{14}
\]

The long term maximum deflection should not exceed 15 %.

where: \( \alpha = 1 - 0.03 \times \varepsilon_o(\%) \)

\[
P_{kr} = \alpha \times 5.63 \times \sqrt{SN \times S_s} \tag{15}
\]

To prevent buckling the use of a factor of safety is required:

\[
F = \frac{P_{kr}}{q} \geq 2.0 \tag{18}
\]

Experience shows that for typical pipes, laid in properly compacted soils buckling will seldom be critical for the design.
Scandinavian method

Design conditions:
- sewer pipe PVC, d 400 x 9.8 mm
  Class N (SN 4kPa);
- laid under highway of load traffic
category KR5.

The presented example shows that in the case of careful pipe instal-
lation and backfilling, even plastic pipes of ring stiffness less than 8.0
kN/m² can be laid under roads.

### Table 10

<table>
<thead>
<tr>
<th>Step</th>
<th>Formula, diagram, table</th>
<th>Symbol</th>
<th>Quantity</th>
<th>Result</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Form. 4</td>
<td>Q_a</td>
<td>vertical load from backfill</td>
<td>13.2x0.15+21.45x0.55+12.1x0.10+11.55x2.2=</td>
<td>40.398</td>
</tr>
<tr>
<td></td>
<td>Form. 5</td>
<td>Q_w</td>
<td>pressure of groundwater</td>
<td>10.3x(0.10+2.20)=</td>
<td>23.691</td>
</tr>
<tr>
<td>2</td>
<td>Diagr. tab. 8</td>
<td>C</td>
<td>load imposed by traffic of category A</td>
<td>2.02</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Form. 7</td>
<td>P</td>
<td>for the pipe cover H=3.0m</td>
<td>60.00</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>q</td>
<td>120/2=</td>
<td>1.5</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>q</td>
<td>factor of loading</td>
<td>20.20</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>q</td>
<td>2.02x1.5x60.001/3.001=</td>
<td>84.289</td>
<td>—</td>
</tr>
<tr>
<td>3</td>
<td>Diagr. Form. 9 Tab. 9</td>
<td>E_s</td>
<td>relative deflection of pipe for saturated compacted soil of ²=0.97</td>
<td>750.00</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ε(%)</td>
<td>(8.3x84.289)/(18x4.00+0.122x750.00)=</td>
<td>4.50</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>l_c</td>
<td>empirical installation factors</td>
<td>0</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B_r</td>
<td>- with control</td>
<td>0</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- compaction with light equipment</td>
<td>0</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>installation factor =</td>
<td>0</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>careful installation in the trench</td>
<td>2</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>with the stones at the bottom</td>
<td>2</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>bedding factor</td>
<td>—</td>
<td>%</td>
</tr>
<tr>
<td>4</td>
<td>Diagr. Form. 10 Tab. 9</td>
<td>E_s</td>
<td>short-term pipe deflection</td>
<td>4.50+0.00+2.00=</td>
<td>6.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ε_s</td>
<td>long-term pipe deflection</td>
<td>2x4.50+0.00+2.00=</td>
<td>11.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>the pipe satisfy conditions of deflections</td>
<td>&lt;8.00</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- short-term deflection</td>
<td>&lt;15.00</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- maximum long-term deflection</td>
<td>—</td>
<td>%</td>
</tr>
<tr>
<td>5</td>
<td>Form. 16</td>
<td>α</td>
<td>buckling</td>
<td>1-0.03x11.00=</td>
<td>0.670</td>
</tr>
<tr>
<td></td>
<td>Form. 15</td>
<td>P_w</td>
<td>pipe ring stiffness</td>
<td>1.50</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Form. 18</td>
<td>F</td>
<td></td>
<td>178.9</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.122</td>
<td>—</td>
<td></td>
</tr>
</tbody>
</table>

### ALGORITHM OF CALCULATION OF PIPE DEFLECTION
According to the ATV A - 127 method

Because of unlimited alternative conditions of pipe laying, only some example diagrams of pipe deflections are here presented. Under actual cases when the height of cover for pipelines (PP, PE) is less than 1.0 m or exceed 6.0 m, please contact Technical Department PIPELIFE Polska. The diagrams presented below have been prepared under following conditions:

- PP Pragma® sewer d₁ = 500 m, laid in the “dry” trench, above groundwater level;
- natural subsoil and consolidated at the degree given in a diagram (Iₛ - % MP %);
- sewer is laid in the sheeted trench, and sheeting is pulled-out by steps, as the trench is backfilled (W 2);
- trench is backfilled with non-cohesive soils (gravel, crushed stone, coarse sands);
- backfill material in the pipe zone (bedding, sidefill, initial fill) is compacted to the degree Iₛ = MP 95%;
- road surface is loaded with the wheeled tractor 800 kN (80 tons);
- road pavement of modulus of elasticity Eᵣ ≥ 300 MPa;
- thickness of the road bituminous layer of 20 cm.

The maximum acceptable value of relative pipe deflection is 8 %

2.6.6 EXAMPLES OF PIPE DEFLECTIONS - DIAGRAMS

![Diagram of Cohesive clayey soils Iₛ=85%](image1)

![Diagram of Cohesive sandy gravel, gravel, silty soils Iₛ=85%](image2)

![Diagram of Semi-cohesive soils Iₛ=85%](image3)

![Diagram of Granular soils Iₛ=92%](image4)
Pipes are to be set on a firm bed and in proper alignment. Soil conditions under road in the subgrade in the pipe-laying zone as well as the depth of ground-water table below the pipe invert determine the method of pipe bedding. Depending on the actual conditions bedding on the native undisturbed ground or bedding on a foundation layer should be provided according to the recommendations given in Table 11.

### Table 11

<table>
<thead>
<tr>
<th>Subgrade soil conditions</th>
<th>Depth of groundwater table below pipe invert level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 1m</td>
</tr>
<tr>
<td><strong>I Soils not susceptible to frost heaving</strong></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>rubbles, no fines</td>
</tr>
<tr>
<td>2</td>
<td>gravels and sandy gravel soils (with grains &gt; 20mm)</td>
</tr>
<tr>
<td>3</td>
<td>coarse, medium and fine-grained sands</td>
</tr>
<tr>
<td><strong>II Soils of slight to medium potential to frost action</strong></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>silty sands</td>
</tr>
<tr>
<td>5</td>
<td>clayey rubbles clayey gravels and sandy gravel soils with fines (with grains &lt; 20mm)</td>
</tr>
<tr>
<td>6</td>
<td>clayey gravel and clayey sandy gravel soils with fines (with grains &lt; 20mm)</td>
</tr>
<tr>
<td><strong>III Soils susceptible to frost heaving</strong></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>stiff clays, sandy and silty stiff clays</td>
</tr>
<tr>
<td>8</td>
<td>clayey sands, silty sands, silts</td>
</tr>
</tbody>
</table>

**NOTES:**

*) when very stiff, stiff, firm (I<0.25); whereas when soft and very soft require individual evaluation

- Thickness of bedding layers given above should not be less than the 1/4 of the outside pipe diameter and in the soils
  - of group III (soils susceptible to frost action) - 1/2 of the outside pipe diameter;
  - under culverts the layer of soil not susceptible to frost heaving should reach at least to the depth of frost penetration

Suitable bedding materials for underground sewer are coarse, medium and fine grained sands. Silty sands can be used only below the depth of frost penetration and at the ground water table at least 2.0 m below pipe invert level. Sandy soil bedding layer should be carefully compacted directly after laying. The required degree of compaction of the subgrade and the bedding layer should not be less than 85% of Modified Proctor test density, and in the case of pipe laid under road, index of compacting can not be less than it results from the depth of pipe laying, the type of structure (cutting embankment) and the category of traffic (see figures in Section 3.1.2). Thickness of layers and method of compaction should be determined depending on the total depth of backfill and the compacting equipment. The moisture of the compacted soil can differ from the optimum moisture content by no more than 2%. The bedding layer 5 cm thick directly underneath the pipe should be only slightly compacted, this enable elastic uniform continuous support to the pipe. Compaction of this layer is increased when the sidefills of the pipe are compacted.

Natural subgrade soil and the bedding layer should meet requirements concerning the index of compacting (I<) and soil secondary strain modulus E2, the same as the backfill of the trench (see section 3.1.2). When for the period of building the ground water table have to be lowered, the design of drainage should be prepared, which provide sewer pipe laying without destruction of the natural soil subgrade.
3.1.2 BACKFILLING THE TRENCH

SIDEFILL

Apart from a proper foundation and bedding, the sidefill in the pipe haunching zone is important in achieving a satisfactory installation of flexible pipeline. Sidefill of the trench around the pipe, to the trench walls, up to the minimum height level with the crown of the pipe should be performed from soils not susceptible to frost action and of the same parameters like bedding material. On embankments, the minimum one side trench width is double pipe outside diameter, but not less than 30 cm, although this may be influenced by the nearest available excavator bucket size. Suitable soil material includes most graded, natural materials with maximum grain size not exceeding 10% of nominal pipe diameter, but not bigger than 60 mm under condition that there will be any close contact between stones and pipe walls. The sidefill should be carefully compacted to the degree of 85% of modified Procter test density. The index of soil compaction ($I_s$) in this zone can't be lower than it results from the position of this layer, type of earth structure (cutting, embankment) and traffic category, as it shown in figures below.

The sidefill should be performed uniformly, both sides of pipe with soil material of moisture close to the optimum moisture content ($\pm 2\%$). The thickness of sidefill layers depends on the equipment used for soil compaction. Only lightweight equipment can be used, not to deform or displace the pipeline.

**BACKFILL DIRECTLY ABOVE THE CROWN OF THE PIPE**

Initial backfill directly above the crown of the pipe to the height of at least 20 cm, but not less then 3 of the outside pipe diameter should be performed of sandy, gravelly or sandy-gravelly soils of maximum grain size not exceeding 20 mm. Backfill material can be compacted with lightweight equipment not to damage the pipe. The degree of compaction should be the same as of the sidefill.

Final backfilling of the trench should be performed with soils not susceptible to frost heaving, in layers dependent on the compacting equipment, uniformly along both sides of the pipe. Moisture of filling material should be close to the optimum moisture content ($\pm 2\%$), soft soils are improper. The refill up to the level of 1,0 m above the crown of the pipe should be compacted with the lightweight equipment. When the designed compaction of this soil layer are accomplished the next layer can be laid. The backfill material density is evaluated on the base of index of compaction ($I_s$). The required values of $I_s$ are depending on the level of the compacted layer, the type of structure (cutting, embankment) and the category of traffic load are presented in figures.
**POLISH ACTS AND REGULATIONS**


2. Dz.U. nr 14 poz. 60 z 1985r. Ustawa o drogach publicznych.


5. Dz.Bud. nr 1/1972r. poz. 1 Zarządzenie nr 60 Ministra Budownictwa i Przemysłu Budowlanych w sprawie warunków technicznych, jakim powinny odpowiadać instalacje wodociągowe i kanalizacyjne.


**POLISH STANDARD CODES OF PRACTICE**


24. DS 430 The laying of underground flexible pipelines of Plastic

25. DS 432

**GUIDELINES PUBLISHED BY THE GENERAL HEAD OFFICE OF HIGHWAYS IN WARSAW**

31. Wytyczne projektowania dróg I i II klasy technicznej WPD-1 (autostrady i drogi ekspresowe) - 1995r.

32. Wytyczne projektowania dróg III, IV i V klasy technicznej WPD-2 - 1995r.


34. Wytycznych Projektowania Obiektów i Urządzeń Budownictwa Specjalnego w Zakresie Komunikacji. Światła mostów i przepustów WP-D 12.

**TECHNICAL APPROVALS**

41. AT/97-03-0096 Studzienki teleskopowe kanalizacyjne i drenażowe MABO. - Wydana przez Instytut Badawczy Dróg i Mostów w Warszawie.

42. AT/99-02-0752 Rury o ściankach strukturalnych typu Pragma® z polipropylenu do kanalizacji zewnętrznej. - Wydana przez COB-RTI INSTAL.

43. AT/2000-02-0875 Teleskopowe studzienki kanalizacyjne z polipropylenu (PP) i poli(chlorku winylu) (PVC-U). - Wydana przez COBRTI INSTAL

44. AT/98-04-0506 System rurowy o ściankach strukturalnych z polipropylenu (PP) do kanalizacji, drenażu oraz przepustów w nasypach komunikacyjnych - Wydana przez IBDiM.

**CATALOGUES**

51. Katalog techniczny. Systemy kanalizacji zewnętrznej z PVC - Pipelife

**MANUALS**


GUIDELINES FOR USAGE OF SUBDRAINAGES MADE OF PVC AND PP DRAINAGE PIPES

CERTIFIKAT JAKOŚCI
ISO 9001
LLOYDS REGISTER

PipeLife
PLASTIC DRAIN PIPES FOR HIGHWAYS SUBDRAINAGES
DESIGN AND INSTALLATION GUIDELINES

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tel.: (+ 48 58) 77 48 888; fax (+ 48 58) 77 48 807; e-mail: dok@pipelife.pl; www.pipelife.pl
These guidelines focus on typical applications of PIPELIFE Polska plastics drain pipe systems for highways subsurface drainages or more simply subdrainages. The term “subdrainage” relates to the control of ground water in its various forms encountered in highway locations.

The sequence chapters present technical characteristics of drain pipes, the rules concerning vertical and horizontal alignment of subdrains, drain pipe depths and slopes, drain envelope materials as well as the method of the drain pipe strength calculation. The last part concerns requirements for earthworks and drain pipe installation and workmanship.

The presented guidelines do not include methods of hydrologic and hydraulic calculations, as this subject are broadly described in the bibliography of the hydraulic, hydrology, sewerage, land drainage and highway engineering [35].

1. DEFINITIONS OF TERMS

<table>
<thead>
<tr>
<th>No.</th>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Absorption inlet (catchpit)</td>
<td>Pit filled with permeable material for collecting and draining of water from the road base and subbase to the crosswise drain.</td>
</tr>
<tr>
<td>2</td>
<td>Accidental parking strip (emergency strip)</td>
<td>The side strip of the highway for stopping and parking technically immobilized vehicles.</td>
</tr>
<tr>
<td>3</td>
<td>Carriageway (trafficway)</td>
<td>Part of road crown usually paved that serves vehicles passing.</td>
</tr>
<tr>
<td>4</td>
<td>Collector drain</td>
<td>Collector pipe that collects discharges from drain pipes (field drains) and carries the discharge to the main drain or to the outlet (ditch).</td>
</tr>
<tr>
<td>5</td>
<td>Drain, drain-line</td>
<td>Perforated pipe laid at a suitable depth in a trench filled with porous granular material aims at controlling the watertable.</td>
</tr>
<tr>
<td>6</td>
<td>Gutter</td>
<td>Drainage providing slightly depressed area (of the depth&lt; 30 cm), that collects and carry out surface water.</td>
</tr>
<tr>
<td>7</td>
<td>Infiltration trench</td>
<td>The trench filled with granular material, but no pipe in the bottom.</td>
</tr>
<tr>
<td>8</td>
<td>Median strip (dividing strip)</td>
<td>The part of a road crown between carriageways (trafficways) of opposite directions.</td>
</tr>
<tr>
<td>9</td>
<td>Nominal inside pipe diameter dᵢ</td>
<td>Number that in the case of corrugated pipe defines the size of pipe in the cross-section of the concave notch.</td>
</tr>
<tr>
<td>10</td>
<td>Nominal outer pipe diameter dₒ</td>
<td>Number, that in the case of corrugated pipe, defines the size of pipe in the cross-section of the convex notch.</td>
</tr>
<tr>
<td>11</td>
<td>Pipe ring stiffness (SN)</td>
<td>Parameter used to classify sewer pipe which represents pipe operating capacity to external load, expressed in kPa, and is dependent on pipe diameter, pipe wall thickness and relaxation modulus of pipe material.</td>
</tr>
<tr>
<td>12</td>
<td>Road crown</td>
<td>Surface including carriageways, roadsides, sidewalks, cycle tracks, parking lanes, accidental parking strips, median strip depending on the road class.</td>
</tr>
<tr>
<td>13</td>
<td>Road right-of-way</td>
<td>The area occupied by carriageways, roadsides for facilities connected with maintenance, road users service, environmental, reserve land for a future development.</td>
</tr>
</tbody>
</table>
2. TECHNICAL SPECIFICATION

2.1. APPLICATIONS AND ELEMENTS OF DRAIN PIPE SYSTEMS

PIPELIFE Polska manufactures the drain pipe systems to use in different drainage applications including agricultural drainage, civil engineering drainage as well as highways drainage. The drain pipe systems are manufactured from polyvinyl chloride (PVC) and polypropylene (PP). From PVC are manufactured corrugated drain pipes and from PP structural double-walled drain pipes so that they have a smooth wall inside. Drain pipes are factory perforated with openings evenly distributed over the pipe circumference. The widths of perforation slots depend on the pipe size and the pipe type and are 0.8, 1.2, 1.4, 1.7, 2.4 and 2.7 mm.

Drain pipes can be delivered without filter envelope and drain pipes wrapped in envelopes of the polypropylene geotextile or the coconut fibre. For drainage system, the Producer delivers also all fittings necessary for pipe assembly as well as inspection chambers of sizes: 200, 315, 400 and 630 mm. For drainage systems all elements of PIPELIFE gravity sewer pipe systems can be also used.

For drainage systems PIPELIFE Polska offers the following elements:
- drain corrugated PVC pipes of outside diameters dn from 50 to 200 mm without filter and with the envelope from polypropylene geotextile or from coconut fibre;
- drain PP pipes (based on the PRAGMA® structural pipes) of outside diameters dn from 110 to 250 mm;
- branches 45° and 90°, equal and unequal, normal and saddle branches;
- bends 90° and adjustable bends;
- straight couplings, junctions, reducers, and caps and outfalls with flap gates;
- inspection chambers ϕ 200, 315, 400 and 630 mm;
- sewer pipes and fittings.

All necessary information on the assortment of PIPELIFE products are presented in Technical Catalogues [31], [32], [33], [34], which are actualized currently as a new products are introduced to the market.

The PVC corrugated drain pipes have obtained the Technical Approval - AT/97-01-0199 by COBRTI "Instal".

The PVC gravity sewer pipes and fitting have got the Technical Approval - AT/97 - 01-0090 of COBR-TI "Instal".

The PP structural double-walled pipes for sewer systems, drainage systems and culverts structures under communication embankments have obtained the following technical Approvals:
- AT/97-01-0205 by COBRTI "Instal";
- AT/98-04-0506 by Highways and Bridges Research Institute (IBDiM) in Warsaw.

The sewer and drainage inspection chambers have got the following Technical Approvals:
- AT/98-01-0395 by COBRI "Instal" and;
- AT/97-03-0096 by IBDiM - Warsaw.

2.2. TECHNICAL CHARACTERISTIC OF DRAIN PIPES

In the Table below are presented the main technical parameters of PIPELIFE drain pipes listed based on the data from Technical Catalogue [31] and Technical Approvals [29] and [30]:

![Table 2](image-url)

Table 2:

**DEFINITIONS OF TERMS**

<table>
<thead>
<tr>
<th>No.</th>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>Road structure body</td>
<td>Earth structure bounded from above with road crown, side fill slopes or inside slopes of road drainage ditches.</td>
</tr>
<tr>
<td>15</td>
<td>Shoulder (verge)</td>
<td>Side strip of road crown next to carriageway (trafficway) used for pedestrian traffic and in special cases for vehicles traffic and parking. The hardened shoulders with pavement provide riding and parking surface.</td>
</tr>
<tr>
<td>16</td>
<td>Subbase</td>
<td>The natural subsoil or embankment soil lying directly below the road surface or the other structure.</td>
</tr>
<tr>
<td>17</td>
<td>Traffic load category</td>
<td>Definition of vehicles traffic expressed as the number of wheel loads (100kN) per day per considered highway.</td>
</tr>
</tbody>
</table>

**CHARACTERISTIC PARAMETERS OF DRAIN PIPES**

<table>
<thead>
<tr>
<th>mark of pipe</th>
<th>inside pipe diameter d1 [mm]</th>
<th>outside pipe diameter d2 [mm]</th>
<th>width of perforation openings S [mm]</th>
<th>total area of pipe perforation [cm²/m]</th>
<th>pipe ring stiffness [kPa]</th>
</tr>
</thead>
<tbody>
<tr>
<td>97/110</td>
<td>97</td>
<td>110</td>
<td>1 × 3</td>
<td>20</td>
<td>≥ 6</td>
</tr>
<tr>
<td>139/160</td>
<td>139</td>
<td>160</td>
<td>1 × 3</td>
<td>20</td>
<td>≥ 8</td>
</tr>
<tr>
<td>174/200</td>
<td>174</td>
<td>200</td>
<td>1 × 3</td>
<td>12</td>
<td>≥ 8</td>
</tr>
<tr>
<td>218/250</td>
<td>218</td>
<td>250</td>
<td>1 × 3</td>
<td>12</td>
<td>≥ 8</td>
</tr>
</tbody>
</table>
Subdrains are a necessary part of the complete drainage system for many highways, and they function along with adequate surface drainage facilities to prevent damage caused by water in its various forms. A highway subdrain usually consists of a drain perforated pipe laid at a suitable depth in a trench, which is then filled with porous, granular material.

Subdrains are installed for a number of purposes most of which can be included in the following classifications:

- Lowering of ground-water table (thus reducing the source of capillary moisture), when the undersurface of the road pavement is less than 1.0 m above the ground-water table;
- Control of seepage in cuts or sidefill locations, these installation are generally called "intercepting drains", e.g. slope drains, cut-off drains;
- Base and shallow subgrade drainage, to prevent excess moisture in the subgrade, to remove water trapped above an impervious subgrade soil;

The Polish Decree [3] demands that ground-water table should be lowered when the pavement structure is less than 1.0 m above the ground water table, regardless the class of highway, the structural quality of the basement soil and the depth of frost penetration.

### Table 2

<table>
<thead>
<tr>
<th>Pipe Diameter</th>
<th>Length (m)</th>
<th>Diameter (mm)</th>
<th>Elevation (mm)</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>50/44</td>
<td>44</td>
<td>50</td>
<td>0.8</td>
<td>1.2</td>
</tr>
<tr>
<td>65/58</td>
<td>58</td>
<td>65</td>
<td>0.8</td>
<td>1.2</td>
</tr>
<tr>
<td>72/80</td>
<td>71.5</td>
<td>80</td>
<td>0.8</td>
<td>1.2</td>
</tr>
<tr>
<td>91/100</td>
<td>91</td>
<td>100</td>
<td>0.8</td>
<td>1.2</td>
</tr>
<tr>
<td>115/125</td>
<td>115</td>
<td>125.5</td>
<td>0.8</td>
<td>1.2</td>
</tr>
<tr>
<td>144/160</td>
<td>144</td>
<td>159.5</td>
<td>0.8</td>
<td>1.2</td>
</tr>
<tr>
<td>182/200</td>
<td>182</td>
<td>199.5</td>
<td>0.8</td>
<td>1.2</td>
</tr>
</tbody>
</table>

Factory made filter envelopes enlarge the outside pipe diameters by about 16.0 mm. Corrugated PVC drain pipes are delivered in coils of lengths from 22.5 m to 250 m depending on the pipe diameter and the applied filter envelope. PP PRAGMA® pipes are socket pipes and can be delivered in sections of the lengths 3 m or 6 m.
The Polish Decrees [1] and [3] demand to lower underground water table with subdrains parallel to the center line, placed at the proper elevations at the edges of road (or shoulders), under bottom of the side road ditch or beneath median strip. Such subdrains should be laid at the depths below the depth of frost penetration given in Polish Standard [5], to avoid freezing of water penetrating to the subdrains as well as inside the drain pipes, even in the case when surface soil layers are frozen. The maximum practical depth of subdrain pipes should not exceed 4m.

Shallow subdrainage drainage is used only to remove water from the previous road base and subbase soil layers.

The requirements and recommendations for highways subdrainages given in Polish Standard [12] are presented below.

The minimum subdrain pipe diameter is 50 mm and the collector pipe 100 mm. The subdrain pipes must be laid on the firm smooth bed of filter layer of thickness at least 20 cm. The maximum width of perforation slots of the drain pipe should not exceed 1.5 mm.

The slopes of shallow subdrain pipes for de-watering of base soil layers (not susceptible to frost action) should be not less than 0.2%. Slopes of deep drainage pipes should conform to the standards used in land melioration.

Flow velocities in drain pipes must provide self-cleansing and they are considered as:
- 0.35 m/s in sandy and silty soils, and;
- 0.20 m/s in clayey and clay soils (in the exceptional cases 0.15 m/s)

Maximum permissible velocity should not exceed:
- 1.2 m/s in sandy and silty soils;
- 1.5 m/s in clayey soils;
- 2.0 m/s in cases of steeper slopes and firm subsoils.

The optimal values of flow velocities are in the range of 0.5÷0.7 m/s.

To provide the most effective de-waterting of subgrade soil the drainage pipes should not flow full. The recommended actual flow depths depend on the function of the pipe in the system and should not exceed the following percentage of pipe diameter:
- 10% in drain pipes of regular pattern;
- 25÷30% in sub-collector pipes, and outlet pipes from base drainage layers;
- 40÷50% in interceptor and main collector pipes.

Inspection chambers or manholes to facilitate junctions and inspection must be placed at connections of drain pipes to collector, at all changes of direction, gradient and diameter, and on long straight lengths at distances not more than 50 m. Recommendations for construction of manholes include:
- the floor to be some 20÷40cm, below the collector invert, thus allowing for a "silt trap";
- a drop between the inflowing drain pipe and out flowing collector pipe about 3÷5 cm.

Short drain pipes, not longer than 50 m can be connected to the collector pipe with blind junctions as...
• lateral positive T-joints, when collector pipes are flowing at depths below 30% of pipe diameter, the recommended angles of joints are in the range 45° - 90°;
• top ("drop in") tee or bend joints, when collector pipes are flowing at the depths over 30% of pipe diameter.

A properly constructed outfall, of a suitable type is to be provided wherever a drain pipe discharges into an open ditch. The invert of the pipe should be positioned at least 20 cm above the bottom of the ditch. Other precautions for collector outlets are to provide a removable greating to prevent small animals from entering the pipe and to prevent additional water flow at the end of the pipe trench. For this purpose, when the outlet is positioned 50 cm or more above the bottom of the ditch, the last section at least 2 m long of the pipe should have neither perforation nor permeable envelope material. The best solution is to install there a rigid full-walled PVC sewer pipe.

Roots of perennial vegetations (trees and shrubs) may grow into a drain pipe and fill the entire drain pipe over a considerable length and thus seriously obstruct water flow. Especially disastrous are hydrophilous trees like willows, poplars, alders. To prevent the entry of roots, some measures can be undertaken, as follows:
• to install drainage pipes at the distances of 10 m from shrubs and 20 m from trees;
• to place the envelope from graded slag of thickness 10 m around drain pipes;
• to install not-perforated PVC sewer pipes at the sections nearby trees and shrubs and wherever the pipelines are not functioning as de-watering pipes (e.g. collector pipes).

There are also recommendations and criteria for permeable material placed around drain pipes to perform different functions. Envelope performs filter function; prevents or restricts soil particles from entering the pipe where they may settle and eventually clog the pipe.

Envelope constitutes a medium of good permeability around the pipe and decreases flow velocity and thus reduces entrance resistance. The next important function is bedding function: to provide all-round support to the pipe in order to prevent damage due to the external load. Note that plastic pipe is embedded in sandy-gravel soils especially for this purpose.

Filter envelope should be provided where the grain diameter d15 of the soil surrounding the drain trench is less than the width of slots of the drain pipe perforations. The highways subrainages can be installed only with envelopes from mineral soil materials or synthetic materials. Organic material envelopes, like coconut fibre can be applied for pipe drainage of recreation areas or agricultural fields of clayey or peaty soils.

Mineral soil envelope materials may be well-graded gravels or sands of smooths rounded grains, and the content of particle size below 0.02 mm should not exceed 5% and organic matter 0.5%. The standard procedure for the design of sandy-gravel envelopes is to match the particle-size distribution of the soil with the particle-size distribution of the filter envelope, according to the following criteria:

\[
D_{50} = 4 \div 5 \cdot d_{50} \quad 4d_{85} \geq D_{15} \geq 4d_{15},
\]
\[
D_{60} / D_{10} \leq 5 \quad D_{15} \geq 1.2S
\]

and hydraulic conductivity of the envelope all-round drain pipe should be over 8 m/d.

The minimum thickness of the envelope and the number of envelope layers depend on the type of de-watered soil. In sandy soils usually one layer envelope of thickness 15 cm is sufficient. In silty, clayey soils multilayer envelope may be necessary, of the minimum thickness 10 cm of each layer. Besides the total thickness of the envelope should fulfill requirement concerning drain pipe bedding and backfilling given in Section 3. In figures are presented some example solutions of drain pipe filter envelopes.
\[ \text{In sandy-clayey soils (of medium permeability) the thickness of envelope layers should be } 15 \div 20 \text{ cm} \]

\[ \text{In clayey soils and clays the thickness of envelope should be more than 20 cm} \]

### 2.4. SHALLOW SUBBASE DRAINAGE

The major aspect of drainage concerns measures to avoid the accumulation of excessive water in the soil layers that compose the pavement structure. Water allowed to enter the subgrade causes softening and resultant loss of supporting power, danger of frost heave. Water may enter the road base courses and subgrade by infiltration downward through cracks in the pavement surface, joints edges and shoulders, or by capillary action from free water or from the wetter strata. Shallow subdrains are installed to prevent excess moisture in the substrata, that is to remove water from the base courses and shoulders very quickly. Shallow drain pipes should be laid at steep gradients, with disposal to the roadside ditch, the deep longitudinal drain pipe or to the surface-water sewers. Drain pipes and filter envelopes have to be placed below the road subbase.

The number, depth and disposition of drains depend upon how much of water have to be disposed and how permeable the soil is.

The amount of water to be drained from the road base courses and subgrade is estimated from laboratory tests or based on data presented in professional literature [35].

The requirements for subdrain pipes gradients, velocities and outfalls are given in Section 2.3.

The shallow subbase drainage can be designed as the crosswise drains, longitudinal one drain-line beneath each shoulder or diagonal (transverse) drains.

#### 2.4.1 CROSSWISE DRAINAGE

Drains of this type are laid in the shoulder, at the angle 750 ÷ 900 to the road center line. Drains of 80 mm diameter are in common use and are laid at the slope not less than 2%. Absorption inlets to the drain pipes have to be protected with the filter soil material matched to the particle size-distribution of the drained layer of the road subbase (see Section 2.3). The range of the catchpit surface shall be of the radius (R) not less than 10cm. When the filter catchpit surface is small (R ≤ 25 cm) one-layer filter can be used, whereas for bigger filter surfaces (R > 25 cm) two-layer filters should be used. In any case water flow velocity in the immediate vicinity of the inlet filter should not be hazardous for filter stability and should not dislocate soil particles.

Spacing of the crosswise drains depend upon the road width, hydraulic conductivity of the drained road subbase and the structure of the inlet catchpit collecting and carrying water to the pipe.
Actual Polish regulations for buried conduits do not include any strength calculations of flexible pipes, and the method used for rigid pipes are not adequate.

Herein the method based on Scandinavian Standard [19] and elaboration [36] is proposed. This method is referred to as the Scandinavian Method (SM).

It is recommended to calculate the strength of the conduit in any design conditions. The Standard [19], on the base of the up to the present experience, does not require calculation of pipe strain for typical common applications, under the following pipe installation conditions:
- maximum depth of burial not exceed 6 m;
- minimum depth of burial is 1 m at traffic load;
- pipe bedding layer, sidefill and initial backfill are made of gravel and sandy material with the patride size of 0.075 mm not exceeding 10%, properly compacted to the 90% of modified Proctor test density;
- pipes show any damages or deformation of cross-section;
- short-term pipe ring stiffness (SN) for PVC pipes is not less then 4, and for pipes under roads of heavy traffic SN ≥ 8;
- maximum permissible initial deflection of pipe after installation does not exceed 8%.

However, in the cases of shallow highway subdrainages the above conditions are not fulfilled as the depth of cover of the drain pipe is usually less than 1.0 m, thus the strength calculations are required (see section 2.5.5.).
The Scandinavian Method is based on the assumption that flexible plastic pipes makes use of the horizontally acting soil support \((q_h)\) as a result of vertical deflection of pipe \((\delta)\) under vertical load \((q)\). In the Scandinavian Model the soil pressure distribution is of parabolic shape. The better are soil parameters and soil support the lower is the pipe deflection.

The design concept of an interaction between the stiffness of a flexible pipe and the soil stiffness is described with the Sprangler formula,

\[
\frac{\delta}{D} = \frac{f(q)}{SN + S_s}
\]  

The soil stiffness \((S_s)\) is determined by the secant modulus of the soil \((E_{s}'\) ). For typical soil materials used for fills like gravels and sands of unit weight \(\gamma = 19 \text{ kN/m}^3\), the secant modulus \((E_{s}')\) depends mainly on the degree of soil compaction and the fill height. In figures, values of the secant modulus \(E_{s}'\) for granular soils are given, based on Scandinavian investigations [36]. According to the German Standard ATV A-127 the values of \(E_{s}'\) are much greater and are not dependent on a depth.

### 2.5.1 SYMBOLS AND QUANTITIES

<table>
<thead>
<tr>
<th>No.</th>
<th>Symbol</th>
<th>Unit</th>
<th>Quantity and application</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(\alpha)</td>
<td>—</td>
<td>coefficient of reduction of buckling stress</td>
</tr>
<tr>
<td>2</td>
<td>(B_t)</td>
<td>%</td>
<td>bedding factor- empirical value refered to quality and super-vision of bottom conditions</td>
</tr>
<tr>
<td>3</td>
<td>(D)</td>
<td>m</td>
<td>outside pipe diameter (D=(d_h+d_i)/2)</td>
</tr>
<tr>
<td>4</td>
<td>(E)</td>
<td>kPa</td>
<td>modulus of elasticity of pipe material</td>
</tr>
<tr>
<td>5</td>
<td>(E_{s}')</td>
<td>kPa</td>
<td>secant modulus of the soil</td>
</tr>
<tr>
<td>6</td>
<td>(E_s)</td>
<td>Mpa</td>
<td>secondary modulus of soilu</td>
</tr>
<tr>
<td>7</td>
<td>(F)</td>
<td>—</td>
<td>factor of safety for buckling stress</td>
</tr>
<tr>
<td>8</td>
<td>(\phi)</td>
<td>—</td>
<td>factor of safety for traffic load</td>
</tr>
<tr>
<td>9</td>
<td>(h)</td>
<td>m</td>
<td>thickness of soil layer</td>
</tr>
<tr>
<td>10</td>
<td>(H)</td>
<td>m</td>
<td>depth of the cover of the pipe</td>
</tr>
<tr>
<td>11</td>
<td>(h_w)</td>
<td>m</td>
<td>height of the ground water table over pipe</td>
</tr>
<tr>
<td>12</td>
<td>(\varepsilon)</td>
<td>%</td>
<td>relative deflection of pipe</td>
</tr>
<tr>
<td>13</td>
<td>(I_f)</td>
<td>%</td>
<td>installation factor- empirical value refered to trench condition and earth work quality, work supervision</td>
</tr>
<tr>
<td>14</td>
<td>(\varepsilon_{lt})</td>
<td>%</td>
<td>long-term pipe deflection</td>
</tr>
<tr>
<td>15</td>
<td>(\varepsilon_i)</td>
<td>%</td>
<td>initial pipe deflection after instalation</td>
</tr>
<tr>
<td>16</td>
<td>(I_s)</td>
<td>%</td>
<td>index of soil compation</td>
</tr>
<tr>
<td>17</td>
<td>(P)</td>
<td>kN</td>
<td>wheel loads on the road surface</td>
</tr>
<tr>
<td>18</td>
<td>(P_{iv})</td>
<td>kPa</td>
<td>buckling stress</td>
</tr>
<tr>
<td>19</td>
<td>(q)</td>
<td>kPa</td>
<td>vertical loads on the pipe</td>
</tr>
<tr>
<td>20</td>
<td>(q_v)</td>
<td>kPa</td>
<td>horizontal load resulting from pipe deflection</td>
</tr>
</tbody>
</table>
2.5.2 STATIC LOADS AND HYDROSTATIC PRESSURE

External static loads on a buried pipeline are imposed by the weight of the soil and by any extra loads imposed by structures (bearing directly over the pipe). The vertical load imposed by soil is calculated as follows:

\[ q_z = \sum_{i=1}^{n} \gamma_i * h_i \]  

(2)

remembering that below groundwater table, water saturated unit weight of the soil (\( \gamma' \)) have to be taken.

Hydrostatic load imposed on an underground sewer is as follows:

\[ q_w = \gamma_w * h_w \]  

(3)

When the ground water table is below the pipe invert level and the differences between unit weights of soil layers are insignificant, the averaged unit weight of soil layers can be used.

2.5.3 TRANSIENT (TRAFFIC) LOADS

Transient loads are imposed by vehicles passing over or close to the pipeline. Standard loading of road surface are treated in different ways in national standards of various countries. Below are listed recommendations based on Polish Standard [13] and Polish Guidelines of Highways Design [20, 21, 22].

According to the above standard and guidelines traffic loads are determined based on the decisive vehicle of three axles and wheel load of 60 kN (front axle) plus 2 x 120 kN (two rear axles) as follows:

- for highways of I and II class - load category A;
- for highways of III, IV and V class - load category B;
- for highways of higher technical classes - load category C.

The one wheel load is evenly distributed over the bearing area of 20 x 60 cm. According to Polish Standard [13] traffic loads depend upon load category, listed in Table 4. For load categories A, B and C the influence of traffic load is calculated by the pres-
2. sure distribution according to the Boussinesq formula:
\[ q_v = \frac{3 \cdot P \cdot H^3}{2 \cdot \pi \cdot R^3} \] [kPa] (4)
where:
\( P \) = wheel load on the road surface [kN]
\( H \) = height of filling over pipe [m]
\( R \) = horizontal distance of point application of force to the considered point [m]

After transformation of formula (4), the expression for vertical load superimposed by traffic is obtained as:
\[ q_z = C \cdot \frac{P}{H^2} \] (5)

The traffic load coefficient \( C \) relationships are presented in the figure.

Besides, the Polish standard [13] demands that for structures where the depth of cover over pipe is less than 1.0 m, the factor of safety for dynamic load should be used, expressed as:
\[ \varphi = 1 + \left( 1 - \frac{h}{0.5} \right) \cdot 0.35 \leq 1.325 \] [5a]

### 2.5.4 STRAIN OF THE PIPE.

Relative deflection of pipe diameter

When the total vertical load \( q = q_z + q_w + q_r \) (see sections 2.5.2 and 2.5.3) and soil stiffness \( E_s' \) are known, the relative initial deflection of pipe can be determined as follows:
\[ \varepsilon(\%) = \frac{\delta}{D} \cdot 100\% = \frac{8.3 \cdot q \cdot I_f}{16 \cdot S_N + 0.122 \cdot E_s'} \] (6)

The relative deflection of pipe \( \varepsilon(\%) \) is then enlarged with empirical values of the installations and bedding factors \( I_f \) and \( B_f \) respectively.

The values of factors \( I_f \) and \( B_f \) listed in Table 5, have to be treated as the approximate because they are adequate only for trenches backfilled with properly compacted gravel or coarse and medium sized sands.
Initial relative deflection of pipe after installation is:

\[ \varepsilon_p(\%) = \varepsilon(\%) + I_f + B_f \leq 8\%. \quad (7) \]

Usually this deflection of pipe does not exceed 5% and the allowed short term deflections are:
- 8% - for PVC pipes;
- 9% - for PP and PE pipes

As a result of settlement and displacement of the pipe and the surrounding soil, the maximum deflection of pipe is also increased to the value:

\[ \varepsilon_0(\%) = 2 \times \varepsilon(\%) + I_f + B_f \leq 15\% \quad (7a) \]

Practice and Scandinavian experience show that the maximum long term deflection of the pipe is observed in a period not longer than 3 years after installation and must not exceed 15%.

**Buckling**

External pressure imposed by the weight of the soil and the ground water, causes compressive ring forces in the pipe wall. When the compressive forces in the pipe are large they can cause failure due to buckling of the pipe wall. For pipes buried in loose soils or in the open, the buckling will occur in a shape near the Cassini curve (ellipse of flattened down and up arch). High values of the pipe ring stiffness and soil stiffness prevent buckling of the pipe wall. In properly compacted firm soils buckling will occur in a small wavy pattern on the whole pipe circuit.

The permissible buckling stress can be determined from expressions:

a) for not buried pipes

\[ P_{kr} = 24 \times SN \]  

b) for pipes installed in loose granular or cohesive soils of low degree of compaction

\[ P_{kr} = 24 \times SN + 2/3 \times S_s \]  

(9) provided the condition

\[ SN > 0.025 \times S_s \]  

is fulfilled

c) for ideally circular pipe

\[ P_{kr} = 5.63 \times \sqrt{SN \times S_s} \]  

(10)

d) for deflected pipe to an ellipse shape

\[ P_{kr} = \alpha \times 5.63 \times \sqrt{SN \times S_s} \]  

(11)

where:

\[ \alpha = 1 - 0.03 \times \varepsilon_0(\%) \]  

(11a)

e) de) for pipe laid on the shallow depth under load of heavy traffic

\[ P_{kr} = \frac{64 \times SN}{\left(1 + 3.5 \times \frac{\delta}{D}\right)^3} \]  

(12)

In the foregoing formulae the tangent modulus of the soil can be put, equal to twice the secant modulus \[ 2 \times E_s' \]  

[36]. At large depths or when the pipe is surrounded by soft silt or clay difficult for compaction, the long term pipe stiffness shall be used, given in Table 6.

To prevent buckling the use of a factor of safety is required:

\[ F = P_{kr}/q \geq 1.5 \]  

(13)

| **VALUES OF PIPES RING STIFFNESS** |
|-----------------|-------|-------|
| short term ring stiffness [kPa] | 4     | 8     | 16    |
| Long term ring stiffness [kPa]  |       |       |       |
| polyvinyl chloride (PVC) pipes  | 1.5   | 3.5   | 6.5   |
| polyethylene (PE) or polypropylene (PP) pipes | 1.0   | 2.5   | 4.5   |
2.5.5 EXAMPLE OF CALCULATION OF THE DRAIN PIPE STRENGTH AND DEFLECTION

Design conditions:
- shallow crosswise drain pipe 91/100 mm;
- pipe ring stiffness SN = 5kPa
- drain laid under highway of load traffic category KR5

The presented example shows that the corrugated drain pipes of the ring stiffness < 8 kPa can be used for shallow subdrainage under condition that pipes are laid in the suitable granular soils at careful installation with supervision.

3. INSTALLATION OF PIPE DRAINS

3.1. EARTHWORKS

Drain pipes are usually laid in the filter envelopes placed around pipes which also compose pipe bedding and sidefill layers. The presented herein guidelines for design and installation of drain envelopes, bedding and sidefill are based on Polish Decrees [1] and [3] and Polish Standard [14].

The drain envelope besides the requirements concerning the filter function and matching the particle-size distribution to prevent washing-out soil particles and clogging the pipe, should to satisfy requirements concerning bedding and backfilling soil material as presented in Section 3.1.2.

It is also recommended to separate the layers of different function and different particle-size (like drain filter envelope, bedding foundation, sidefill, and road subbase layers) with strips of suitable geotextiles.
Drain pipes are to be set on a firm bed and in proper alignment. Soil conditions under road in the subgrade, in the pipe-laying zone as well as the depth of ground-water table below the pipe invert determine the method of pipe bedding. Depending on the actual conditions’ bedding on the native undisturbed ground or bedding on a foundation layer should be provided according to the recommendations given in Table 7. In the table are listed the minimum thickness of the bedding layers when drain pipes are laid without soil filter envelope, e.g, drain pipes surrounded with the sheets of geotextile or with the factory wrapped filters. When the sandy / gravel filter envelopes are applied, apart from requirements given in Table 7, the design criteria for drainages laid under roads presented in Section 2.3. must be taken into account.

### 3.1.1 BEDDING CONDITIONS

Suitable bedding materials for underground drain pipes are coarse, medium and fine grained sands. Silty sands can be used only below the depth of frost penetration and at the ground water table at least 2.0 m below pipe invert level. Sandy soil bedding layer should be carefully compacted directly after laying. The required degree of compaction of the subgrade and the bedding layer should not be less than 85% of Modified Proctor test density, and in the case of pipe laid under road, index of compacting can not be less than it results from the depth of pipe laying, the type of structure (cutting, embankment) and the category of traffic (see figures in Section 3.1.2). Thickness of layers and method of compaction should be determined depending on the total depth of backfill and the compacting equipment.

The moisture of the compacted soil can differ from the optimum moisture content by no more than 2%. The bedding layer 5 cm thick directly underneath the pipe should be only slightly compacted, this enable elastic uniform continuous support to the pipe. Compaction of this layer is increased when the sidefill of the pipe are compacted.

Natural subgrade soil and the bedding layer should meet requirements concerning the index of compacting (I_d) and soil secondary strain modulus E_2, the same as the backfill of the trench (see section 3.1.2).

When for the period of building the ground water table have to be lowered, the design of drainage should be prepared, which provide sewer pipe laying without destruction of the natural soil subgrade.

<table>
<thead>
<tr>
<th>Subgrade soil conditions</th>
<th>Depth of groundwater table below pipe invert level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 1 m</td>
</tr>
<tr>
<td>I Soils not susceptible to frost heaving</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>rubbles, no fines</td>
</tr>
<tr>
<td>2</td>
<td>gravel and sandy gravel soils (with grains &gt; 20 mm)</td>
</tr>
<tr>
<td>3</td>
<td>gravel and sandy gravel soils (with grains &lt; 20 mm)</td>
</tr>
<tr>
<td>4</td>
<td>coarse, medium and fine-grained sands</td>
</tr>
<tr>
<td>II Soils of slight to medium potential to frost action</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>silty sands</td>
</tr>
<tr>
<td>6</td>
<td>Clayey rubbles, clayey gravels and sandy gravel soils with fines (with grains &lt; 20 mm)</td>
</tr>
<tr>
<td>III Soils susceptible to frost heaving*</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>stiff clays, sandy and silty stiff clays</td>
</tr>
<tr>
<td>8</td>
<td>clayey sands, silty sands, silts</td>
</tr>
</tbody>
</table>

NOTES:

*) when very stiff, stiff, firm (I, L 0.25), whereas when soft and very soft require for individual evaluation
3.1.2 BACKFILLING THE TRENCH

Sidefill
Apart from a proper foundation and bedding, the sidefill in the pipe haunching zone is important in achieving a satisfactory installation of flexible pipeline. Sidefill of the trench around the pipe, to the trench walls, up to the minimum height level with the crown of the pipe should be performed from soils not susceptible to frost action and of the same parameters like bedding material. On embankments, the minimum one side trench width is double pipe outside diameter, but not less than 30 cm, although this may be influenced by the nearest available excavator bucket size. Suitable soil material includes most graded, natural materials with maximum grain size not exceeding 10% of nominal pipe diameter, but not bigger than 60 mm under condition that there will be any close contact between stones and pipe walls. The sidefill should be carefully compacted to the degree of 85% of modified Proctor test density. The index of soil compaction ($I_s$) in this zone can't be lower than it results from the position of this layer, type of earth structure (cutting, embankment) and traffic category, as it shown in figures below.

The sidefill should be performed uniformly, both sides of pipe with soil material of moisture close to the optimum moisture content ($\pm 2\%$). The thickness of sidefill layers depends on the equipment used for soil compaction. Only lightweight equipment can be used, not to deform or displace the pipeline.

Required parameters of road subgrade on embankments

<table>
<thead>
<tr>
<th>Traffic load category</th>
<th>Motorways and expressways</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E_2$ \ [MPa]</td>
<td>$E_2$ \ [MPa]</td>
</tr>
<tr>
<td>$f_0$</td>
<td>$f_0$</td>
</tr>
<tr>
<td>$I_s$</td>
<td>$I_s$</td>
</tr>
<tr>
<td>$E_2$ \ [MPa]</td>
<td>$E_2$ \ [MPa]</td>
</tr>
<tr>
<td>$f_0$</td>
<td>$f_0$</td>
</tr>
<tr>
<td>$I_s$</td>
<td>$I_s$</td>
</tr>
</tbody>
</table>

Final backfilling of the trench should be performed with soils not susceptible to frost heaving, in layers dependent on the compacting equipment, uniformly along both sides of the pipe. Moisture of filling material should be close to the optimum moisture content ($\pm 2\%$), soft soils are improper. The refill up to the level of 1.0 m above the crown of the pipe should be compacted with the lightweight equipment. When the designed compaction of this soil layer is accomplished the next layer can be laid. The backfill material density is evaluated on the base of index of compaction ($I_b$). The required values of $I_b$ depending on the level of the compacted layer, the type of structure (cutting, embankment) and the category of traffic load are presented in figures.
2. Pipelife Polska S.A. ul.Torfowa 4; Kartoszyno; 84-110 Krokowa
tel.:(+ 48 58) 77 48 888; fax (+ 48 58) 77 48 807; e-mail: dok@pipelife.pl; www.pipelife.pl

3. POLISH ACTS AND REGULATIONS

4. POLISH STANDARD CODES OF PRACTICE
[19] DS 430 The laying of underground flexible pipelines of Plastic

5. GUIDELINES PUBLISHED BY THE GENERAL HEAD OFFICE OF HIGHWAYS IN WARSAW
[23] Wytyczne projektowania dróg VI i VII klasy technicznej WPD-3 - 1995r.

6. TECHNICAL APPROVALS
[31] AT/97-01-0199 Rury drenarskie karbowane z PVC-U produkcji Pipelife. - wydana przez Centralny Ośrodek Badawczo-Rozwojowy Techniki Instalacyjnej INSTAL
[33] AT/97-03-0096 Studzienki teleskopowe kanalizacyjne i drenażowe MABO. - wydana przez Instytut Badawczy Dróg i Mostów w Warszawie.
[34] AT/98-04-0506 System rurowy o ściankach strukturalnych z polipropylenu (PP) do kanalizacji, drenażu oraz przepustów w nasypach komunikacyjnych - wydana przez IBDiM.
[35] AT/99-02-0752 Rury o ściankach strukturalnych typu Pragma® z polipropylenu do kanalizacji zewnętrznej. - Wydana przez COBRTI INSTAL.

7. CATALOGUES
[41] Rury drenażowe i osprzęt. Charakterystyka materiałowa - Pipelife Polska
[42] Rury drenażowe i osprzęt. Wytyczne projektowe - Pipelife Polska
[43] Rury drenażowe i osprzęt. Wytyczne montażu i eksploatacji - Pipelife Polska
[44] Katalog techniczny. Systemy kanalizacji zewnętrznej z PVC - Pipelife

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1. INTRODUCTION

1.1. SCOPE

This publication is produced as a guide to installation of the PIPELIFE φ 630 mm PRAGMA® inspection and gully chambers with the use of various types of chamber access encases and covers. The encases of the chambers can be constructed of poured concrete or precast concrete collar bed-plates, suitable for the wide range of the produced cast iron frames and covers or gully gratings.

The proposed designs meets the requirements of the various positions of sewers and drainage inspection and inlet chambers, including:

- greens and parks, unsurfaced roads, sidewalks, roads of asphalt and small-sized elements (stone or ceramic) pavements.

The presented within designs include applications of extensive range of chamber access elements produced by:

- PIPELIFE Polska
  - cast iron frames and covers: UFL-40 (class D 400), TO5D (A50);
  - cast iron frames and gratings: T50K (D400), T40K (A50), T30K (B125);

- Polish foundry plant - Koneckie Zaklady Odlewnicze
  - cast iron frames and grating: WUK C or D;
  - cast iron frames and covers: AO φ 400÷800 (A50), φ600 (B125÷D400), CO φ 600 - W (C250), φ 600 (B125÷D400), CO φ 600 - W (C250), φ 600 (D400 according to EN 124), φ 800 (B125 ÷D400).

- Polish plant - Stąporków - Meier Sp.zo.o. :
  - cast iron frames and covers and BEGU®, circular: φ 600 and 800 (A15 ÷D400).

1.2. DEFINITIONS OF TERMS

Table 1

<table>
<thead>
<tr>
<th>No.</th>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Accidental parking strip (emergency strip)</td>
<td>The side strip of the highway next to traffic lane for stopping and parking technically immobilized vehicles.</td>
</tr>
<tr>
<td>2</td>
<td>Carriageway (roadway)</td>
<td>Part of road crown, usually paved that serves vehicles passing.</td>
</tr>
<tr>
<td>3</td>
<td>Category of mining area</td>
<td>Area of specified mining damage and deformations according to the Polish Standard [15].</td>
</tr>
<tr>
<td>4</td>
<td>Chamber base</td>
<td>The bottom part of inspection/gully chamber which enables assembly of chamber riser, and inlet and outlet pipes.</td>
</tr>
<tr>
<td>5</td>
<td>Chamber access-hole</td>
<td>The top part of inspection (or gully) chamber composed of the encased frame and solid cover or open-type cover (gully).</td>
</tr>
<tr>
<td>6</td>
<td>Chamber encase</td>
<td>The surrounding of the chamber access to support the access frame and cover.</td>
</tr>
<tr>
<td>7</td>
<td>Collar base slab</td>
<td>The precast reinforced concrete circular slab laid surround chamber riser to carry loadings from backfill and traffic.</td>
</tr>
<tr>
<td>8</td>
<td>Gully (inlet)</td>
<td>The compact storm water inlet facility (grate) to catch gutter flow.</td>
</tr>
<tr>
<td>9</td>
<td>Inlet (gully) chamber</td>
<td>The access chamber sited on the storm water sewer with access hole covered with grating to collect surface water and discharge into the storm water sewer and to enable maintenance.</td>
</tr>
<tr>
<td>10</td>
<td>Inspection chamber</td>
<td>Access facility on the non-passage sewer of small size access hole to perform sewer inspection and cleaning from the surface.</td>
</tr>
<tr>
<td>11</td>
<td>Median strip (dividing strip)</td>
<td>The part of road crown between carriageways of opposite directions</td>
</tr>
<tr>
<td>12</td>
<td>Non-passage sewer</td>
<td>Sewer conduit of the inside diameter (or height) less than 1.0 m.</td>
</tr>
</tbody>
</table>
### 3. SEWER SYSTEM COMPONENTS

The sewer pipe systems of PVC and PP produced by PIPELIFE Polska are suitable for all sewerage systems (sanitary sewers - domestic and industrial, storm sewers and combined sewers) to transport wastes by gravity flow. Pipes and fittings are manufactured from rigid polyvinyl chloride (PVC-U) and polypropylene (PP). Pipe sections are produced with sockets and elastic rubber or elastomer sealing rings, which ensure that joints are very tight and stable, at the inside pressure at least 0.05 MPa. Pipes and fittings are resistant to internal chemical effects of household sewage, storm rainwater and most industrial wastes where the concentration of mineral oil fraction do not exceed 10%. In cases where the concentration of petrol is higher the elastomer gaskets have to be used.

The PIPELIFE Polska products spectrum covers:

- **a)** PVC smooth wall, socket pipe system;
- **b)** PVC PERMA-LOCK socket pipe system of profiled - outside walls;
- **c)** PP PRAGMA® pipe system of structural double walls;
- **d)** PVC and PP inspection chambers. Within these systems are produced:
  - **socket pipes:**
    - of smooth walls of class (SN=2), N (SN=4) and T (SN=8) with nominal diameters 110 mm to 400 mm (110 mm only of class T);
    - PERMA - LOCK of Class N with inside diameters from 400 to 800 mm;
    - PRAGMA® of Class T with outside diameters from 160 to 630 mm.
  - **fittings:**
    - bends, elbows, branches;
    - couplings double sockets, connectors, slip couplings;
    - reducers, access pipes, plugs and caps;
    - adaptors for different pipe materials;
    - **in-situ** entries to concrete manholes and wall penetration sleeves;
    - access, inspection and inlet chambers from PVC and PP with diameters from 110 to 630 mm.

The detailed information on the assortment of the PIPELIFE Polska products are included in the main PIPELIFE Technical Catalogue [40], which is edited by the producer and actualized as the new products are introduced into the market.

All pipes, fitting and chamber components for sewerage systems have obtained the following Technical Approvals:

- **AT/96-01-0058 - PVC - PERMA - LOCK profiled wall pipes for sewer systems,** by COBRTI-Instal;
- **AT/97-01-0090 - PVC-U pipes and fittings for sewer systems,** by COBRTI-Instal;
- **AT/97-01-0205 - PP PRAGMA® structural, double-walled pipes for sewer systems,** by COBRTI-Instal;
- **AT/97-01-0205 - PVC and PP MABO telescopic sewer and drainage inspection chambers,** by IBDM in Warsaw;
- **AT/98-01-0395 - PVC and PP MABO telescopic sewer chambers,** by COBRTI-Instal;
- **AT/98-04-0506 - PP structural double-walled pipe system for sewer and drainage systems and for culverts structures under communication embankments.**

### DEFINITIONS OF TERMS

<table>
<thead>
<tr>
<th>No.</th>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>Pipe ring stiffness (SN)</td>
<td>Parameter used to classify sewer pipe which represents pipe operating capacity to external load, dependent on the pipe diameter, pipe wall thickness and relaxation modulus of the pipe material.</td>
</tr>
<tr>
<td>14</td>
<td>Riser pipe</td>
<td>Vertical part of chamber between the base and the access hole encase.</td>
</tr>
<tr>
<td>15</td>
<td>Road base</td>
<td>The road layer on which base courses and surface courses are laid.</td>
</tr>
<tr>
<td>16</td>
<td>Road crown</td>
<td>The crowned road surface including carriageways, sidewalks, cycle tracks etc., depending on the road class.</td>
</tr>
<tr>
<td>17</td>
<td>Road right-of-way</td>
<td>The area occupied by carriageways, roadsides and for facilities connected with maintenance, road users service, as well as reserve land for future development.</td>
</tr>
<tr>
<td>18</td>
<td>Road structure body</td>
<td>Earth structure bounded from above with road surface, side fill slopes or inside slopes of the road drainage ditches.</td>
</tr>
<tr>
<td>19</td>
<td>Sediment trap</td>
<td>Catch basin in the bottom part of the chamber riser pipe in which inlet and outlet pipes are placed some distance above the bottom of the chamber and where debris and sand are trapped.</td>
</tr>
<tr>
<td>20</td>
<td>Shoulder, verge</td>
<td>Side strip of road crown next to carriageway used for pedestrian traffic, and in special cases for vehicles traffic and parking.</td>
</tr>
<tr>
<td>21</td>
<td>Sewer</td>
<td>Linear underground, watertight conduit, generally circular in cross-section for conveying waste waters or surface storm water by gravity.</td>
</tr>
<tr>
<td>22</td>
<td>Subgrade</td>
<td>The natural subsoil or embankment soil laying under the road surface or other structures.</td>
</tr>
<tr>
<td>23</td>
<td>Telescopic pipe</td>
<td>The segment of pipe with one end equipped with factory fitted gasket on other with cost iron frame and cover assembled to the riser pipe.</td>
</tr>
<tr>
<td>24</td>
<td>Traffic load category</td>
<td>Definition of vehicles traffic expressed as the number of wheel loads (100kN) per day per considered highway.</td>
</tr>
</tbody>
</table>
1.4. ASSEMBLY ELEMENTS OF φ 630 MM CHAMBER

The complete inspection or inlet φ 630 mm chambers consist of the following components:

a) plastic material elements
   • riser pipe of PP double-walled pipe;
   • telescopic PVC pipe;
   • plugs and covers;
   • reducers φ 630/400 and φ 630/500/400;

b) precast reinforced concrete slabs or cast in-place concrete collar surround,

c) cast iron chamber access hole elements:
   • frame and cover UFL-400 mm Class 400, produced by PIPELIFE;
   • frame and cover T05D φ 315 mm Class A50, produced by PIPELIFE;
   • frame and grating T50K φ 315 mm Class D 400, produced by PIPELIFE;
   • frame and grating T 40K φ 315 mm Class A50, produced by PIPELIFE;
   • frame and grating T30K φ 315 mm Class 125, produced by PIPELIFE;
   • frames and covers circurlar in shape, produced by Polish foundry plant - Koneckie Zakłady Odlewnicze (KZO) - Class A 50 with clear openings 400 to 800 mm and Class B 125, C250, D400 with clear openings 600 mm and 800 mm;

2. TECHNICAL SPECIFICATION

2.1. LOCATION OF SEWERS IN ROAD RIGHT-OF-WAY

The designed location and installation of sewer pipelines in the road right-of-way shall be coordinated with the road investor, owner and service as well as with all statutory Authorities having any interest in any part of the sewer installation, and in the case of mining areas of categories II-IV (see Polish Standard [15]) also with the Regional Mining Office.

When the access hole to the inspection or gully chamber occurs in the traveled way it always cuts through all road layers. Therefore special care must be taken in the design and placing of the chamber frame and cover relative to the finished road wearing surface if traffic is not to be imposed by the presence of the inspection of gully chamber. Any repairs around the entrance to the chamber is a very hard task, which requires temporary shut-down of a road lane or even a section of a roadway. For that reason location of sewers under roadways in paved shoulders and accidental parking strips should conform to the obligatory acts and standards, especially in relation to motorways, expressways and highways of categories KR5 and KR6, as well as be agreed with the all authorities responsible for road making, development and maintenance.

2.2. APPLICATIONS OF CONCRETE, REINFORCED CONCRETE AND CAST IRON ELEMENTS

Depending on the position of the chamber in the road right-of-way and road traffic load category, the suitable design of the chamber access hole should be used.

Requirements concerning the design of the chamber access have been divided into several grades based on the Annex A to the Polish Standard PN-H-74124:1993 (EN124) [18], as follows:

- grade no 1 (required Class A15kN) - for use in greens and footways, cycle tracks, and for occasionally passing very slow moving vehicles, e.g. an access road to the garages;
- grade no 2 (required Class B 125 kN) - for roads and paved areas available for pedestrian traffic and for slow moving vehicles, e.g. promenades, parking spaces;
- grade no 3 (required Class C 250 kN) - for road shoulders, and strip along curbs exposed to the loading of slow moving trucks;
- grade no 4 (required Class D 400 kN) - road carriageways.

2.2.1 CHAMBER ACCESS HOLES COMPONENTS PRODUCED BY POLISH FOUNDRY PLANT KZO IN KOŃSKIE

Collar precast reinforced concrete base-slab φ 980 mm with the clear opening φ 600 mm enables to apply circular sewer chamber access holes cast iron elements in diameters of φ 600 and 700 mm produced by Polish foundry plant KZO as follows:

- frame and cover AO class A 50 in diameters from 600 to 700 mm;
- frame and cover Class B 125 in diameter of 600 mm;
- frame and cover Class C 250 in diameter of 600 mm;
- frame and ribbed cover Class C 250 or D 400 in diameter of 600 mm;
- frames with screwed covers Class B 125, C250 or D 400 in diameter of 600 mm;
- frame with ventilation cover CO600 - W Class C250 in diameter of 600 mm;
- frame and cover according to EN124 Class D400 in diameter of 600 mm;
- frame and cover of type 221300 (2160A) in diameter of 546 mm;
- frame and cover of type 221330 (2170A) in diameter of 526 mm.

Foundation of the collar precast reinforced concrete slab:

- in greens - on the concrete surround (Class B-20 concrete), in diameter of 114 cm and minimum 16 cm thick, cast in-place on the bedding made of well compacted gravel or sandy/gravel soil layer minimum 10 cm thick. The required minimum value of the index of compation of the bedding layer is Is = 1.0;
- in unpaved roads - on the concrete collar (Class B-20 concrete), in diameter of 114 cm and minimum 46 cm thick, cast in-place on the bedding made of well compacted layer of gravel or sandy/gravel soil minimum 10 cm thick, compacted to the degree Is = 1.0
- in sidewalks made from small-sized (stone or ceramic) elements - the collar slab in embedded on the concrete.
2.2.2 APPLICATION OF REDUCERS TO ø 400 MM

Application of the reducers ø 630/400 or ø 630/500/400 enables to use frames and covers produced by PIPELIFE (see the Technical Catalogue [40]).

The usage of the reducer ø 630/400 enable the assembly of the following cast iron sets for chamber access holes:

- frame and cover UFL-40 Grade D 400, produced by PIPELIFE,
- frame and cover TO5D Grade A50,
- frame and grating T50K Grade B125, produced by PIPELIFE.

Produced by PIPELIFE:
- frame and grating T50K Grade B125, produced by PIPELIFE,
- frame and grating T40K Grade B125, produced by PIPELIFE,
- frame and grating T30K Grade B125, produced by PIPELIFE.

Application of the reducer ø 630/500/400 enables the assembly of the following cast iron sets for chamber access holes:

- frame and cover TO5D Grade A50,
- frame and cover TO5D Grade A50,
- frame and cover TO5D Grade A50,
- frame and cover TO5D Grade A50,
- frame and cover TO5D Grade A50,
- frame and cover TO5D Grade A50.

2.2.3 CHAMBER FRAMES AND COVERS PRODUCED BY THE POLISH PLANT STĄPORKÓW - MEIER

The precast collar slab ø 980 with the clear opening of ø 600 mm enables application of the circular chamber sets of frames and covers with clear opening of ø 600 mm in Grades A15, B125, C250 and D400 produced by Polish plant STĄPORKÓW - MEIER. The sets of frames and covers are cast iron or cast iron-concrete BEGU®. Foundation of the precast collar slab should be performed in the same way like for the sets of frames and covers ø 600 mm produced by Polish plant KZO embedded on the slab ø 980 (see Section 2.2.1.).

The precast collar slab ø 1300 enables application of the sets of circular frames and covers LW800 in Grades B125 and D400 with clear opening of ø 800 mm produced by Polish plant STĄPORKÓW-MEIER. The sets of cover and frames are cast iron or cast iron-concrete BEGU®. Foundation of the precast collar slab:

- in greens and sidewalks - on the concrete surround (Class B-15 concrete) in diameter of 130 cm and 25 cm thick, cast in-place on the bedding layer minimum 10 cm thick made of gravel or sandy/gravel soil,
- in road wearing courses - on the concrete surround (Class B-20 concrete) in diameter of 130 cm and minimum 46 cm thick, cast in-place on the bedding layer minimum 10 cm thick, made of sand stabilized with cement (1:4). The surface of the contact between asphalt and concrete layers should be sealed with a plastic bituminous strip.

2.3 EARTHWORKS

2.3.1 BEDDING REQUIREMENTS AND PREPARATION

Inspection and inlet chambers should be set on a firm stable bedding layer. Soil conditions in the subgrade and the depth of ground-water table below the chamber base determine the method of chamber foundation. Depending on the actual subgrade conditions the chamber can be assembled on the native undisturbed subgrade or on the bedding layer according to the recommendations listed in Table 2.
Soil to be placed for bedding should be capable of maintaining the specified soil density. Suitable bedding materials for chamber bases are granular and noncohesive soils like coarse, medium and five grained sands. Silty sands can be used only below frost line determined in the Polish Standard [11] (and presented in the figure below), and where the groundwater table is at least 1,0 m below the chamber bedding layer. The sandy bedding layer should be firmly compacted directly after laying. The required degree of compaction of the subgrade and the bedding layer should be minimum 85% Modified Proctor test density, whereas in the case of pipes laid under roads, the index of soil compaction Is should not be less than it results from the depth of pipe laying, the type of road structure (cutting or embankment) as well as the category of traffic loads (see figure in Section 2.3.2.). Placing of the embedment material should be done in layers. The thickness of layers is specified depending on the total depth of the backfill and the tamping equipment. The moisture of the compacted soil can differ from the optimum moisture content by no more than ± 2%.

The bedding layer, 5 cm thick, directly underneath the pipe or the chamber base should be slightly compacted to provide uniform support. Compaction of this layer is increased when the compaction of sidefill of the trench is performed.

The natural subgrade soil and the bedding layer should meet requirements related to the index of soil compaction Is, and soil secondary strain modulus \( E_2 \), the same as the backfill of the trench (see Section 2.3.2.).

Digging below the water table in permeable soils required a well dewatering system to keep the water level below the trench bottom and to provide sewer pipe laying without destruction of the natural soil subgrade.

### Table 2

<table>
<thead>
<tr>
<th>Subgrade soil conditions</th>
<th>Depth of groundwater table below pipe invert level</th>
</tr>
</thead>
<tbody>
<tr>
<td>I Soils not susceptible to frost heaving</td>
<td>&lt; 1 m</td>
</tr>
<tr>
<td>1</td>
<td>• rubble, no fines</td>
</tr>
<tr>
<td>2</td>
<td>• gravels and sandy gravel soils (with grains &gt; 20 mm)</td>
</tr>
<tr>
<td>3</td>
<td>• decomposable slags</td>
</tr>
<tr>
<td>II Soils of slight to medium potential to frost action</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>• silty sands</td>
</tr>
<tr>
<td>5</td>
<td>• clayey rubbles, clayey gravels and sandy gravel soils with fines (with grains &lt; 20 mm)</td>
</tr>
<tr>
<td>6</td>
<td>• clayey gravels and clayey sandy gravel soils with fines (with grains &lt; 20 mm)</td>
</tr>
<tr>
<td>III Soils susceptible to frost heaving*</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>• stiff clays, sandy and silty stiff clays</td>
</tr>
<tr>
<td>8</td>
<td>• clays, sandy clays, silty clays</td>
</tr>
</tbody>
</table>

**NOTES:**

*) when very stiff, stiff, firm \((I_s<0,25)\); whereas when soft and very soft require for individual evaluation
2.3.2 BACKFILLING THE TRENCH

The excavated space outside of chamber up to the level 30 cm above the top pipes connected to the chamber (and not less than 3/4 of the outside pipe diameter) should be filled with gravel or sandy-gravel soils of grain size not exceeding 20 mm.

Final backfill should be completed with soils not susceptible to frost heaving, uniformly around the chamber riser body in consideration of other factors such as paving. The materials such as slags, soils with stones or other which might damage walls of riser pipe should be avoided.

The final backfill should be performed in layers compacted directly after laying. The thickness of layer is specified depending on the tamping equipment. The moisture of the compacted soil can differ from the optimum moisture content by no more than ±2%.

It is inadmissible to perform backfill of soft soils. The compaction of the backfill material should be completed with lightweight tamping equipment not to deform or displace the chamber riser. The degree of consolidation of the backfill material is evaluated on the base of the index a soil compaction (I_s). The required values of I_s, depending on the level of the compacted layer, the type of subgrade structure (cutting or embankment) and the category of traffic loads are presented in figures.

2.4 DESIGNS OF THE PRECAST COLLAR SLABS

The collar slabs are applied to carry loadings from vehicles. The design vertical load is taken as wheel load of Category A (60kN) according to the Polish Standard [21], and for chamber frames and covers of Grade A50 kN - the wheel load of category E (50kN).

The collar base slabs are precast units made from class B-30 concrete, reinforced with Class A - I steel bars.

Bedding layers to the depth of frost penetration can be performed of the road subbase material or of granular soils not susceptible to frost heaving from Class I - group 3 (see Table 2). Bedding should be firmly compacted to a density consistent with the index of soil compaction I_s = 1.0.

The thickness of the bedding layer is from 10 cm to 20 cm (see catalogue sheets of chambers).
2.5 CHAMBER BASES

Chamber bases can be installed on the soil layers according to the recommendations given in Table 2.

The chamber bases can be performed from the plastic units (PVC plugs and caps) placed on the soil bedding layer or on the concrete base (class B-15 concrete). The PRAGMA® structural double-walled riser pipes can be also embedded directly in the concrete footing, class B-15 concrete to be used. In the case of the aggressive waste waters the bottom should be sealed with the PVC cap or plug.

2.6 ASSEMBLY RECOMMENDATIONS

The chamber cast iron frames and encasements should be assembled in the precast elements with the use of low-shrinkable mortars.

To keep the center line, of the frame and the precast collar slab ø 980 and ø 1300, the anchorage should used, e.g. 3 pins ø 6 mm shooted on the circumference of collar slab. The cover frames should be surrounded with the concrete of class B-20.

In the asphalt pavements all surfaces of the contact between bituminous layers and concrete elements should be sealed with plastic bituminous strips.

Suppliers of the low-shrinkable mortars:
• mortar REPA CO-1-10-Technical Approval IBDM AT/97-03-00-87 Firma Produkcyjno - Handlowa PUSZ, O4-833 Warszawa, ul. Szermawska 8
• mortars Fibre-Patch, Spray - Con and Gem - Plast - Technical Approval IBDM AT/97-03-0126 GEMITE Polska, 02-237 Warszawa, ul. Instalatorów 7
• mortar Tapecrete - technical Approval IBDM AT/96-03-0010 Tarcopol Sp.z.o.o., 27-200 Starachowice, ul. Składowa 16
• mortar EMACO S 88, Producer: Master Builders Technologies (Austria) Polish Supplier: PHZ Transpol Warszawa, ul. Stawki 2
• mortar M-38 Instytut Materiałów Budowlanych in Krakowie

Suppliers of putties and plastic bituminous fillings:
• asphaltic - rubber putty - LABERBIT - B Technical Approval ITB AT/96-12-0010, Certificate IBDM349/94 Centralny Ośrodek Badawczo-Rozwojowy Przemysłu Izolacji Budowlanej w Katowicach, Oddział w Pruszkowie, 05-800 Pruszków, ul. Warzyńskiego
• bituminous strip IGA S profile R Sika Polska, Warszawa, tel. (0-22) 644-76-93, 644-77-64
3. REFERENCE ACTS, STANDARDS, DOCUMENTS AND CATALOGUES

POLISH ACTS AND REGULATIONS
[3] Dz.Bud. nr1 poz.1 z 15.03.71r. Zarządzenie nr 60 Ministra Budownictwa i Przemysłu Materiałów Budowlanych sprawie warunków technicznych, jakim powinny odpowiadać instalacje wodociągowe i kanalizacyjne.

POLISH STANDARD CODES OF PRACTICE

TECHNICAL APPROVALS
[31] AT/99-02-0752 Rury o ściankach strukturalnych typu Pragma®, z polipropylenu do kanalizacji zewnętrznej (wydana przez COBRTI INSTAL).
[33] AT/97-03-0096 Studzienki teleskopowe kanalizacyjne i drenażowe MABO (wydana przez Instytut Badawczy Dróg i Mostów w Warszawie).
[34] AT/98-04-0506 System rurowy o ściankach strukturalnych z polipropylenu (PP) do kanalizacji, drenażu oraz przepustów w nasypach komunikacyjnych (wydana przez IBDIM).

CATALOGUES
[41] Katalogi Techniczny - systemy kanalizacji zewnętrznej z PVC. Wydawnictwo MABO-Turlen
[42] Katalog wyrobów ’98 Koneckich Zakładów Odlewniczych
[43] Lista wyrobów Stąporków-Meier
3. CATALOGUE CARDS AND CONSTRUCTION DRAWINGS

Chambers bases $\phi$ 630 with sediuret trap
Chambers $\phi$ 630 made of Pragma® pipes - concrete base ........................................ card 1
Chambers $\phi$ 630 made of Pragma® pipes - bottom made of pipe cup on sand bed . . . card 2
Chambers $\phi$ 630 made of Pragma® pipes - bottom made of pipe cup on concrete foot card 3
Chambers $\phi$ 630 made of Pragma® pipes - bottom with plug on sand bed . . . . . . . card 4
Chambers $\phi$ 630 made of Pragma® pipes - bottom with plug on concrete foot . . . . . card 5

Covers made by Koneckie Zakłady Odlewnicze
Prefabricated slab - construction ........................................................ card 6
Prefabricated slab - construction, reinforcement ................................. card 7
Covers on collar slab $\phi$ 980 - location in greens .................................. card 8
Covers on collar slab $\phi$ 980 - location in unsurfaced roads ................. card 9
Covers on collar slab $\phi$ 980 - location in sidewalks ............................ card 10
Covers on collar slab $\phi$ 980 - location in concrete or boulder pavements . card 11
Covers on collar slab $\phi$ 980 - location in asphalt pavements ................ card 12

Reductions to 400mm diameter
Reduction $\phi$ 630/400 made of Pragma® pipes .......................................... card 13
Reduction $\phi$ 630/400 made of PVC pipes ................................................. card 14

Chambers accesses made by Stąporków - Meier Sp. z o.o.
Prefabricated slab $\phi$ 1300 - construction ............................................... card 15
Prefabricated slab $\phi$ 1300 - construction, reinforcement ....................... card 16
Lid slab $\phi$ 1300 - sewer access $\phi$ 800 in sidewalks .............................. card 17
Lid slab $\phi$ 1300 - sewer access $\phi$ 800 D400 LW800 in roads ................. card 18

Gully WUK C (D)
Slab for gully WUK C (D) - construction ............................................. card 19
Slab for gully WUK C (D) - construction, reinforcement ..................... card 20
Slab for gully WUK C (D) - construction, reinforcement ..................... card 21
Gully WUK C (D) - location in pavement ............................................. card 22
Gully WUK C (D) - cross-sections ...................................................... card 23
beton B-15
podsypka piaskowa min. 100mm
rura Pragma® Ø630
dno kinety
dno osadnika
wypełnienie z betonu B-15

Ø630
Ø900

dno osadnika

min. Ø1200

beton B-15

podsypka piaskowa min. 100mm

skala 1:10

karta 1 | Dno betonowe
Dno studzienki

STUDZIENKA Ø630 z rur Pragma®
pokrywa do rur Pragma® Ø630
podsypka piaskowa min. 100mm
rura Pragma® Ø630
min. Ø900
Dno studzienki z osadnikiem
STUDZIENKA Ø630 z rur Pragma®
skala 1:10
Studzienka Ø630 z rur PRAGMA
Dno z pokrywy do rur

beton B-15

podsypka piaskowa min. 100mm

pokrywa do rur Pragma® Ø630

Dno studzienki z osadnikiem

STUDZIENKA Ø630 z rur PRAGMA

skala 1:10
Dno studzienki z osadnikiem
STUDZIENKA Ø630 z rur Pragma®
Dno z korkiem
karta 4
skala 1:10

połączenie kielichowe

rura Pragma® Ø630

korek do rur Pragma® Ø630

min. Ø900

podсыпка пiaскowa min. 100mm

min. 100

PIPELIFE
Dno studienki z osadnikiem

STUDZIENKA Ø630 z rur Pragma®

Dno z korkiem

karta 5

skala 1:10

podsypka piaskowa min. 100mm

rura Pragma® Ø630

połączenie kielichowe

Ø630

min. Ø1200

korek do rur Pragma® Ø630

stopa z betonu B-15

podsypka piaskowa min. 100mm

OK. 150

150

100
<table>
<thead>
<tr>
<th>Beton</th>
<th>kl. B30</th>
<th>V = 0.052m³</th>
<th>m = 124.8 kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stal</td>
<td>St3SX</td>
<td></td>
<td>m = 12.34 kg</td>
</tr>
</tbody>
</table>
Wykaz stali dla 1 płyty

<table>
<thead>
<tr>
<th>Nr</th>
<th>Stal</th>
<th>Ø</th>
<th>Dł. 1 szt.</th>
<th>Ilość</th>
<th>Długość całkowita [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A-I</td>
<td>10,0</td>
<td>327</td>
<td>2</td>
<td>8,0</td>
</tr>
<tr>
<td>2</td>
<td>A-I</td>
<td>10,0</td>
<td>262</td>
<td>2</td>
<td>5,24</td>
</tr>
<tr>
<td>3</td>
<td>A-I</td>
<td>8,0</td>
<td>57</td>
<td>16</td>
<td>12,84</td>
</tr>
<tr>
<td>4</td>
<td>A-I</td>
<td>8,0</td>
<td>93</td>
<td>4</td>
<td>3,72</td>
</tr>
</tbody>
</table>

Długość razem [m]: 12,84, 11,78

Masa 1m [kg]:
- Ø10 L=327m: 0,222
- Ø10 L=2618m: 0,395
- Ø8 L=930m: 0,617

Masa razem [kg]:
- Ø10 L=327m: 5,07
- Ø10 L=2618m: 7,27

Masa ogółem [kg]: 12,34
*) - wymiar dopasować do wysokości stosowanego włazu
Podbudowa: żwir, pospółka lub materiał ulepszenia nawierzchni wymagany wskaźnik zagęszczenia Is=1.0
*) - wymiar dopasować do wysokości stosowanego włazu
Zastosowanie:

w chodnikach z ceramicznych lub kamiennych elementów drobnowymiarowych np. z kostki BAUMA

*) - wymiar dopasować do wysokości stosowanego włazu

placa Ø980
beton B-15
podszypka piaskowa
min. 100mm

min. 50
Ø980
min. 50
Ø1140
min. 50
Ø640
min. 50
Ø630
Podbudowa:
material podbudowy nawierzchni lub piasek z cementem 1:4
wymagany wskaźnik zagęszczenia Is=1.0
Zastosowanie:
w jezdniach z betonowych lub kamiennych elementów drobnowymiarowych
*) - wymiar dopasować do wysokości stosowanego włazu

Obraz przedstawia lokalizację w nawierzchniach betonowych lub brukowych. Właz na płycie pokrywowej Ø980

* * *
*) - wymiar dopasować do wysokości stosowanego włazu
uszczenia plastyczną taśmą bitumiczną np. LATERBITEM

<table>
<thead>
<tr>
<th>karta 12</th>
<th>Lokalizacja w nawierzchniach asfaltowych</th>
</tr>
</thead>
<tbody>
<tr>
<td>Właz na płycie pokrywowej Ø980</td>
<td></td>
</tr>
<tr>
<td>STUDZIENKA Ø630</td>
<td></td>
</tr>
</tbody>
</table>
Zastosowanie:
do wszystkich zwieńczeń przewidzianych w katalogu studienek Ø400

Uwaga:
na rysunku pokazano przykładowe rozwiązanie z wykorzystaniem wpustu T50K

Uwaga:
na rysunku pokazano przykładowe rozwiązanie z wykorzystaniem wpustu T50K
STUDZIENKA z rury gladkiej z PVC Ø400

Zastosowanie:
do wszystkich zwieńczeń przewidzianych w katalogu studzienek Ø400

Uwaga:
narysunku pokazano przykładowe rozwiązanie z wykorzystaniem wpustu T50K
<table>
<thead>
<tr>
<th>BETON</th>
<th>kl. B30</th>
<th>V=0.104m³</th>
<th>m=248.7 kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>STAL</td>
<td>St3SX</td>
<td></td>
<td>m= 20.55kg</td>
</tr>
</tbody>
</table>

Rzut zbrojenia

Widok z góry

Przekrój pionowy

---

**KARTA 15**

**KONSTRUKCJA**

Płyta prefabrykowana Ø1300

STUDZIENKA Ø630

---

**Rodzaj betonu**: kl. B30

**Objętość** V=0.104m³

**Masa** m=248.7 kg

**Rodzaj stali**: St3SX

**Masa** m=20.55kg
### Wykaz stali dla 1 płyty

<table>
<thead>
<tr>
<th>Nr</th>
<th>Stal</th>
<th>Ø mm</th>
<th>Dł. 1 szt. (cm)</th>
<th>Ilość</th>
<th>Długość całkowita (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A-I</td>
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<td>429</td>
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<td>10,0</td>
<td>311</td>
<td>2</td>
<td>6,22</td>
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<td>348</td>
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<td>93</td>
<td>4</td>
<td>3,72</td>
</tr>
</tbody>
</table>

**Długość razem (m):** 28,92 14,75

**Masa 1m (kg):** 0,322 0,355 0,317

**Masa razem (kg):** 0,00 11,42 9,13

**Masa ogółem (kg):** 20,55

---

**KONSTRUKCJA-ZBROJENIE**

**STUDZIENKA Ø630**

**skala 1:20**
Właz kanałowy B125 LW800

- hak wyciąć
- obetonować betonem B-30
- Ū630 Ø0,60
- ok. 650
- min. 100
- szalunek tracony

Płyta pokrywowa Ø1300
- Właz Ø800 w chodnikach
- obetonowana betonem B-30
- hak wyciąć

Właz kanałowy Begu® B125 LW800

- plywood Ø1300
- beton B-15
- podbudowa
- podsypka piaskowa

karta 17 Właz Ø800 w chodnikach
Płyta pokrywowa Ø1300
STUDZIENKA Ø630

skala 1:10
uszczelnienie plastyczną taśmą bitumiczną np. LATERBITEM

Właz kanałowy D400 LW800

- obetonować betonem B-30
- uszczelnienie

Płyta pokrywowa Ø1300

- wypełnić betonem B-15
- uszczelnienie

beton B-20

- podbudowa

piasek z cem. 1:4

łaznik naprawczy

lub szalunek tracony

 plyta Ø1300

niezależnie od nowej uszczelnienia plastyczną taśmą bitumiczną np. LATERBITEM
STAL BETON kl. B30
St3SX
V=0.076m³
m=6.84kg
m=182.4 kg

120
Ø700
Ø440
Ø1000

Płyta pod wpust WUK C (D)
STUDZIENKA Ø630

<table>
<thead>
<tr>
<th>BETON</th>
<th>kl. B30</th>
<th>V=0.076m³</th>
<th>m=182.4 kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>STAL</td>
<td>St3SX</td>
<td></td>
<td>m= 6.84kg</td>
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</tbody>
</table>
Wykaz stali dla 1 płyty

<table>
<thead>
<tr>
<th>Nr</th>
<th>Stal</th>
<th>Ø</th>
<th>Dł. 1 szt.</th>
<th>Ilość</th>
<th>Długość całkowita [m]</th>
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<tbody>
<tr>
<td>1</td>
<td>A-I</td>
<td>8.0</td>
<td>327</td>
<td>2</td>
<td>6.34</td>
</tr>
<tr>
<td>2</td>
<td>A-I</td>
<td>8.0</td>
<td>186</td>
<td>2</td>
<td>3.72</td>
</tr>
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<td>70</td>
<td>16</td>
<td>11.23</td>
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<tr>
<td>4</td>
<td>A-I</td>
<td>8.0</td>
<td>93</td>
<td>4</td>
<td>3.72</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Długość razem [m]</th>
<th>11.23</th>
<th>0.00</th>
<th>13.78</th>
</tr>
</thead>
<tbody>
<tr>
<td>Masa 1m [kg]</td>
<td>0.125</td>
<td>0.222</td>
<td>0.395</td>
</tr>
<tr>
<td>Masa razem [kg]</td>
<td>1.40</td>
<td>0.00</td>
<td>5.44</td>
</tr>
<tr>
<td>Masa ogółem [kg]</td>
<td>6.84</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

nr 1 Ø8 l=3266
szt. 2

nr 2 Ø8 l=1858
szt. 2

nr 3 Ø4.5 l=702
szt. 16

nr 4 Ø8 l=930
szt. 4
podbudowa z beton B-20

plyta pokrywowa beton B-25

pospolki lub piasek z cementem 1:4

uszczelnienie styku z nawierzchnią asfaltową plastyczną taśmą bitumiczną np. LATERBITEM

Przekrój A-A

nawierzchnia asfaltowa

Przekrój B-B

uszczelnienie styku z nawierzchnią asfaltową plastyczną taśmą bitumiczną np. LATERBITEM

Przekrój B-B

ø630

Przekrój A-A

ø1300

ø440

ø650

ø1000

Wpust WUK C (D)

STUDZIENKA Ø630

skala 1:10

karta 23

Przekroje