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BSI Standards Publication

Systems for renovation of drains and sewers — Lining with a rigidly anchored plastics inner layer (RAPL)

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National foreword

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The UK participation in its preparation was entrusted to Technical Committee B/505, Wastewater engineering.

A list of organizations represented on this committee can be obtained on request to its secretary.

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English Version

Systems for renovation of drains and sewers - Lining with a rigidly anchored plastics inner layer (RAPL)

Systèmes de rénovation des réseaux d'assainissement - Chemisage par revêtement de plastique interne rigidement ancré

Systeme für die Renovierung von Abwasserkanälen und -leitungen - Lining mit fest verankerter Kunststoffauskleidung

This European Standard was approved by CEN on 18 July 2014.

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Foreword

This document (EN 16506:2014) has been prepared by Technical Committee CEN/TC 165 “Wastewater engineering”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by April 2015 and conflicting national standards shall be withdrawn at the latest by April 2015.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

Products conforming to this standard do not belong to the product family “Plastics piping systems for renovation of underground non-pressure drainage and sewerage networks”, because the structural behaviour depends mainly on the cementitious grout and the plastics inner layer serves primarily as permanent formwork for corrosion protection.

For the technique of spirally wound pipes in particular the scope of EN ISO 11296-7 is distinguished from that of this standard in requiring the plastics pipe component to have adequate ring stiffness to resist all external loads on its own without any structural contribution from grout used as annular filler as given in EN 15885:2010, 5.7. Plastic piping systems used for renovation are specified in the standards series EN ISO 11296, comprising a “Part 1: General” and various technique related parts.

This document follows the approach in considering products used for renovation at the “M” stage and the “I” stage as specified in EN 13380 and the series EN ISO 11296.

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

1 Scope

This European Standard specifies performance requirements and test methods for pipes and fittings for the renovation of underground drain and sewer systems 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. It is applicable to plastics inner layers and grout systems with or without steel reinforcement.

This European Standard 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 European Standard.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

EN 206:2013, *Concrete - Specification, performance, production and conformity*

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

EN 728, *Plastics piping and ducting systems - Polyolefin pipes and fittings - Determination of oxidation induction time*

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 1610:1997, *Construction and testing of drains and sewers*

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

EN 1979, *Plastics piping and ducting systems - Thermoplastics spirally-formed structured-wall pipes - Determination of the tensile strength of a seam*

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 10048, *Hot rolled narrow steel strip - Tolerances on dimensions and shape*

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 semifinished 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*

EN 14654-1, *Management and control of operational activities in drain and sewer systems outside buildings - Part 1: Cleaning*

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

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

EN ISO 527-2:2012, *Plastics - Determination of tensile properties - Part 2: Test conditions for moulding and extrusion plastics (ISO 527-2:2012)*

EN ISO 527-3, *Plastics - Determination of tensile properties - Part 3: Test conditions for films and sheets (ISO 527-3)*

EN ISO 1133-1:2011, *Plastics - Determination of the melt mass-flow rate (MFR) and melt volume-flow rate (MVR) of thermoplastics - Part 1: Standard method (ISO 1133-1:2011)*

EN ISO 1133-2:2011, *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 1133-2:2011)*

EN ISO 1183-1, *Plastics - Methods for determining the density of non-cellular plastics - Part 1: Immersion method, liquid pyknometer method and titration method (ISO 1183-1)*

EN ISO 2039-1, *Plastics - Determination of hardness - Part 1: Ball indentation method (ISO 2039-1)*

EN ISO 4624:2003, *Paints and varnishes - Pull-off test for adhesion (ISO 4624:2002)*

EN ISO 6259-1, *Thermoplastics pipes - Determination of tensile properties - Part 1: General test method (ISO 6259-1)*

EN ISO 11296-1:2011, *Plastics piping systems for renovation of underground non-pressure drainage and sewerage networks - Part 1: General (ISO 11296-1:2009)*

EN ISO 11296-7:2013, *Plastics piping systems for renovation of underground non-pressure drainage and sewerage networks - Part 7: Lining with spirally-wound pipes (ISO 11296-7:2011)*

3 Terms and definitions

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

3.1
lining with a rigidly anchored plastics inner layer
RAPL
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
lateral connection collar
fitting for reconnecting a lined main pipe to an existing or renovated lateral pipe

[SOURCE: EN ISO 11296-4:2011, 3.1.11]

3.4
design thickness
thickness of grout required by structural design

3.5
annulus
gap between the internal layers and host pipe or external layers

3.6
reinforcement
steel bars incorporated in the grout or steel stiffening elements placed alongside or encapsulated within the plastics inner layer

3.7
grout system
cement based grout including any fillers, reinforcement or other additives or admixtures, in specified proportions

3.8
declared value
limiting value of a characteristic declared in advance by lining system supplier which becomes the requirement for the purposes of assessment of conformity

[SOURCE: EN ISO 11296-1:2011, 3.1.12]

3.9
virgin material
material in a form such as granules or powder that has not been subjected to use or processing other than that required for its manufacture and to which no reprocessable or recyclable material has been added

[SOURCE: EN ISO 11296-1:2011, 3.4.1]

3.10
own reprocessable material
material prepared from rejected unused plastics strips or sheets, including trimmings from the production of other products of the same material, that will be reprocessed in a manufacturer's plant after having been previously processed by the same manufacturer by a process such as moulding or extrusion, and for which the complete formulation is known

4 Symbols and abbreviations

4.1 Symbols

A_w cross-sectional area of the profiled plastics strip

$d_{e,min}$ minimum outside diameter of inner plastics layer in circular pipes

e_o overall profile height

e_w waterway wall thickness

e_a height of neutral axis of the strip above its base

e_1 thickness of plastic at any point over the top (short side) of an encapsulated steel strip

e_2 thickness of plastic at any point over the height (long side) of an encapsulated steel strip

f_{bt} bending tensile stress from crushing strength

f_h anchoring strength of plastics inner layer

I_w second moment of area of the strip

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

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

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

w effective width of the strip

4.2 Abbreviations

RAPL Rigidly anchored plastics inner layer

PE Polyethylene

PVC-U Unplasticized poly(vinyl chloride)

5 Pipes at the “M” stage

5.1 General

Since by definition RAPL is partly manufactured on site, requirements of the finished product can only be verified at the “I” stage. “I” stage requirements are specified in Clause 8.

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

— anchored plastics inner layer;

— grout system;

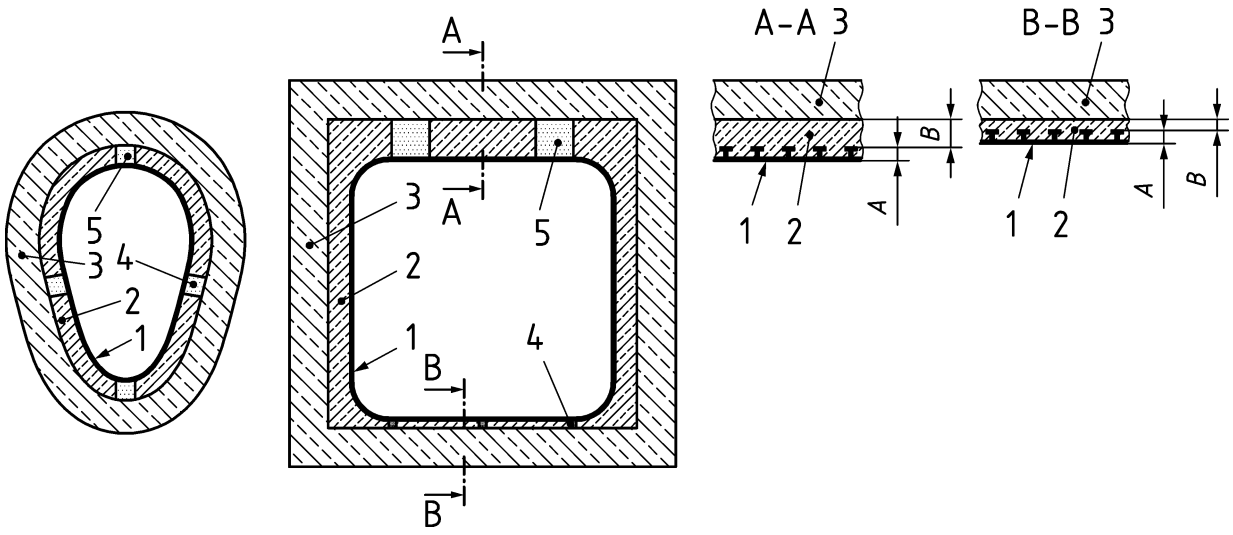
and optionally:

— reinforcement;

— spacers to ensure grout thickness and prevent flotation;

— external layer.

An example of a lining system with RAPL is shown in Figure 1.



Key

1 anchored plastics inner layer

2 grout system

3 existing pipe

4 spacer (technique dependent)

5 anti-flotation spacers

A height of anchors (equivalent to e_0)

B minimum thickness of grout above height of anchors

Figure 1 — Example of wall construction of a lining system with RAPL

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

a) PE sheet material with integral anchors;

b) PVC-U profiled strips with integral or separate seam locking mechanisms.

NOTE The anchored plastics inner layer can incorporate steel stiffening elements.

5.2 Appearance

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 Materials

5.3.1 Components of RAPL

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 in accordance with 5.3.2.1
	Profiled plastics strips in accordance with 5.3.2.2
Grout system	Cementitious grout in accordance with 5.3.3
Steel bars incorporated in the grout (optional)	Steel in accordance with EN 10025-1 and EN 10025-2
Steel stiffening elements (optional)	Steel in accordance with EN 10048
External layer (optional)	PE in accordance with 5.3.2.1 or Profiled plastics strips in accordance with 5.3.2.2

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

5.3.2 Material characteristics of inner layers

5.3.2.1 Material characteristics of PE sheet material

The internal layers made from PE sheet material shall conform to the requirements given in Table 2.

Table 2 — Material characteristics of PE sheet material

Characteristic	Requirement	Test parameters		Test method
		Parameter	Value	
Density of base material	≥ 930 kg/m^3	EN ISO 1183-1		
Modulus of elasticity (tension)	≥ 500 N/mm^2	Temperature	23 °C	EN ISO 527-3 or EN ISO 527-2, as applicable
Tensile elongation Elongation at yield stress	≥ 8 %	Temperature	23 °C	EN ISO 527-3 or EN ISO 527-2, as applicable
Longitudinal tensile stress at yield point	> 15 MPa	Speed of testing for $e \leq 12$ mm $e > 12$ mm	(100 ± 10) mm/min (25 ± 2,5) mm/min	EN ISO 6259-1
		Temperature	23 °C	
Elongation at break	> 350 %	Test piece shape and initial gauge length	Specimen type 1B in accordance with EN ISO 527-2:2012	
Ball indentation hardness	(26 ± 1,5) N/mm^2	EN ISO 2039-1		
Dimensional stability in heat	≥ 54 °C	EN 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	EN ISO 1133-1:2011 or EN ISO 1133-2:2011, as applicable
Thermal stability (OIT)	≥ 20 min	Temperature	200 °C	EN 728
Variation in longitudinal and transversal dimensions	≤ 1 %	EN 1107-2		

The material characteristics of the PE anchored plastics inner layer and external layer, if applicable, shall be demonstrated through a declaration of compliance.

5.3.2.2 Requirements for profiled plastics strips

Materials used for profiled plastics strips shall conform to EN ISO 11296-7.

5.3.3 Material characteristics of the grout system

The characteristics of the grout shall be in accordance with Table 3.

To allow for different viscosities of the fresh grout mix specified by different systems suppliers either the marsh cone test in accordance with EN 14117 or the flow table method in accordance with EN 1015-3 may be used to define workable life.

The heat of hydration of the grout mix shall not distort or otherwise damage the plastics inner layer during the curing process.

Except where an external layer is provided, the resistance of the grout system against chemical attack from the environment of the host pipe, its soil surround and ground water shall be classified as XA1, XA2 or XA3 in accordance with EN 206:2013, Table 1.

Table 3 — 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	Time intervals from completion of mixing	5 min and 15 min and at end of declared workable life	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	–	–	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	–	–	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.

Attention is drawn to national regulations restricting use of potentially contaminating materials in areas of groundwater abstraction.

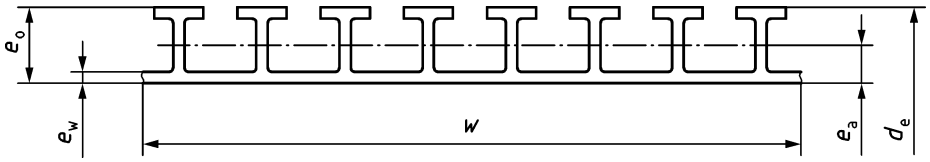
5.4 Geometric characteristics

5.4.1 General

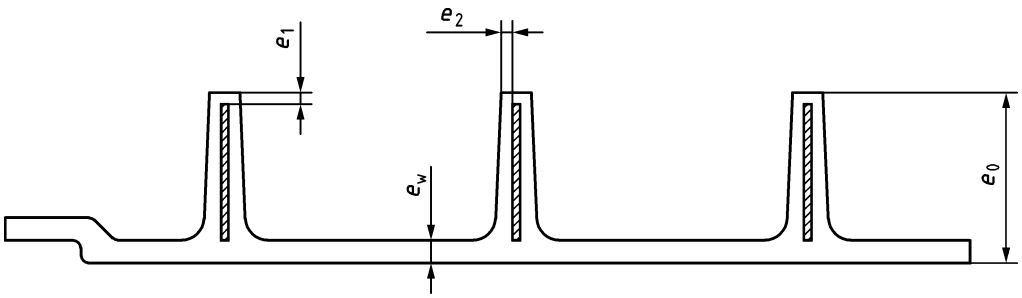
The dimensions and section properties including tolerances of the plastics inner layer shall in all cases be declared.

5.4.2 Profiled plastics strips

An example of a profiled plastics strip excluding the seam is illustrated in Figure 2 a). An example of a profiled plastics strip with encapsulated steel is illustrated in Figure 2 b).



a) Example of a cross section of a profiled plastics strip



b) Example of a cross section of a profiled plastics strip with encapsulated steel

Figure 2 — Examples of profiled plastics strips

For the characteristics given in Table 4, the dimensions shall be measured or calculated and the values declared, where applicable.

Table 4 — Profiled plastic strip dimensions and section properties

Characteristics	Symbol	Units	Requirements
Profiled strip dimensions	e_0	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
	e_1	mm	Declared value but not less than 1,4 mm
	e_2	mm	Declared value but not less than 1,4 mm
	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]
[a] $d_{e,min}$ or $r_{e,min}$ shall be limited by the maximum allowable winding strain in the profile strip.			

The profiled plastics strip supplier shall assign to each profile strip a unique product code (see EN ISO 11296-7:2013, 5.8) for which the dimensions and section properties listed in Table 4 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.

5.4.3 PE sheet material with integral anchors

The geometrical design of the anchor shall be such as to meet the requirements for the bond between anchored inner layer and grout depending on the RAPL lining system. The thickness of the PE sheet, the shape and spacing in two dimensions of the integral anchors shall be declared.

5.5 Jointing of components of internal layers

5.5.1 General

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.

5.5.2 Welding of PE-sheet material with studs to form it into tube

PE sheets with anchors shall be manufactured by extrusion. The size of the PE sheet shall be dimensioned so as to ensure the required diameter or perimeter when welding has been completed. The dimensioned PE sheets shall be welded using the double seam wedge welding method by overlapping the sheets, 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 seam wedge shall have a central air channel along its length and conform to the leak tightness in accordance with the requirements of Table 5.

Table 5 — Jointing characteristics of PE-sheet material with studs formed into a tube

Characteristics	Requirement	Parameter	Test frequency
Leaktightness	An air pressure of at least 6 bar shall be applied to the air channel between the double seam wedge weldings	No leakage shall occur when the air pressure is maintained for one minute	Every welding seam

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

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

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

5.5.3 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 6. 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 6 — 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	Test piece width	(15 ± 0,5) mm	EN 1979
		Distance between grips	Both grips at (10 ± 1) mm of the edge of the seam	
		Speed of testing	5 mm/min	

6 Marking

6.1 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 production period (specified by at least year and month), and production site if manufacturer is producing at several sites.

6.2 Marking of packaged 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 production period (specified by at least year and month), and production site if manufacturer is producing at several sites;

d) weight of contents.

7 Fittings at the “M” stage

7.1 General

Since by definition RAPL is partly manufactured on site, requirements of the finished product can only be verified at the “I” stage. “I” stage requirements are specified in Clause 8.

7.2 Lateral connections

7.2.1 Materials

Lateral connections shall be compatible with the RAPL to ensure the execution of leak tight connections.

NOTE Generally, this requires the lateral connection collar to be of the same type of material, i.e. PVC-U or PE, as the plastics inner layer.

7.2.2 Geometric characteristics

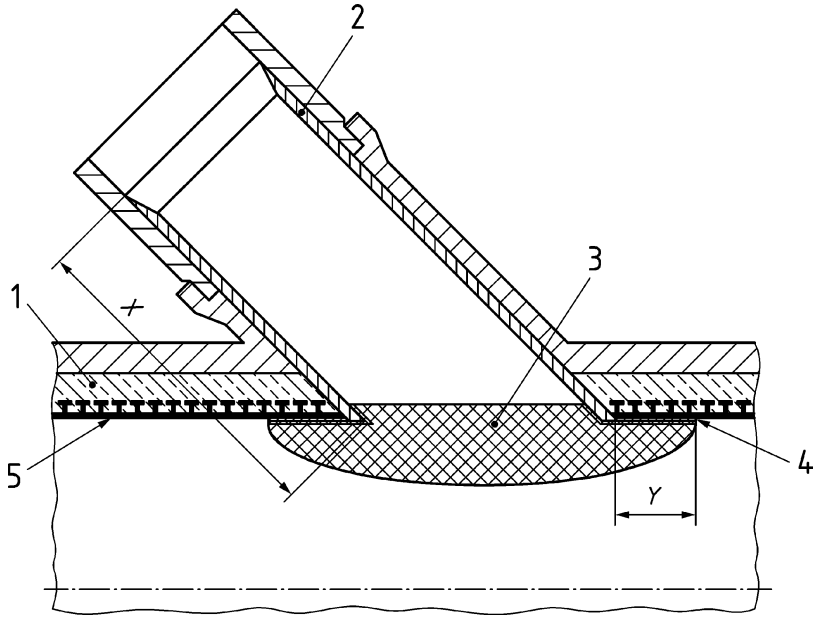
Lateral connections shall be classified as indicated in Table 7 in accordance with the minimum distance extended into the lateral pipe.

Table 7 — Classification of lateral connection collars

Class	Minimum extension *X* into lateral pipe
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 3).

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 (solvent cemented for PVC-U, extrusion welded or electro fused for PE)
5 anchored plastics inner layer
X minimum extension into lateral pipe
Y minimum length of overlap into the main pipe

Figure 3 — Schematic representation of RAPL lateral connection

8 Lining system at the "I" stage

8.1 General

This clause 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.

8.2 Wall thickness

The wall thickness of the installed pipe shall conform to Table 8.

Table 8 — Geometric characteristics

Characteristic	Requirement	Test method
Minimum dimension A + B in accordance with Figure 1	Not less than the design thickness	By coring 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

NOTE 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 the wall thickness.

8.3 Performance requirements

Simulated samples prepared in accordance with 8.4 shall conform to the requirements given in Table 9.

Table 9 — 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		
Watertightness	No visible leakage	Test pressure	0 kPa rising to 50 kPa	EN 1610:1997, 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	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 3)		

[a] Crushing strength test shall be carried out after 28 d of manufacture in accordance with EN 1916:2002, Annex C, for unreinforced pipes. Samples shall be prepared and the tensile strength f_{bt} calculated in accordance with Annex B.

8.4 Preparation and conditioning of simulated "I" stage samples

Simulated installations shall be carried out using a host pipe which does not contribute to load-bearing capacity. The defined 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 28 d under water at a temperature of (15 ± 5) °C to simulate installed conditions on site.

9 Installation

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 standard. The existing pipeline shall be surveyed, cleaned in accordance with the requirements of EN 14654-1, inspected internally and otherwise prepared. 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.

9.2 Storage, handling and transport of pipe components

Raw materials shall be stored and used in accordance with the recommendations of their 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 standard.

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 procedures

The procedures for site handling, site impregnation (where applicable), insertion and cure of RAPL shall be documented in the installation manual.

The plastic strips or sheet material of the internal layers shall be connected by welding 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 defined. For gluing, preparation of surfaces, the type of glue, and the range of permissible application temperatures shall be defined. 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 Lining termination in manholes

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.

9.6 Reconnecting 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 defined in Clause 5, or a lateral liner of thermoplastic pipe suitably sealed at both ends without use of a connection collar.

9.7 Final inspection

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.

10 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 describes 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 1542:1999, 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 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

Diamond core drill and barrel shall comply with EN 1542:1999, 4.10.

A.3.6 Pull-off test equipment

The pull-off test equipment shall comply with EN 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 EN ISO 4624:2003, 9.4.2 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 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 Carrying out test

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:

A: failure within the plastics inner layer,

B: failure by pull out of the anchor from the grout,

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 occurs, calculate the anchoring strength to the nearest 0,1 MPa, using Formula (A.1):

$$f_{\mathrm{h}} = \frac{4F_{\mathrm{h}}}{\pi D^2} \qquad \text{(A.1)}$$

where

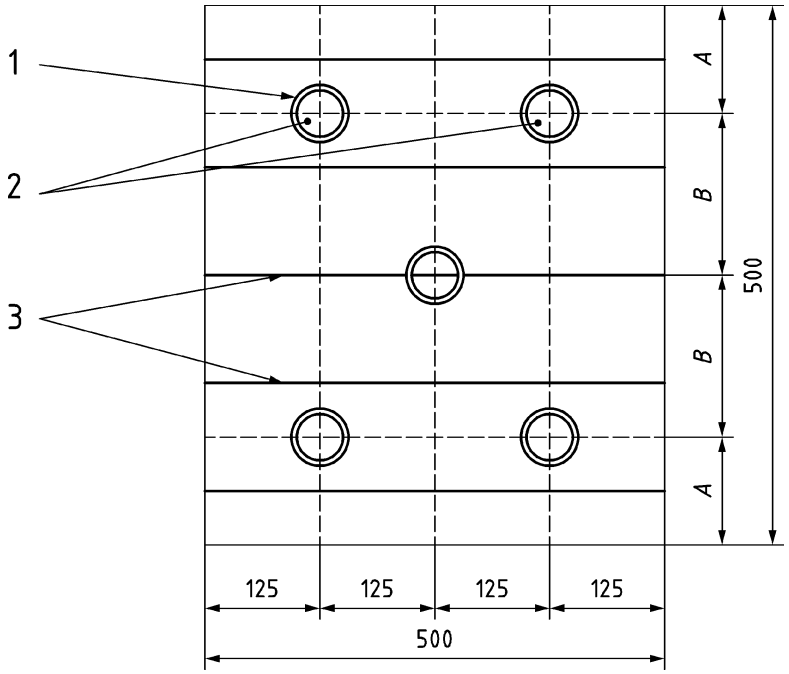
f_{h} is the anchoring strength of the test specimen, in megapascals;

F_{h} is the failure load, in newtons;

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

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

Dimensions in millimetres



Key

1 annulus around test area, formed by coring

2 steel or aluminium dolly, diameter 50 mm

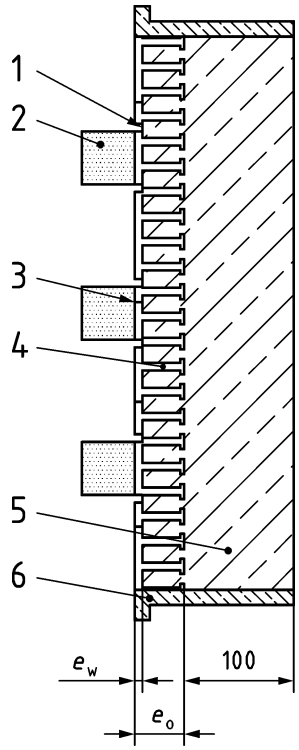
3 jointing of plastics inner layer (technique dependent)

A min. 75 mm (technique dependent)

B min. 100 mm (technique dependent)

Figure A.1 — Plan of specimen showing dolly locations

Dimensions in millimetres



Key

1 annulus around test area, formed by coring
2 steel or aluminium dolly, diameter 50 mm
3 jointing of plastics inner layer (technique dependent)
4 anchored plastics inner layer
5 grout system
6 mould
e_0 overall profile height of anchored plastics inner layer
e_w waterway wall thickness of plastics inner layer

Figure A.2 — Schematic section through specimen, showing coring and dollies

A.5.5 Test report

The test report shall include the following information:

a) a reference to this European Standard, including the number, title and date of issue;

b) the place, date and time of specimen preparation and testing;

c) identification of the type, origin and designation of the RAPL product or system under test;

d) methods used for preparation, curing and conditioning of the specimens;

e) the size of the test specimen;

f) the diameter, thickness and the material of the dolly used and the type of adhesive;

g) a description of the pull-off test equipment, stating the make, type, load capacity and measurement range;

h) the failure load and the mean diameter of the dolly *D* for each location from Figure A.1;

i) the individual anchoring strength test results, and the mean results;

j) the type of failure for each location;

k) photographs of each failure surface;

l) any anomalies or points of note recorded during testing.

Annex B
(normative)

"I" stage crushing strength test

B.1 Scope

This annex describes a method for sample preparation and testing of the crushing strength of an "I" stage RAPL system to determine the tensile bending stress f_{bt}.

B.2 Principle

A simulated ring sample of RAPL is prepared in a cylindrical mould, e.g. a cardboard tube as typically used for casting concrete columns, or the external layer of RAPL where applicable.

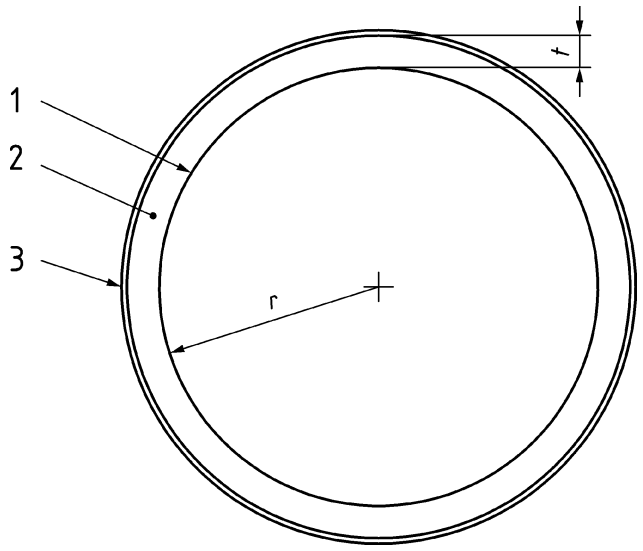
The cardboard tube or other formwork is normally removed for testing of crushing strength of the RAPL in accordance with EN 1916:2002 (see Figure B.1).

B.3 Equipment

Equipment shall comply with EN 1916:2002, Annex C.

B.4 Preparation

Depending on the RAPL technology, the test specimens may be prepared either by lining through the formwork in a horizontal position directly simulating site installation, or by inserting the preformed plastics inner layer in a vertically oriented formwork and casting the grout into the annulus. The length of the test specimen shall be not less than 3 times the internal diameter of the RAPL.



Key

1 anchored plastics inner layer

2 grout system

3 external layer / low strength former

r radius

t wall thickness

Figure B.1 — RAPL sample piece for crushing strength test

B.5 Carrying out test

The crushing test shall be performed in accordance with EN 1916:2002, Annex C. The load shall be taken to the ultimate (collapse) load and a record made of that load.

B.6 Calculation and expression of results

The effective crushing test result F_a shall be obtained in accordance with EN 1916:2002, Annex C.

Afterwards the bending tensile stress f_{bt} should be calculated using the following formula:

$$f_{bt} = \frac{6 \cdot F_u \cdot r_m}{\pi \cdot t_{act}^2} \quad \text{(B.1)}$$

where

f_{bt} is the bending tensile stress, in MPa;

F_u is the ultimate (collapse) load, in kN/m;

r_m is the mean radius of the RAPL system, in mm;

t_{act} is the mean measured wall thickness at the crown of the pipe, in mm.

B.7 Test report

The test report shall contain the following information:

a) reference to this European Standard (i.e. EN 16506);

b) the identification of the thermoplastics pipe, including:

   1) manufacturer;

   2) type of RAPL system;

   3) dimensions;

   4) production date;

   5) length of test pieces;

c) the test temperature;

d) the measured values of the ultimate (collapse) load (F_U);

e) the calculated value of the bending tensile stress, f_{bt};

f) any factors which could have affected the results, such as any incidents or any operating details not specified in this European Standard;

g) the date of test.

Bibliography

EN 13380, *General requirements for components used for renovation and repair of drain and sewer systems outside buildings*

EN 15885, *Classification and characteristics of techniques for renovation and repair of drains and sewers*

EN ISO 11296-4:2011, *Plastics piping systems for renovation of underground non-pressure drainage and sewerage networks - Part 4: Lining with cured-in-place pipes (ISO 11296-4:2009, corrected version 2010-06-01)*

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