INTERNATIONAL STANDARD

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Plastics piping systems for renovation of underground non-pressure drainage and sewerage networks —

Part 9: Lining with a rigidly anchored plastics inner layer

Systèmes de canalisations en plastique pour la rénovation des réseaux de branchements et de collecteurs d'assainissement enterrés sans pression —

Partie 9: Tubage par coffrage plastique interne rigidement ancré

Reference number
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 138, *Plastics pipes, fittings and valves for the transport of fluids*, Subcommittee SC 8, *Rehabilitation of pipeline systems,* in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 165, *Waste water engineering,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

A list of all parts in the ISO 11296 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document is a part of a family of system standards for plastics piping systems of various materials used for the renovation of existing pipelines in a specified application area. System standards for renovation deal with the following applications:

— the ISO 11296 series, *Plastics piping systems for renovation of underground non-pressure drainage and sewerage networks (this series);*

— the ISO 11297 series, *Plastics piping systems for renovation of underground drainage and sewerage networks under pressure;*

— the ISO 11298 series, *Plastics piping systems for renovation of underground water supply networks;*

— the ISO 11299 series, *Plastics piping systems for renovation of underground gas supply networks.*

These system standards are distinguished from those for conventionally-installed plastics piping systems by the requirement to verify certain characteristics in the "as-installed condition", after site processing. This is in addition to specifying requirements for plastics piping system components "as manufactured".

Each of the system standards series comprises a:

— *Part 1: General*

and all applicable renovation technique family-related parts, which for non-pressure drainage and sewerage networks includes or potentially includes the following:

— *Part 2: Lining with continuous pipes;*

— *Part 3: Lining with close-fit pipes;*

— *Part 4: Lining with cured-in-place pipes;*

— *Part 5: Lining with discrete pipes;*

— *Part 7: Lining with spirally-wound pipes;*

— *Part 8: Lining with pipe segments;*

— *Part 9: Lining with rigidly anchored plastics inner layer (this document);*

— *Part 10: Lining with sprayed polymeric materials.*

The requirements for any given renovation technique family are specified in Part 1, applied in conjunction with the relevant other part. For example, both ISO 11296-1 and this document together specify the requirements relating to lining with a rigidly anchored plastics inner layer. For complementary information, see ISO 11296-1. Not all technique families are pertinent to every area of application and this is reflected in the part numbers included in each system standard series.

A consistent structure of clause headings has been adopted for all parts of the ISO 11296 series in order to facilitate direct comparisons across renovation technique families.

Figure 1 shows the common part and clause structure and the relationship between ISO 11296-1 and the system standards for other application areas.

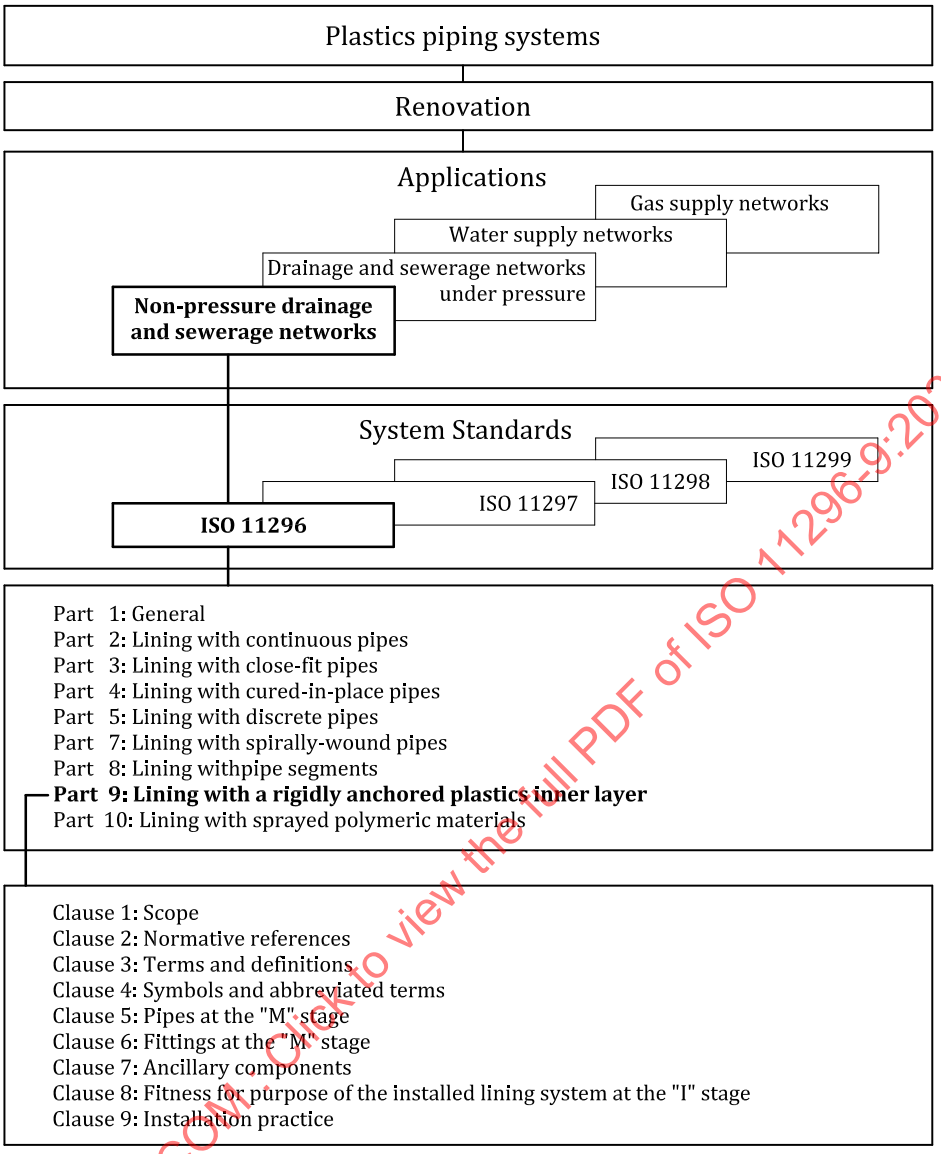


Figure 1 — Format of the renovation system standards

Plastics piping systems for renovation of underground non-pressure drainage and sewerage networks —

Part 9:
Lining with a rigidly anchored plastics inner layer

1 Scope

This document, in conjunction with ISO 11296-1, specifies the requirements and test methods for pipes and fittings for the renovation of underground non-pressure drainage and sewerage networks by lining with a single rigid annulus of structural cementitious grout formed behind a plastics inner layer. This plastics layer serves as permanent formwork anchored to the grout.

This document is applicable to plastics inner layers and grout systems with or without steel reinforcement. It does not apply to the structural design of the lining system.

NOTE Systems with multiple annuli are available, but these are controlled by patent rights and not covered by this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 37, *Rubber, vulcanized or thermoplastic — Determination of tensile stress-strain properties*

ISO 48-4, *Rubber, vulcanized or thermoplastic — Determination of hardness — Part 4: Indentation hardness by durometer method (Shore hardness)*

ISO 75-2:2013, *Plastics — Determination of temperature of deflection under load — Part 2: Plastics and ebonite*

ISO 306, *Plastics — Thermoplastic materials — Determination of Vicat softening temperature (VST)*

ISO 527-1, *Plastics — Determination of tensile properties — Part 1: General principles*

ISO 527-2, *Plastics — Determination of tensile properties — Part 2: Test conditions for moulding and extrusion plastics*

ISO 630-1, *Structural steels — Part 1: General technical delivery conditions for hot-rolled products*

ISO 630-2, *Structural steels — Part 2: Technical delivery conditions for structural steels for general purposes*

ISO 1133-1, *Plastics — Determination of the melt mass-flow rate (MFR) and melt volume-flow rate (MVR) of thermoplastics — Part 1: Standard method*

ISO 1133-2, *Plastics — Determination of the melt mass-flow rate (MFR) and melt volume-flow rate (MVR) of thermoplastics — Part 2: Method for materials sensitive to time-temperature history and/or moisture*

ISO 1183-1, *Plastics — Methods for determining the density of non-cellular plastics — Part 1: Immersion method, liquid pycnometer method and titration method*

ISO 4624:2016, *Paints and varnishes — Pull-off test for adhesion*

ISO 4948-2, *Steels — Classification — Part 2: Classification of unalloyed and alloy steels according to main quality classes and main property or application characteristics*

ISO 6935 (all parts), *Steel for the reinforcement of concrete*

ISO 11296-1:2018, *Plastics piping systems for renovation of underground non-pressure drainage and sewerage networks — Part 1: General*

ISO 11296-4:2018, *Plastics piping systems for renovation of underground non-pressure drainage and sewerage networks — Part 4: Lining with cured-in-place pipes*

ISO 11296-4:2018/Amd 1:2021, *Plastics piping systems for renovation of underground non-pressure drainage and sewerage networks — Part 4: Lining with cured-in-place pipes — Amendment 1: Updated definitions, marking requirements and procedure for alternative expression of flexural test results*

ISO 11296-7, *Plastics piping systems for renovation of underground non-pressure drainage and sewerage networks — Part 7: Lining with spirally-wound pipes*

ISO 11357-6, *Plastics — Differential scanning calorimetry (DSC) — Part 6: Determination of oxidation induction time (isothermal OIT) and oxidation induction temperature (dynamic OIT)*

ISO 12162, *Thermoplastics materials for pipes and fittings for pressure applications — Classification, designation and design coefficient*

ISO 13262, *Thermoplastics piping systems for non-pressure underground drainage and sewerage — Thermoplastics spirally-formed structured-wall pipes — Determination of the tensile strength of a seam*

EN 196-1, *Methods of testing cement — Part 1: Determination of strength*

EN 445:2007, *Grout for prestressing tendons — Test methods*

EN 1015-3, *Methods of test for mortar for masonry — Part 3: Determination of consistence of fresh mortar (by flow table)*

EN 1015-6, *Methods of test for mortar for masonry — Part 6: Determination of bulk density of fresh mortar*

EN 1107-2, *Flexible sheets for waterproofing — Determination of dimensional stability — Part 2: Plastic and rubber sheets for roof waterproofing*

EN 1542:1999, *Products and systems for the protection and repair of concrete structures — Test methods — Measurement of bond strength by pull-off*

EN 1610:2015, *Construction and testing of drains and sewers*

EN 1916:2002, *Concrete pipes and fittings, unreinforced, steel fibre and reinforced*

EN 10025-1, *Hot rolled products of structural steels — Part 1: General technical delivery conditions*

EN 10025-2, *Hot rolled products of structural steels — Part 2: Technical delivery conditions for non-alloy structural steels*

EN 12814-2, *Testing of welded joints of thermoplastics semi-finished products — Part 2: Tensile test*

EN 12814-8, *Testing of welded joints of thermoplastics semi-finished products — Part 8: Requirements*

EN 13067, *Plastics welding personnel - Qualification testing of welders — Thermoplastics welded assemblies*

EN 13100-4, *Non-destructive testing of welded joints of thermoplastics semi-finished products — Part 4: High voltage testing*

EN 13412:2006, *Products and systems for the protection and repair of concrete structures — Test methods — Determination of modulus of elasticity in compression*

EN 14117, *Products systems for the protection and repair of concrete structures — Test methods — Determination of time of efflux of cementitious injection products*

CEN/TR 14920, *Jetting resistance of drain and sewer pipes — Moving jet test method*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 11296-1 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
lining with a rigidly anchored plastics inner layer
lining with pipe comprising a single rigid annulus of structural cementitious grout and a plastics inner layer anchored to the grout

3.2
anchored plastics inner layer
layer with integral anchors which forms the inside surface of the pipe after installation

3.3
profiled plastics strip
extruded profile of unplasticized poly(vinyl chloride) (PVC-U) or polyethylene (PE), with integral or separate *seam* (3.5) locking mechanism, used to form the waterway wall of a pipe liner

3.4
joiner strip
extruded profile of PVC-U or PE used to connect adjacent profiled plastic strips

3.5
seam
joint between adjacent *profiled plastics strips* (3.3) formed by an *integral locking mechanism* (3.6), use of a separate *joiner strip* (3.4) and/or *seam sealant* (3.7)

3.6
integral locking mechanism
mechanical interlock achieved by suitable design of the edges of the extruded profile, without use of a separate *joiner strip* (3.4)

3.7
seam sealant
thermoplastic or adhesive material added to the *integral locking mechanism* (3.6), *joiner strip* (3.4) or *profiled plastics strip* (3.3) surface to make the *seam* (3.5) leaktight

3.8
studded PE sheet
polyethylene sheet with integral anchoring studs

3.9
lateral connection collar
fitting for reconnecting a lined main pipe to an existing or renovated lateral pipe

3.10
annular space
gap between the plastics inner layer and either the host pipe or the external layer where present

3.11
reinforcement
steel bars incorporated in the grout or steel stiffening elements placed alongside or encapsulated within the plastics inner layer

3.12
grout system
cement-based grout including any fillers, *reinforcement* (3.11) or other additives or admixtures, in specified proportions

3.13
design thickness
combined thickness of plastics inner layer and grouted annulus required by structural design

3.14
spacer
block of material compatible with *grout system* (3.12) used to maintain minimum thickness of *annular space* (3.10) and prevent flotation of inner plastics layer during filling with grout

4 Symbols and abbreviated terms

4.1 General

For the purpose of this document, the symbols and abbreviated terms given in ISO 11296-1 and the following subclauses apply.

4.2 Symbols

A_w	cross-sectional area of the profiled plastics strip per unit width
b_c	width of air test channel
D	mean diameter of the dolly
d_e	outside diameter of inner plastics layer in circular pipes
$d_{e,min}$	minimum outside diameter of inner plastics layer in circular pipes
e_o	overall height of anchored plastics inner layer
e_w	waterway wall thickness
e_a	height of neutral axis of the strip above its base
e_g	thickness of grout above height of anchors
$e_{g,min}$	minimum thickness of grout above height of anchors
F_a	effective crushing test result
F_h	failure load
F_u	ultimate (collapse) load
f_{bt}	bending tensile stress from crushing strength
f_h	anchoring strength of plastics inner layer
f_s	short-term tensile welding factor

I_w second moment of area of the strip per unit width

$R_{c,28}$ compressive strength after 28 days

$R_{f,28}$ flexural strength after 28 days

r radius

$r_{e,min}$ minimum local radius of curvature of inner plastics layer in cross section of non-circular pipe

r_m mean cross-sectional radius of the RAPL system

s regular stud spacing

s_{max} maximum stud spacing in vicinity of seam

t wall thickness

t_{act} mean measured wall thickness at the crown of the pipe

w effective width of the strip

X minimum extension into lateral pipe

X' additional manufactured length of lateral extension required to cover thickness of RAPL liner

Y minimum extension of rim into the main pipe

4.3 Abbreviated terms

CCTV closed-circuit television

OIT thermal stability

PE polyethylene

PVC-U unplasticized poly(vinyl chloride)

MFR melt mass-flow rate

MRS minimum required strength

RAPL rigidly anchored plastics inner layer

5 Pipes at the "M" stage

NOTE Clause 5 specifies separate requirements for the anchored plastics inner layer and grout system. Since by definition a rigidly anchored plastics inner layer (RAPL) is partly manufactured on site, requirements for the finished product can only be verified at the "I" stage. "I" stage requirements are specified in Clause 8.

5.1 Materials

5.1.1 Product variants

The anchored plastics inner layer shall consist of one of the following:

a) studded PE sheet;

b) profiled plastics strips of PVC-U with integral seam locking mechanism or separate joiner strips;

c) profiled plastics strips of PE with integral seam locking mechanism or separate joiner strips.

NOTE Profiled plastics strips can incorporate steel stiffening elements.

5.1.2 Components of RAPL

The lining pipes shall consist of at least the following components:

— anchored plastics inner layer;

— grout system;

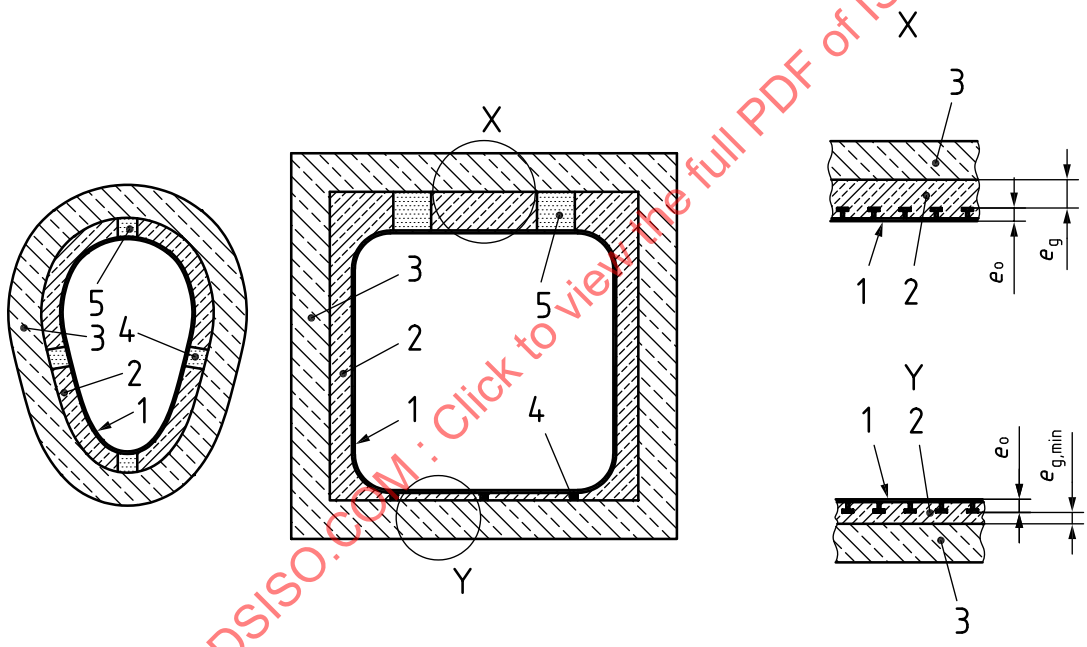
and optionally:

— reinforcement;

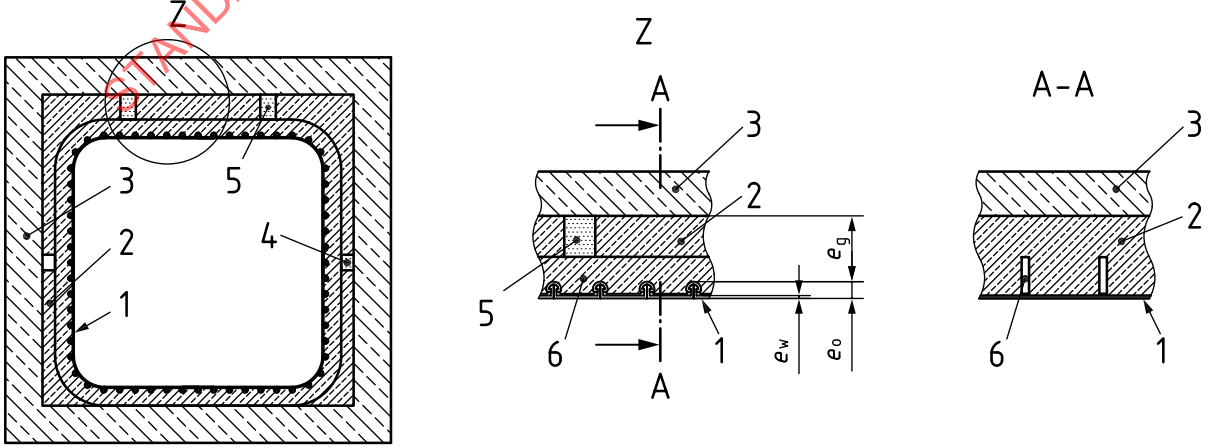
— spacers to ensure grout thickness and prevent flotation;

— external layer.

Examples of RAPL lining systems are shown in Figure 2.



a) System using helically wound profiled plastics strip



b) System using longitudinal plastics strips attached to steel support hoops

Key

1	anchored plastics inner layer
2	grout system (with or without optional reinforcement)
3	existing pipe
4	spacer (technique dependent)
5	anti-flotation spacer
6	steel support hoops for attachment of longitudinal plastics strips
e_o	overall height of anchored plastics inner layer
e_w	waterway wall thickness
e_g	thickness of grout above height of anchors
$e_{g,min}$	minimum thickness of grout above height of anchors
X, Y, Z	enlarged details of corresponding circled areas of diagrams
A-A	cross section of detail Z

Figure 2 — Examples of wall construction of RAPL lining systems

The detailed structure of the lining system shall be declared in the manufacturer's product specification. RAPL components shall comprise the materials specified in Table 1.

Table 1 — Materials for RAPL components

Component	Material
Anchored plastics inner layer	PE sheet in accordance with 5.3.1
	Profiled plastics strips in accordance with 5.3.2 or 5.3.3
Grout system	Cementitious grout in accordance with 5.3.4
Steel bars incorporated in the grout (optional)	Steel in accordance with the ISO 6935 series
Steel stiffening elements or support hoops (optional)	Steel of declared classification in accordance with ISO 4948-2, ISO 630-1 and/or ISO 630-2
External layer (optional)	PE in accordance with 5.3.1, or profiled plastics strips in accordance with 5.3.2 or 5.3.3

For the anchored plastics inner layer either virgin material or the manufacturer's own re-processable material shall be used.

5.2 General characteristics

When viewed without magnification the surfaces of the anchored plastics inner layer shall be smooth, clean and free from scoring, cavities and other defects which can affect their performance.

5.3 Material characteristics

5.3.1 Material characteristics of studded PE sheet and PE profiled plastics strip

Studded PE sheet and PE profiled plastics strips shall conform to the requirements given in Table 2.

Table 2 — Material characteristics of polyethylene in studded PE sheet and PE profiled plastics strips

Characteristic	Requirement	Test parameters		Test method
		Parameter	Value	
Density of base material	≥ 930 kg/m³	ISO 1183-1		
Modulus of elasticity under tension	≥ 500 MPa	Temperature	(23 ± 2) °C	ISO 527-1 ISO 527-2
Tensile strain at yield	≥ 8 %	Temperature	(23 ± 2) °C	
Tensile stress at yield	Declared value but not less than 15 MPa	Speed of testing Temperature	in accordance with ISO 527-2 (23 ± 2) °C	
Tensile strain at break	> 300 %	Test piece shape and initial gauge length	Specimen type 1B in accordance with ISO 527-2	
Dimensional stability in heat	≥ 54 °C	ISO 75-2:2013, Method B		
Melt mass-flow rate (MFR-value)	≤ 3 g/10 min (permitted max. change by processing the compound: ±20 %)	Test temperature Test period Load	190 °C 10 min 5 kg	ISO 1133-1 or ISO 1133-2, as applicable
Thermal stability (OIT)	≥ 20 min	Temperature	200 °C	ISO 11357-6
Variation in longitudinal and transversal dimensions	≤ 1 %	EN 1107-2		
Minimum required strength (MRS)	Declared value but not less than 8 MPa.	ISO 12162		

5.3.2 Material characteristics of PVC-U profiled plastics strips

Materials used for profiled plastics strips of PVC-U shall conform to ISO 11296-7.

5.3.3 Material characteristics of seam sealant

Thermoplastic elastomers used as seam sealants shall conform to the material requirements of Table 3.

Table 3 — Material characteristics of seam sealant

Characteristics	Requirement	Test parameter		Test method
		Parameter	Value	
Tensile strength	≥ 1 MPa	Speed of testing	500 mm/min	ISO 37
Elongation at break	≥ 200 %	Specimen	Type 1	
Shore hardness A	25 ± 10	—		ISO 48-4

5.3.4 Material characteristics of the grout system

The characteristics of the grout shall be in accordance with Table 4.

Table 4 — Material characteristics of the grout system

Characteristic		Requirement	Test parameters		Test method
			Parameter	Value	
Fresh grout[a]					
Bulk density		Declared value within tolerances specified by the lining system supplier	EN 1015-6		
Either	Time of efflux	Declared values within tolerances specified by the lining system supplier	Discharge tube diameter Time intervals from completion of mixing	(8 ± 0,1) mm 5 min, 15 min and 30 min and at end of declared workable life	EN 14117 with modified discharge tube diameter[b]
Or	Flow diameter	Declared values within tolerances specified by the lining system supplier[d]	Time intervals from completion of mixing[e]	5 min and 15 min and at end of declared workable life[d]	EN 1015-3
Stability of the mixture after 3 h		Bleeding < 1 % of initial volume	—	—	EN 445:2007, 4.4
Cured grout system					
Compressive strength $R_{c,28}$		Declared value but not less than 35 MPa without steel bars incorporated in the grout	—	—	EN 196-1[c]
		Declared value but not less than 20 MPa with steel bars incorporated in the grout	—	—	EN 196-1[c]
Flexural strength $R_{f,28}$		Declared value but not less than 5 MPa	—	—	EN 196-1[c]
E-Modulus		> 20 GPa after 28 d without steel bars incorporated in the grout	—	—	EN 13412, Method 2
		> 10 GPa after 28 d with steel bars incorporated in the grout	—	—	EN 13412, Method 2
Change in volume after 24 h		−1 % to +5 %	—	—	EN 445:2007, 4.4

[a] Further characteristics of the fresh grout system which have an influence for a specific RAPL product on:

— complete filling of the annular space; and/or

— achievement of the required characteristics of the cured grout system

shall be declared with corresponding test methods in the installation manual for that product.

[b] The modified diameter is needed because the grain size of mortar mixes used for this application is typically larger than that used for other common applications of cementitious injection products.

[c] The preparation and the conditioning of the prismatic test specimens shall be as specified in EN 196-1. Mixing ratio and mixing technology shall be that actually used in the installation as declared by the manufacturer.

[d] Where self-levelling grout of high fluidity is used, such that the flow diameter exceeds the 300 mm diameter of the table plate of the standard EN 1015-3 test apparatus, the test shall be modified as follows:

— truncated conical mould replaced by simple cylindrical mould of internal diameter 50 mm and height 100 mm;

— time of first flow diameter measurement reduced to 3 min from completion of mixing;

— if necessary, use of a larger table plate (width or diameter of 500 mm recommended).

[e] Or from time of delivery to the construction site in the case of premixed grout.

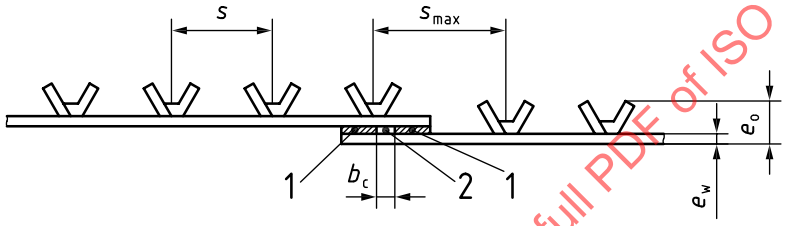
5.4 Geometric characteristics

5.4.1 General

The dimensions and section properties including tolerances of the plastics inner layer shall in all cases be declared.

5.4.2 Studded PE sheet

An example cross-section of a studded PE sheet including a double hot wedge welded seam is illustrated in Figure 3. The geometrical design of the integral stud anchors shall be such as to meet the requirements for the bond between anchored inner layer and grout depending on the RAPH lining system. The waterway wall thickness, e_w, of the PE sheet shall be declared and shall not less than 2,5 mm. The shape and spacing in two dimensions of the integral stud anchors shall also be declared and shall have an overall height, e_o, of not less than 10 mm. The maximum spacing, s_{max}, of studs either side of a welded seam shall not exceed 1,25s, where s is the standard spacing within the sheet in the same direction.



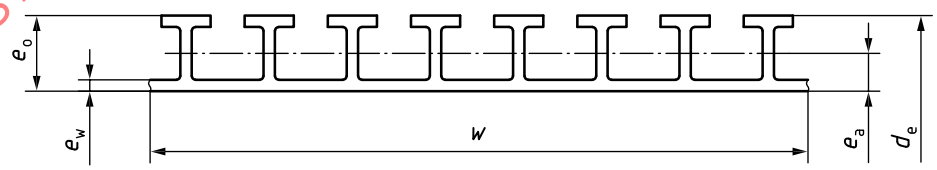
Key

b_c	width of air test channel
e_o	overall height of anchored plastics inner layer
e_w	waterway wall thickness
s	regular stud spacing
s_{max}	maximum stud spacing in vicinity of seam
1	PE weld
2	channel for compressed air testing

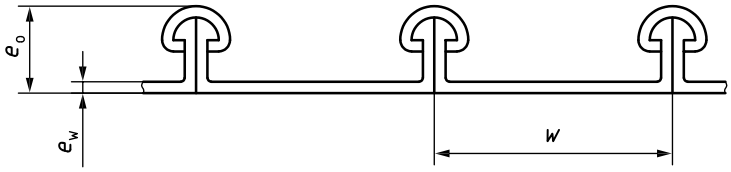
Figure 3 — Example of studded PE sheet with double hot wedge welded seam

5.4.3 Profiled plastics strips

An example cross-section of a profiled plastics strip excluding the seam is illustrated in Figure 4 a). An example cross-section of a profiled plastics strip assembly with separate joiner strips is illustrated in Figure 4 b).



a) Example cross-section of a profiled plastics strip excluding locking mechanism forming the seam



b) Example cross-section of a profiled plastics strip assembly with separate joiner strips

Key

e_o overall height of anchored plastics inner layer
e_w waterway wall thickness
e_a height of neutral axis of the strip above its base
d_e outside diameter of inner plastics layer in circular pipes
w effective width of strip

Figure 4 — Examples of profiled plastics strips

For the characteristics given in Table 5, the dimensions shall be measured or calculated and the values declared, where applicable.

Table 5 — Profiled plastic strip dimensions and section properties

Characteristics	Symbol	Units	Requirements
Profiled strip dimensions	e_o	mm	Declared value but not less than 4,5 mm
	e_w	mm	Declared value but not less than 1,4 mm
	e_a	mm	Declared value
	w	mm	Declared value
	A_w	mm^2/mm	Declared value
	I_w	mm^4/mm	Declared value
Minimum outside diameter or local radius of curvature of wound inner plastics layer	$d_{e,min}$ $r_{e,min}$	mm	Declared value [a, b]
[a] $d_{e,min}$ and $r_{e,min}$ shall be limited by the maximum allowable winding strain in the profiled strip.			
[b] Applicable only to profiled strips used for helical winding.			

The profiled plastics strip supplier shall assign to each profile strip a unique product code (see ISO 11296-7:2019, 5.8) for which the dimensions and section properties listed in Table 6 shall be declared.

The pipe diameter, wall thickness and shape in the "M" stage depending on the RAPL lining technique shall be declared, with their tolerances, by the manufacturer. "M" stage dimensions are needed to obtain specified "I" stage dimensions.

5.5 Mechanical characteristics

No mechanical requirements apply at the "M" stage.

5.6 Physical characteristics

The profiled plastics strip shall conform to the physical requirements of Table 6.

Table 6 — The Vicat softening temperature of profiled plastics strips

Characteristic	Requirement	Test parameter		Test method
		Parameter	Value	
PVC-U				
Vicat B 50	Declared value but not less than 75 °C	Test piece thickness	≥ 3 mm	ISO 306
PE				
Vicat A 50	Declared value but not less than 100 °C	Test piece thickness	≥ 3 mm	ISO 306

5.7 Jointing

5.7.1 General

This subclause applies to the jointing of components of the plastics inner layer.

The plastics inner layer of the RAPL shall provide a protective continuous barrier between the grout and the wastewater over the entire length of the renovated pipeline. Protective coatings shall also be applied to the grout at points of connection to manhole chambers and laterals.

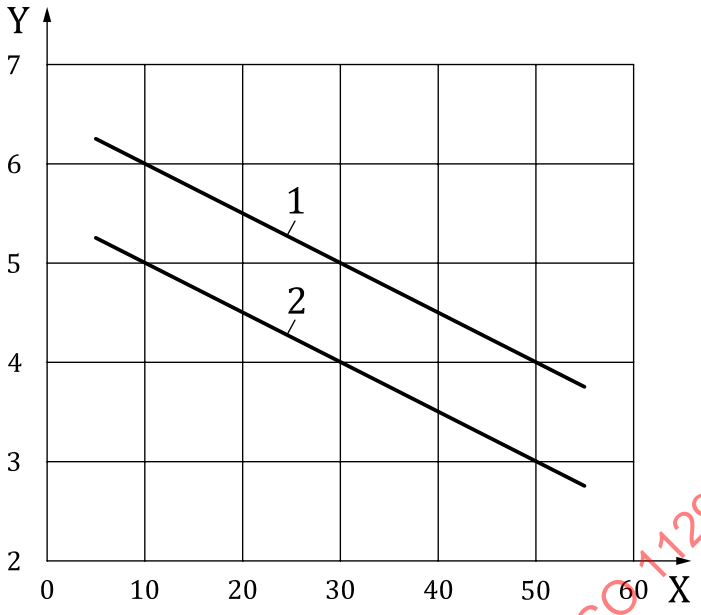
5.7.2 Welding of studded PE sheet to form it into tube

Studded PE sheets shall be manufactured by extrusion. The size of the PE sheet shall be dimensioned so as to produce the required tube diameter or perimeter when welding has been completed. Longitudinal joints in the dimensioned PE sheets shall be formed using the double hot wedge welded seam method, i.e. by overlapping the sheets and joining them by heated wedge welding. Circumferential joints shall be formed by overlapping and using hot gas welding, hot gas extrusion welding or butt welding methods. Welding shall only be carried out by personnel qualified in accordance with EN 13067.

The double hot wedge welded seam shall have a central air channel along its length (see Figure 3) and conform to the leaktightness requirements of Table 7.

Table 7 — Jointing characteristics of studded PE sheet formed into a tube

Characteristic	Test method	Requirement	Test frequency
Leaktightness	An air pressure determined from Figure 5 as a function of ambient temperature and test channel width shall be applied to the channel between the double seam welds.	No leakage shall occur when the air pressure is maintained for one minute.	Every welded seam.



Key

X ambient temperature (°C)

Y test pressure (bar)

NOTE 1 bar = 0,1 MPa = 10^5 Pa; 1 MPa = 1 N/mm^2

1 width of air test channel, b_c = 10 mm

2 width of air test channel, b_c = 20 mm

Figure 5 — Welded seam test pressure as function of ambient temperature and air test channel width [Source DVS 2225-2:2019 (modified)]

When using hot gas welding, hot gas extrusion welding or butt welding methods the leaktightness shall be determined in accordance with EN 13100-4.

The weld shall have a tensile strength not less than the value declared for the sheet material when tested in accordance with Table 2.

Testing of the weld tensile strength (hot gas, hot gas extrusion or butt welding methods) shall be performed in accordance with EN 12814-2. The minimum required short-term tensile welding factor, f_s shall conform to EN 12814-8.

5.7.3 Mechanical jointing of spirally wound PVC-U plastics profiled strips

The PVC-U plastics profiled strips are formed to a plastics inner layer either by using a winding machine which mechanically joins the strips or by manual placing of strips with separate jointing elements. Therefore, the PVC-U plastics profiled strips have at least one lock (male and female) to determine the tight jointing between the strips. Details of the jointing method shall be declared in the installation manual of the RAPL lining system.

Once one spool is finished and a new spool is required for continuing the RAPL lining, the edges of both PVC-U strips shall be joined as described in the installation manual of the RAPL lining system. The mechanical characteristics of PVC-U strips shall conform to the requirements given in Table 8. The RAPL formed by mechanically locked plastic strips shall be designed to meet the water or air tightness requirements in accordance with EN 1610 at the "I" stage.

Table 8 — Mechanical characteristics of PVC-U plastics profiled strips

Characteristics	Requirements	Test parameters		Test method
		Parameters	Value	
Tensile strength of a locked seam	Declared value, but not less than 4 N/mm^2	Test piece width	(15 ± 0,5) mm	ISO 13262
		Distance between grips	Both grips at (10 ± 1) mm of the edge of the seam	
		Speed of testing	5 mm/min	

5.7.4 Mechanical jointing of PE plastics profile strips

The design of the assembly comprising PE profiled plastics strips and joiner strips [see example in Figure 4 b)] shall create a watertight joint between the strips, with or without the use of seam sealant. Details of the jointing method, including any seam sealant applied, and the method of fixing the strips in place prior to grouting, shall be declared in the installation manual of the RAPL lining system.

NOTE Where PE profile strips are installed parallel to the longitudinal axis of the pipe, steel hoops placed within the eventual annulus provide points for fixing the plastics inner layer prior to grouting; see Figure 2 b).

The resistance to pull out of a PE profiled strip from the joiner strips to which it is attached on either side [see Figure 4 b)] shall be sufficient to resist the maximum permitted grouting pressure specified in the lining system installation manual. A suitable method for testing this resistance, by application of a force to the back of the strip in a direction perpendicular to the plane of the jointed plastics layer, shall also be documented in the installation manual.

5.8 Marking

5.8.1 Marking of plastics inner layers

Layers conforming to this document shall be permanently and legibly marked in such a way that the marking does not initiate cracks or other types of premature failure and that storage, weathering, handling and installation do not affect the legibility of the marking.

Marking shall contain at least the following information:

a) code of layer;

b) name and/or trademark of manufacturer;

c) material;

d) information in clear figures or in code, providing traceability to the production period (specified by at least year and month) and production site if the manufacturer is producing at several sites.

5.8.2 Marking of packaged or bulk containerised grout

Each package of grout shall be durable and legibly marked with:

a) code of grout;

b) name of manufacturer;

c) information in clear figures or in code, providing traceability to the production period (specified by at least year and month) and the production site if the manufacturer is producing at several sites;

d) weight of contents.

Where grout is delivered premixed from the factory in bulk containers, the information in a) to d) shall be recorded in documents accompanying each container.

5.9 Regional requirements for pipes

In countries of the single European market, the International Standards ISO 630-1 and ISO 630-2 referenced in Table 1 are substituted by EN 10025-1 and EN 10025-2, respectively.

6 Fittings at the "M" stage

6.1 General

This clause specifies fittings for making lateral connections to RAPL installations. Any other fittings forming part of an individual RAPL lining system shall be specified in an accompanying installation manual.

6.2 Materials

Lateral connection collars shall be compatible with the RAPL to ensure the execution of leaktight connections. This generally requires the lateral connection collar to be of the same type of material, i.e. PVC-U or PE, as the plastics inner layer.

Cured-in-place lateral connection collars shall conform to ISO 11296-4:2018 and ISO 11296-4:2018/Amd1:2021, Clause 6 and 8.5.2.

6.3 Geometric characteristics

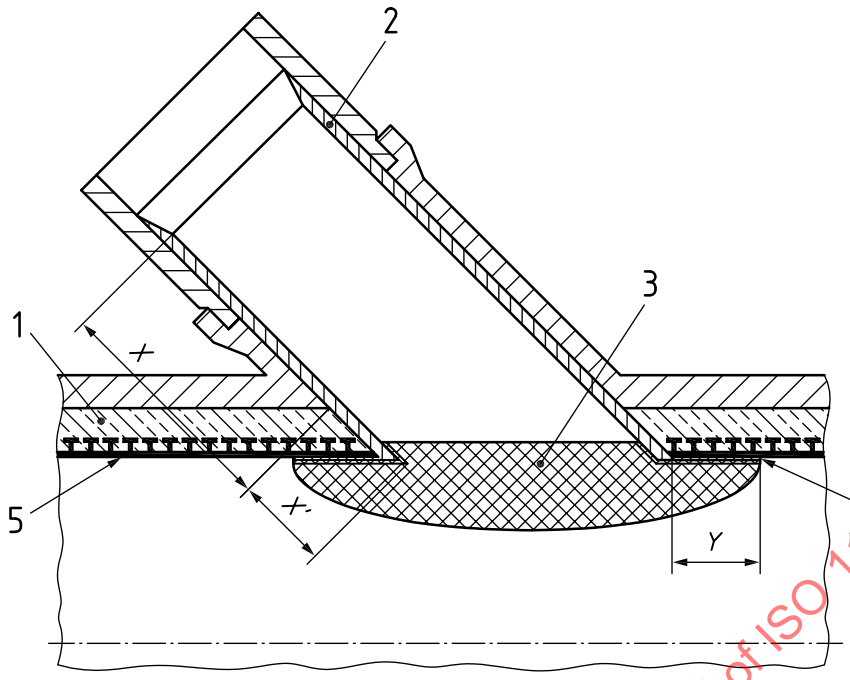
Lateral connection collars shall be classified as indicated in Table 9 in accordance with the minimum distance extended into the lateral pipe.

Table 9 — Classification of lateral connection collars

Class	Minimum extension into lateral pipe, *X*
A	1 000 mm
B	400 mm and at least 150 mm beyond first joint in existing lateral pipe
C	100 mm

In addition, the rim of any lateral connection collar shall overlap the main pipe by a length, *Y*, not less than 50 mm (see Figure 6).

To avoid obstructions to flow and maintenance equipment, the transitions between lateral liner and collar or main pipe, and between lateral liner and lateral pipe, should both be smooth.



Key

1 grout system
2 lateral liner
3 lateral connection collar
4 sealing of connection collar to plastics inner layer
5 anchored plastics inner layer
X minimum extension into lateral pipe
X' additional manufactured length of lateral extension required to cover thickness of RAPL liner
Y minimum extension of rim into the main pipe

Figure 6 — Schematic representation of RAPL lateral connection

7 Ancillary components

This document does not apply to any ancillary components.

8 Fitness for purpose of the installed lining system at the "I" stage

NOTE Clause 8 includes the requirements for the finished RAPL, the manufacture of which, by definition, is not completed until the grout is cured at the "I" stage.

8.1 Materials

The RAPL pipe and any fittings may consist of different material components selected from the ranges specified in 5.1.

8.2 General characteristics

There shall be no damage to the profiled plastics strip due to the winding process, which would prevent fitness for purpose of the installed lining system.

8.3 Material characteristics

The material characteristics of all plastics components and the cured grout system shall conform to 5.3, as applicable.

8.4 Geometric characteristics

The wall thickness of the installed pipe shall conform to Table 10.

Table 10 — Geometric characteristics

Characteristic	Requirement	Test method
Minimum dimension $e_o + e_g$ in accordance with Figure 1	Not less than the design thickness	By coring[a] and measurement
Internal cross-section of liner	Circular liners: minimum diameter not less than (specified diameter minus permitted deflection) Non-circular liners: within shape tolerances specified by design	Laser profiling, use of a template or measurement of appropriate linear dimensions with an instrument accurate to within the greater of 2 mm or 1 % of nominal diameter
[a] The cylindrical samples obtained by coring can be used to test the crushing strength and sedimentation stability of the grout system, and the interlocking bond between the grout and the profile, as well as to measure the wall thickness.		

8.5 Mechanical characteristics

Simulated samples prepared in accordance with 8.8 shall conform to the requirements given in Table 11.

Table 11 — Characteristics at the "I" stage

Characteristic	Requirement	Test parameters		Test method
		Parameter	Value	
Bending tensile stress from crushing strength test, f_{bt} [a]	Declared value, but not less than 2 MPa	Annex B		
Water-tightness	No visible leakage	Test pressure	0 kPa rising to 50 kPa	EN 1610:2015, 13.3
Jetting resistance	See 5.2 (appearance of surface)	Surface conditions	No visible damage	CEN/TR 14920
Anchoring strength of plastics inner layer, f_h	Declared value, but not less than 0,5 MPa [b]	Annex A		
Sedimentation of the grout system	No visible separation of the grain mixture	Visual examination by cutting or splitting the hardened concrete sample from the test "stability of the mixture" (in accordance with Table 4)		
[a] Crushing strength test shall be carried out 28 d after manufacture in accordance with EN 1916:2002, Annex C, for unreinforced pipes. Samples shall be prepared and the bending tensile strength, f_{bt}, calculated in accordance with Annex B. [b] Specification of anchorage strength for design purposes shall take account of any anticipated long-term hydrostatic pressure developing at the interface between inner plastics layer and grout.				

8.6 Physical characteristics

No physical requirements apply at the "I" stage.

8.7 Additional characteristics

No additional requirements apply at the "I" stage.

8.8 Sampling

Simulated installations shall be carried out using a host pipe which does not contribute to load-bearing capacity. The specified annulus between the host pipe and the internal layer shall be grouted. The maximum curing process temperature shall not exceed the maximum permitted temperature of the material of the inner layer.

Before testing, the samples shall be conditioned for 28 d under water at a temperature of (15 ± 5) °C to simulate installed conditions on site.

9 Installation practice

9.1 Preparatory work

For installation, the site conditions shall be considered in such a way that the properties of the installed RAPL meet the requirements of this document. The existing pipeline shall be surveyed, cleaned, inspected internally and otherwise prepared, including controlling any running infiltration that could impair the properties of the injected grout. Special care shall be taken to ensure that the host pipe is free from wastewater and debris after plugging of all lateral connections and either plugging or bypassing the main pipe.

NOTE 1 Site conditions can indicate a need for the grout system to be resistant to chemical attack from the outside.

NOTE 2 EN 14654-3 provides guidance on cleaning the existing pipeline.

9.2 Storage, handling and transport of pipe components

Raw materials shall be stored and used in accordance with the recommendations of their respective or non-respective manufacturers. The liner materials shall be stored and transported under conditions, which do not impair performance of the as-installed product in such a way as to prevent conformity to this document.

9.3 Equipment

All technique-specific equipment shall be documented in the installation manual provided by the manufacturer. The items described should include at least:

— grout storage, mixing and pumping equipment;

— equipment for insertion of the plastics inner layer;

— quality control equipment;

— finishing equipment (e.g. for trimming ends and reopening lateral connections).

9.4 Installation

The procedures for site handling, insertion, grouting and quality control of RAPL shall be documented in the installation manual.

The plastic strips or sheet material of the internal layers shall be connected by mechanical interlock, welding and/or gluing, as applicable. Detailed instructions shall be given in the manufacturers' installation manual. For welding, at least the welding temperature, pressure and welding time shall be specified. For gluing, preparation of surfaces, the type of glue and the range of permissible application temperatures shall be specified. The installation manual shall also describe the measures necessary to prevent flotation and/or deformation of the plastics inner layer during injection of the grout.

The type and mixing ratio of the grout and the minimum temperature for application shall be declared in the installation manual. The calculated quantity of grout required for each installation shall be documented in advance and the actual quantity used monitored against this. All measures taken during installation shall be documented.

At the "I" stage, after the grout has cured, at least one method of verifying that the annular space is completely filled with grout shall also be documented in the installation manual.

NOTE One possible verification method in man entry pipes would be to apply the pull-off test in situ in accordance with Annex A.

9.5 Process-related inspection and testing

Process-related inspection and testing shall confirm to ISO 11296-1:2018, 9.5.

9.6 Lining termination

After installation and cure, the RAPL shall be trimmed to re-establish manhole access without disrupting the integrity of the connection to the manhole. The technique to be applied shall be documented in the installation manual. The exposed end of the grouted annulus shall be treated to create a seal between the inner plastics layer and the host pipe. Any local void between the grouted annulus and host pipe shall be filled and the exposed end of the grouted annulus treated to create a seal between the inner plastics layer and the host pipe.

9.7 Reconnection to existing laterals

The opening in the RAPL shall be formed to restore the flow of the lateral without irregularities, steps or burrs, which could trap debris causing blockages in either the main pipe or the lateral.

The methods of connecting the installed lining system to existing laterals and the recommended method of making subsequent lateral connections shall be documented in the installation manual.

Lateral reconnections can be made from the inside of the main pipe using a lateral liner and connection collar assembly as specified in Clause 5, or a lateral liner of thermoplastic pipe suitably sealed at both ends without use of a connection collar.

9.8 Final inspection and testing

The installed lining system shall be subject to a recorded internal visual examination, either by walk-through or closed-circuit television (CCTV), throughout its length on completion.

9.9 Documentation

All process parameters shall be recorded through all stages of installation at intervals of sufficient frequency to capture possible events of short duration.

Annex A
(normative)

Test method for anchoring strength of plastics inner layer by pull-off

A.1 General

This annex specifies a method for measuring the strength of bond between the anchored plastics inner layer and the grout system of a RAPL product.

A.2 Principle

The method of test is by direct dolly pull-off as described in EN 1542, using a dolly bonded to the surface of the plastics inner layer with the test area having been defined by coring through the surface with or without other preparation. The test determines whether a failure occurs within the plastics inner layer, by pull out of the anchor from the grout, or by tensile failure of the grout system beyond the anchor, and the failure load in each case.

A.3 Apparatus and equipment

A.3.1 Mixing technology for the grout system

Mixing technologies shall be in accordance with EN 196-1 or as declared by the manufacturer.

A.3.2 Moulds

Test specimens of the RAPL products shall be produced in flat moulds in accordance with Figure A.1.

A.3.3 Adhesive

For bonding dollies to the surface of the RAPL test specimen, rapid hardening two-component epoxy adhesive, or similar, as recommended by the manufacturer shall be used.

A.3.4 Circular dollies

Circular dollies shall comply with EN 1542:1999, 4.7.

A.3.5 Diamond core drill and barrel

A.3.6 Pull-off test equipment

The pull-off test equipment shall conform to ISO 4624 with a pulling capacity sufficient to cause tensile bond failure of the specimen. The accuracy shall be within ±2 %.

The pull off equipment shall be capable of applying the load in accordance with ISO 4624:2016, 8.4.2 and shall be provided with a measurement device that displays the exerted force by an analogue or digital system. The measurement device shall retain the reading of maximum force exerted.

A.4 Preparation

A.4.1 General

The preparation of flat samples of the plastics inner layer (e.g. such as jointing profile strips) and the grout system (e.g. mixing ratio, mixing technology, etc.) shall simulate the material and overall wall thickness characteristics of the installed lining system as declared by the manufacturer.

A.4.2 Preparation of test specimens

A.4.2.1 Size of test specimens

The test specimens shall have dimensions as shown in Figure A.1 and Figure A.2 and the height shall be the total height of plastics inner layer plus (100 ± 5) mm of the grout system.

A.4.2.2 Number of test specimens

A minimum of one test specimen is required from which five bond tests shall be carried out. The arrangement of the test areas, etc. is shown in Figure A.1. The minimum acceptable number of tests yielding a valid result, i.e. excluding failure of the bond between the dolly and the plastics layer, is three.

A.4.2.3 Moulding of test specimens

The test specimens shall be prepared in such a way that the plastics inner layer is as flat as possible and sealed into a mould (dimensions depending on technology) with the anchors visible from above. Where the plastics inner layer has continuous ribs, the ribs, but not the waterway wall, shall be pre-cut at the eventual dolly positions. The method of cutting and registering of position shall be specified for each lining system by the manufacturer.

The mixed and fresh grout system should be applied onto the side of the plastics inner layer where the anchors are. The grout system shall be applied such that no air is included and the grout system is homogenous but in all other respects simulating the conditions typically obtained on site.

A.4.2.4 Handling and storage before demoulding

Place a plate of glass, steel or other impermeable material which does not react with cement on the mould to cover the grout system. The plate shall have an approximate size of 600 mm × 600 mm × 6 mm.

Place each covered mould, without delay, on a horizontal base in the moist air room or cabinet. The moist air shall have access to all sides of the mould. Moulds shall not be stacked one upon the other.

The moist air room or the large cabinet for storage of the specimens in the mould shall be maintained at a temperature of (20 ± 2) °C and a relative humidity of not less than 90 %.

Each mould shall be removed from storage at its appropriate time for demoulding.

A.4.2.5 Demoulding and curing of specimens in water

After 24 h the test specimen shall be removed from the mould and stored in water for a further 27 d.

Submerge the specimens without delay in a convenient manner, horizontally in water maintained at (20 ± 1) °C in the containers.

Place the specimens on gratings within the conditioning tank and keep them apart from each other so that the water has free access to all six faces of the specimens.

At no time during storage shall the spaces between the specimens or the depth of water above the upper faces of the specimens be less than 5 mm.

A.5 Procedure

A.5.1 General

Core drilling shall be done in accordance with EN 1542:1999, 7.1, except that the total drill-in depth shall be the thickness of the waterway wall of the plastics inner layer only (see Figure A.2). In the case of plastics inner layers with discrete anchoring studs, each dolly shall be positioned centrally over a stud. In the case of plastics inner layers with continuous ribs, each dolly shall be positioned to coincide with a location where the ribs have been pre-cut (see A.4.2.3).

Applying the dolly, setting the pull-off equipment and applying the load shall be done in accordance with EN 1542:1999, 7.2, 7.3, and 7.4 respectively.

A.5.2 Determination of the type of failure

From a visual assessment, determine the type of failure of the specimen. The types of failure are as follows:

Type A: failure within the plastics inner layer, including separation of profile strips from their joiner strip where applicable;

Type B: failure by pull out of the anchor from the grout; and

Type C: tensile failure of the grout system beyond the anchor.

Any failure within the grout which exposes the surface of an anchoring element (stud or rib) of the plastics inner layer shall be classified as Type B.

A.5.3 Validity of the test result

For each test location, the load at failure is valid for all failure types, except where failure occurs within the adhesive used to attach the dolly to the plastics inner layer, or has been influenced by cracking of the grout or other damage to the test specimen caused by prior failure at an adjacent location.

A.5.4 Calculation

For each test location where a valid failure of Type B or C as defined by A.5.2 occurs, calculate the anchoring strength to the nearest 0,1 MPa, using Formula (A.1):

$$f_h = \frac{4F_h}{\pi D^2} \tag{A.1}$$

where

f_h is the anchoring strength of the test specimen, in MPa;

F_h is the failure load, in N;

D is the mean diameter of the dolly, in mm, i.e. 50 mm.

The mean anchoring strength shall be determined from a minimum of three test results.