Thermoplastics pipes and fittings with profiled outer and smooth inner surfaces

Part 2: Technical delivery conditions

DIN 16961-2

ICS 23.040.20; 23.040.45

Supersedes February 1989 edition.

Rohre und Formstücke aus thermoplastischen Kunststoffen mit profilierter Wandung und glatter Rohrinnenfläche – Teil 2: Technische Lieferbedingungen

In keeping with current practice in standards published by the International Organization for Standardization (ISO), a comma has been used throughout as the decimal marker.

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Translation by DIN-Sprachendienst.

In case of doubt, the German-language original should be consulted as the authoritative text.

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Foreword

This standard has been prepared by Technical Committee *Profilierte Rohre aus thermoplastischen Kunststoffen mit glatter Innenwand* of the *Normenausschuss Kunststoffe* (Plastics Standards Committee).

Amendments

This standard differs from the February 1989 edition in that specifications regarding the melt mass-flow rate (MFR) have been changed to take account of relevant European Standards, and the standard has been revised in form and content.

Previous editions

DIN 16961-2: 1977-09, 1989-02.

1 Scope

This standard specifies technical delivery conditions for pipes and fittings with profiled outer and smooth inner walls, made from high density polyethylene (PE-HD), unplasticized polyvinyl chloride (PVC-U), polypropylene (PP), homopolymers or copolymers.

For the purposes of this standard, profiled pipes are those with profiled outside surfaces, flanged pipes, helically wound pipes, and pipes with foamed inserts in their walls.

Pipes manufactured in accordance with this standard may also be used as components in process engineering.

Individual requirements specified here may be superseded by technical delivery conditions for particular applications.

NOTE: Any relevant European Standards shall also be observed.

2 Normative references

This standard incorporates, by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text, and the titles of the publications are listed below. For dated references, subsequent amendments to or revisions of any of these publications apply to this standard only when incorporated in it by amendment or revision. For undated references, the latest edition of the publication referred to applies.

DIN 8061	Unplasticized polyvinylchloride (PVC-U) pipes – General quality requirements and testing
DIN 8074	Polyethylene pipes – Dimensions
DIN 8075	Polyethylene pipes – General quality requirements and testing
DIN 8078	Types 1, 2 and 3 polypropylene (PP) pipes – General quality requirements and testing
DIN 16961-1	Thermoplastics pipes and fittings with profiled outer and smooth inner surfaces – Dimensions
DIN 18200	Inspection of construction materials, structural members and types of construction – General principles
DIN 19537-1	High-density polyethylene (PE-HD) pipes and fittings for drains and sewers – Dimensions
DIN EN 1610	Construction and testing of drains and sewers
DIN EN ISO 178	Determination of the flexural properties of plastics (ISO 178 : 1993)
DIN EN ISO 899-2	Plastics – Determination of creep behaviour – Flexural creep by three-point loading (ISO 899-2 : 1993)
DIN EN ISO 9969	Thermoplastics pipes – Determination of ring stiffness (ISO 9969 : 1994)
ISO 1133: 1991	Plastics – Determination of the melt mass-flow rate (MFR) and the melt volume-flow rate (MVR) of thermoplastics

ATV-Arbeitsblatt (ATV Code of practice) A 127 *Richtlinie für die statische Berechnung von Entwässerungskanälen und -leitungen* (Code of practice for the structural analysis of drains and sewers)[1)]

1) Obtainable from *Wiley-VCH Verlag*, Bühringstraße 10, 13086 Berlin, Germany.

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DVS-Richtlinie (DVS Code of practice) 2203-1 *Prüfen von Schweißverbindungen an Tafeln und Rohren aus thermoplastischen Kunststoffen; Prüfverfahren, Anforderungen* (Welded joints in thermoplastics sheets and pipes – Requirements and testing)[2])

DVS-Richtlinie 2203-5 *Prüfen von Schweißverbindungen an Tafeln und Rohren aus thermoplastischen Kunststoffen – Technologischer Biegeversuch* (Bend testing of welded joints in thermoplastics sheet and pipes)

DVS-Richtlinie 2207-1 *Schweißen von thermoplastischen Kunststoffen – Heizelementschweißen von Rohren, Rohrleitungsteilen und Tafeln aus PE-HD* (Welding of high-density polyethylene pipes and pipe fittings for gas and water pipework)[2])

DVS-Richtlinie 2207-11 *Schweißen von thermoplastischen Kunststoffen – Heizelementschweißen von Rohren, Rohrleitungsteilen und Tafeln aus PP* (Welding of polypropylene pipes and pipe fittings for gas and water pipework)[2])

DVS-Richtlinie 2209-1 *Schweißen von thermoplastischen Kunststoffen – Extrusionsschweißen – Verfahren, Merkmale* (Extrusion welding of thermoplastics – Welding procedure and characteristics)[2])

3 Material

Pipes and fittings shall be made from one of the following moulding materials:

- high-density polyethylene (PE-HD) as in DIN 8075;
- unplasticized polyvinyl chloride (PVC-U) as in DIN 8061;
- polypropylene homopolymers and copolymers as in DIN 8078.

Inserts used for shaping may be made from other suitable materials.

4 Requirements

4.1 Form supplied

Pipe ends should be cut as square as possible to the pipe axis. Pipes shall be free from any blisters and irregularities (including foreign matter) which could affect their performance.

4.2 Strength

4.2.1 Ring stiffness

When tested as in subclause 5.3.1, the mean vertical deflection (i.e. the ratio of the change in inside diameter, Δd_{iv}, to the inside diameter before testing, d_i, shall be no greater than $0{,}03 \times d_i$. Table 1 sets out the required ring stiffness for pipe series 1 to 7.

Table 1: Ring stiffness

Pipe series no.	1	2	3	4	5	6	7
Minimum ring stiffness, S_{R24}, in kN/m²	2	4	8	16	31,5	63	125

The ring stiffness shall be calculated using equation (1).

$$S_{R\,24} = \frac{E_{c\,24} \cdot I}{r^3} \qquad (1)$$

where

E_{c24} is the creep modulus, in kN/m², determined as in subclause 5.3.2;

I is the moment of inertia of the pipe profile, in $m^4 \cdot m^{-1}$;

r is the radius up to the neutral line of the pipe wall, in m.

NOTE: Ring stiffness S_{R24} is not identical to ring stiffness S in DIN EN ISO 9969 because different methods of measurement and calculation are used in the two standards.

4.2.2 Creep modulus

The creep modulus of pipes shall be at least equal to the values given in table 2.

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[2]) Obtainable from *Deutscher Verband für Schweißen und verwandte Verfahren*, P.O. Box 101965, 40010 Düsseldorf, Germany.

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Table 2: Creep modulus

Test duration/ Creep modulus	Minimum value of creep modulus, in kN/m²			
	PE-HD[1])	PVC-U	PP[2])	
			Homopolymer	Copolymer
1 minute/E_{ck}	8 $\times 10^5$	36 $\times 10^5$	$12{,}5 \times 10^5$	8 $\times 10^5$
24 hours/E_{c24}	$3{,}8 \times 10^5$	30 $\times 10^5$	$5{,}1 \times 10^5$	$3{,}6 \times 10^5$
2000 hours/E_{c2000}	$2{,}5 \times 10^5$	23 $\times 10^5$	$4{,}2 \times 10^5$	$2{,}1 \times 10^5$
50 years/E_{c50}	$1{,}5 \times 10^5$ [3])	$17{,}5 \times 10^5$ [3])	$2{,}7 \times 10^5$	$1{,}2 \times 10^5$
Testing as in subclause	5.3.2			

[1]) Higher E_{c50} values require testing by an accredited test house.
[2]) Higher values require testing by an accredited test house.
[3]) Cf. ATV-A 127.

4.2.3 Welds on PE-HD and PP fittings

Welds on fittings made from PE-HD and PP pipe sections shall be as specified in DVS 2207-1 and DVS 2209-1.

4.3 Watertightness of joints

4.3.1 Tightness under internal hydrostatic pressure

When tested as in subclause 5.4.1, joints shall be watertight.

4.3.2 Tightness under external hydrostatic pressure

When tested as in subclause 5.4.2, joints shall be watertight.

4.4 Resistance to root penetration

Joints in buried pipes conveying fluids shall be resistant to root penetration when tested as in subclause 5.5.

4.5 Melt mass-flow rate for PE-HD and PP pipes and fittings

When tested as in subclause 5.6, the melt mass-flow rate, MFR 190/5, of the unmoulded material shall be 1,6 g or less per ten minutes for polyethylene and 1,5 g or less per ten minutes for polypropylene.

The melt mass-flow rate of pipes and fittings shall not differ from that of the unmoulded material by more than 0,2 g per ten minutes for polyethylene and by more than 0,4 g per ten minutes for polypropylene.

4.6 Surface finish

When inspected as in subclause 5.7, pipes and fittings shall have outer and inner surfaces consistent with their manufacture. Minor sink marks and fluctuations in wall thickness are permissible, provided that the minimum wall thickness is maintained throughout and ring stiffness is not impaired.

4.7 Colour

Pipes and fittings shall be uniformly coloured throughout. The colour shall be selected for the application.

4.8 Dimensions

The dimensions of pipes and fittings shall comply with the specifications of DIN 16961-1.

4.9 Weldability of PE-HD and PP pipes and fittings

When tested as in subclause 5.10, PE-HD and PP pipes and fittings shall meet the requirements of DVS 2203-1.

5 Testing

5.1 General

Unless otherwise specified, pipes, fittings and joints shall be tested at least 15 hours after manufacture.

5.2 Form supplied

The pipes shall be visually examined.

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5.3 Strength

5.3.1 Ring stiffness

NOTE: It is to be checked by analysis or testing whether the following test method is applicable to the particular type of pipe.

Take three pipe sections with a length, l, equal to or greater than $2d_i$ (cf. figure 1), but no longer than 1 m. Avoid cutting through end profiles by, for example, cutting the pipe section one profile longer than required at each end.

Testing shall be carried out at (23 ± 2) °C. The test force shall be applied normal to the pipe axis. The pipe inside diameter, d_i, shall be measured at points $0{,}2d_i$, but not more than 50 mm, from each end, and at mid-length. The points shall be marked before measurement, and the mean shall be reported from three measurements.

The test force, F, in kN, shall be calculated using equation (2).

$$F = \frac{S_{R\,24} \cdot 0{,}03 d_i \cdot l}{\xi} \qquad (2)$$

where

$S_{R\,24}$ is the ring stiffness, in kN/m², as specified in table 1;

d_i is the effective pipe inside diameter, in m;

l is the effective pipe section length, in m;

ξ is the coefficient of deformation; here, ξ = 0,1548 (see table 3).

Table 3: Coefficient of deformation

Percentage deflection, $\Delta\overline{d}_{iv}/d_i$	Coefficient of deformation, ξ
0	0,1488
1	0,1508
2	0,1528
3	0,1548
4	0,1568
5	0,1588
6	0,1608
7	0,1628
8	0,1648
9	0,1668
10	0,1688
11	0,1708
12	0,1728
13	0,1748
14	0,1768
15	0,1788
NOTE: Intermediate values may be obtained by linear interpolation.	

The test force shall be applied axially, along the entire length of the pipe section, with the section either being supported on a bearing plate (cf. figure 1) or on steel angles (cf. figure 2) with dimension e not exceeding $0{,}05d_i$. In the latter case, care shall be taken not to damage the pipe wall. The inside pipe diameter shall be measured vertically before applying force; then, the load shall be applied and increased steadily over ten minutes until the test force, F, is reached. d_i, shall be measured one hour, six hours and 24 hours after applying the test force, to an accuracy of 1 % but to within ± 1 mm, and the mean of these measurements, $\Delta\overline{d}_{iv}$, used to calculate the deflection, as a percentage.

If extrapolation up to a period of 50 years is required, testing shall be carried out for up to 2000 hours after applying the test force, taking measurements at appropriate intervals.

NOTE: The ring stiffness, S_R, is to be calculated using the following equation and determined by measuring deflection in a loading test:

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$$S_R = \frac{E \cdot J}{r^3} \tag{3}$$

where

E is the modulus of elasticity of the material, in kN/cm²;

J is the moment of inertia in the pipe wall, in m⁴/m;

r is the radius of the neutral line of the pipe wall, in m.

Where the load and the support are linear, S_R can be calculated using the following equation:

$$S_R = \frac{F}{\Delta\bar{d}_{iv} \cdot L} \cdot \xi \tag{4}$$

where

F is the test force, in kN;

$\Delta\bar{d}_{iv}$ is the mean vertical deflection of the pipe, in m;

L is the length of the pipe section, in m;

ξ is the coefficient of deformation.

Establishing ring stiffness involves determining the effective moment of inertia of profiled pipes and the elasticity module of materials, thus providing reliable parameters for pipe design.

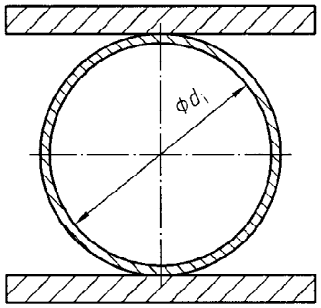

Figure 1: Ring stiffness test using bearing plates

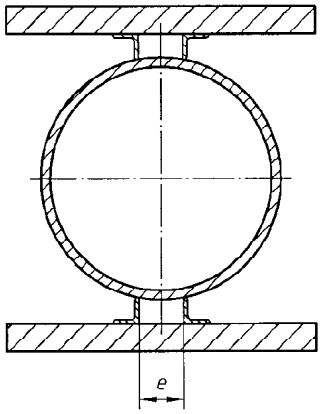

Figure 2: Ring stiffness test using steel angles

5.3.2 Creep modulus

If the pipe profile makes it impossible to take specimens for determining the creep modulus, the long-term ring stiffness shall be verified.

For a given profile geometry, the test method described below allows the influence of pipe material and temperature on ring stiffness to be established, provided the moment of inertia of the pipe wall is determined exactly.

In the case of pipes with a diameter of 1 200 mm and greater, the creep modulus can be established in order to determine the ring stiffness.

Test bars shall be taken, preferably along the pipe axis, their opposite faces being machined so as to be parallel to each other. They shall be 120 mm long, 10 mm wide and 3 mm to 4 mm thick. Width and height shall be measured at a number of different points and the mean values determined to an accuracy of 0,01 mm. For testing, the specimens shall be arranged so that the tension zone is in the outer layer of the pipe. The creep modulus shall be determined at a temperature of 23 °C by four-point loading, on the lines of DIN EN ISO 899-2.

A flexural stress of 2 000 kN/m² shall be applied within ten seconds and, after one minute, the deflection, f_k, shall be determined to an accuracy of 0,01 mm. The short-term creep modulus, E_{ck}, in kN/m², shall be calculated using the following equation:

$$E_{ck} = \frac{l}{f_k} \cdot \frac{M_b}{b} \cdot C \tag{5}$$

where

l is the test bar length, in m;

f_k is the deflection of the test bar, in m, to the nearest 0,01 mm;

M_b is the bending moment, in kN/m;

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b is the test bar width, in m;
C is a factor allowing for the height, h, of the test bar, in m^{-1} (see equation (8)).
The bending moment, M_b, is to be calculated using equation (6):

$$M_b = \sigma_b \cdot W \tag{6}$$

with the section modulus, W, being calculated using equation (7):

$$W = \frac{h^2 \cdot b}{6} \tag{7}$$

where, in equations (6) and (7):
σ_b is the flexural stress in kN/m² (here, σ_b = 2 000);
h is the test bar height, in m;
b is the test bar width, in m (here, b = 10).
C shall be calculated from equation (8), by elasticity theory:

$$C = \frac{3}{2 \cdot h} \cdot \left(\frac{l'^2}{h^2} - \mu \right) \tag{8}$$

where
h is the test bar height, in m;
l' is the gauge length of the deflection measuring device, in m; (here, l' = 60)
μ is the transverse shrinkage coefficient (for plastics, μ = 0,4).
After measuring f_k and calculating E_{ck}, the deflection under a flexural stress of 2 000 kN/m² shall be determined after loading periods of 24 hours and 2 000 hours, $f_{(t)}$. Equation (9) shall be used to calculate the creep modulus, $E_{c(t)}$, in kN/m², for each loading period.

$$E_{c(t)} = E_{ck} \cdot \frac{f_k}{f_{(t)}} \tag{9}$$

5.4 Watertightness of pipe joints

5.4.1 Tightness under internal hydrostatic pressure

An assembly including a welded joint or a socket joint with elastomeric seal shall be filled with water at ambient temperature and subjected to a pressure of 0,5 bar for 15 minutes, in accordance with DIN EN 1610.
If there are no signs of leakage, the joint shall be considered watertight.

5.4.2 Tightness under external hydrostatic pressure

The test described below shall only be carried out on pipe joint assemblies with seals which are likely to behave differently under external pressure than under internal pressure (e.g. lip seals).
A pipe assembly 2 m in length, including a joint, shall be placed in water and its interior subjected to a negative pressure of 0,5 bar for 15 minutes. The joint shall be considered watertight if there is a pressure increase no greater than 0,05 bar.

5.5 Resistance to root penetration

Welded joints may be considered resistant to root penetration. Socket joints with elastomeric seals shall be considered resistant if they fulfil watertightness requirements when tested as in subclause 5.4.1.

5.6 Melt mass-flow rate for PE-HD and PP pipes and fittings

Testing shall be carried out as in ISO 1133, using a test force of (50 ± 2) N at 190 °C for PE-HD pipes (test condition T) and a test force of 21,6 N at 230 °C (test condition M) for PP pipes.

5.7 Surface finish

The outer and inner surfaces of pipes and fittings shall be examined visually with suitable backlighting.

5.8 Colour

Surfaces and cut faces of pipes and fittings shall be examined for uniform colour.

5.9 Dimensions

The dimensions of pipes and fittings shall be measured using suitable measuring devices.

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5.10 Weldability of PE-HD and PP pipes and fittings

Heated tool butt welding shall be used to make a test weld on pipe sections, as described in *DVS-Richtlinie* 2207-1 or *DVS-Richtlinie* 2207-11. Weldability (i.e. the strength of the weld) shall be tested using the bend test as in *DVS-Richtlinie* 2203-5.

6 Inspection

6.1 General

Inspection shall be in accordance with DIN 18200 and subclauses 6.2 and 6.3 of this standard.

Internal control and third-party inspection shall be used to check that the requirements set out in clause 4 are met.

6.2 Internal control

6.2.1 Scope and frequency of control

The manufacturer shall be responsible for carrying out internal control testing in accordance with table 4.

Table 4: Scope and frequency of internal control

Item no.	Material	Articles to be checked		Property	Frequency	Requirement as in subclause	Testing as in subclause
		Pipes	Fittings				
1	PE-HD	x	–	Melt mass-flow rate	At each raw material change	4.5	5.6
	PVC-U	–	–			–	–
	PP	x	–			4.5	5.6
2	PE-HD	x	x	Design	At regular intervals	4.1	5.2
	PVC-U	x	x			4.1	5.2
	PP	x	x			4.1	5.2
3	PE-HD	x	x	Surface finish	Every two hours or each pipe/fitting	4.6	5.7
	PVC-U	x	x			4.6	5.7
	PP	x	x			4.6	5.7
4	PE-HD	x	x	Colour	At regular intervals	4.7	5.8
	PVC-U	x	x			4.7	5.8
	PP	x	x			4.7	5.8
5	PE-HD	x	–	Dimensions	Every two hours or each pipe	4.8	5.9
	PVC-U	x	–			4.8	5.9
	PP	x	–			4.8	5.9
6	PE-HD	x	–	Weldability	When material-related parameters change	4.9	5.10
	PVC-U	–	–			–	5.10
	PP	x	–			4.9	–
7	PE-HD	x	–	Ring stiffness	Monthly, and whenever material-related parameters or manufacturing processes change	4.2.1	5.3.1
	PVC-U	x	–			4.2.1	5.3.1
	PP	x	–			4.2.1	5.3.1

6.2.2 Defects

If the requirements set out in table 4 are not met, the manufacturer shall take immediate steps to remedy defects. The customer shall be informed if this is necessary to prevent consequential damage.

After the defects have been eliminated, testing shall be repeated as required. Products which do not meet requirements shall be rejected.

6.2.3 Documentation

The results of internal control testing shall be recorded, and, as far as possible, statistically evaluated. Records shall be kept for at least five years, and submitted to the inspection agency on request (see subclause 6.3).

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6.3 Third party inspection

6.3.1 Type, scope and frequency of inspection

6.3.1.1 Third party inspection shall be undertaken at least twice a year by a suitable inspection agency (e.g. quality assurance association) or by a body accredited for this purpose. The required scope and frequency of testing associated with third party inspection are set out in table 5. Third party inspection shall also include checking for compliance with personnel and equipment requirements.

Table 5: Scope and frequency of third party inspection

Item no.	Articles to be inspected		Property	Frequency	Requirement as in subclause	Testing as in subclause
	Pipes	Fittings				
1	x	x	Dimensions	Twice a year, one nominal size per inspection	4.8	5.9
2	x	x	Design		4.1	5.2
3	x	x	Ring stiffness		4.2.1	5.3.1
4	x	x	Surface finish		4.6	5.7
5	x	x	Checking internal control		6.2	–
6	x	x	Melt mass-flow rate		4.5	5.6

6.3.1.2 Before commencing third party inspection, the inspection agency shall undertake testing as in clause 5 to determine whether pipes and fittings fulfil the requirements specified in clause 4. The agency shall also ascertain whether personnel and equipment enable the manufacturing process to be carried out correctly at all times and internal control to be undertaken as required. After the initial inspection has been successfully concluded, third party inspection as set out in subclause 6.3.1.1 shall be carried out.

6.3.1.3 If the results of third party inspection are not satisfactory, the inspection shall be repeated without delay, testing the same number of specimens, which shall fulfil the requirements set out in table 5. Defects which are detected during internal control and which are immediately eliminated may be ignored for the purposes of third party inspection.

6.3.2 Sampling

The inspector or the person appointed by the inspection agency shall take samples from as large a stock as possible or from released articles. Samples shall be representative. Undamaged samples may also be taken from a dealer's stock, or, in special cases from construction site stock. Defective articles may only be excluded from sampling if they are clearly marked as such and are stored separately (see subclause 6.2.2). Samples shall be immediately marked so as to preclude any confusion.

The sampler shall make a record of details of the samples taken, sign it and have it countersigned by the works manager or deputy. Records shall include the following information:

a) manufacturer and factory;
b) origin of samples, if elsewhere;
c) product designation (e.g. standard designation);
d) marking of samples;
e) date and place of sampling;
f) signature(s) of responsible person(s).

6.3.3 Inspection report

The results of third party inspection shall be recorded in an inspection report, which may consist of a test certificate and a report on the inspector's visit. The inspection report shall refer to this standard and include the following information:

a) manufacturer and factory;
b) product designation (e.g. standard designation);
c) scope, results and assessment of internal control;
d) relevant sampling details;
e) results of third party inspection and indication whether requirements have been met;
f) overall assessment;
g) date and place of inspection;
h) signature of inspector and stamp of inspection agency.

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The manufacturer and the inspection agency shall keep inspection reports on file for at least five years. If the manufacturer is entitled to use a quality mark issued by an accredited quality assurance association, this shall be recognized as proof of third party inspection.

7 Marking

Pipes and fittings shall be clearly and indelibly marked with the following details:

a) standard number ('DIN 16961-2');
b) pipe series;
c) nominal size;
d) pipe inside diameter;
e) type of moulding material;
f) melt mass-flow rate group;
g) manufacturer's mark;
h) year of manufacture.

Pipes shall be marked at least once each. Marking indicates that the manufacturer assures compliance of pipes and fittings with this standard.

Explanatory notes

Pipes installed underground are subject to flexural stress due to the earth load. The resulting strain tends to decrease gradually in the case of PE-HD pipes because of the viscoelastic behaviour of thermoplastics. If a stress analysis is carried out, the following points should therefore be verified :

a) short-term flexural stress: when testing as in DIN EN ISO 178, an average value of 3×10^4 kN/m² shall be obtained for PE-HD samples;
b) long-term flexural stress: to date, no method exists for testing long-term flexural stress.

In the case of pipes installed underground, there is usually no need for a stress analysis, because the stresses under normal loading lie well below the critical level. However, if an analysis is carried out, the values from the creep curves obtained for internal hydrostatic pressure tests can be used to estimate the permissible long-term stresses.

If the permissible short-term stress is 17000 kN/m², the permissible long-term stress (50 years at 20 °C) may be assumed to be 8200 kN/m².

A rough estimate of the long-term stress may be obtained by multiplying the short-term stress of 3×10^4 kN/m² by a factor (allowing for time) derived from the above values (8,2 : 17 = 0,48), giving a value of 14400 kN/m².

In order to compare the ring stiffness of pipes covered in this standard with that of unprofiled extruded pipes (e.g. as in DIN 8074 or DIN 19537-1), the equivalent wall thickness, s_{eq}, may be determined using equations (10) and (11).

$$PN = \sqrt[3]{\frac{1000 \cdot \sigma^3}{E_c} \cdot 12 S_R} = 10 \cdot \sigma \cdot \sqrt[3]{\frac{12 \cdot S_R}{E_c}} \qquad (10)$$

$$s_{eq} = \frac{PN}{10} \cdot \frac{d_i}{2 \cdot \sigma - \frac{PN}{10}} \qquad (11)$$

where

PN is the pressure rating;
d_i is the inside diameter;
σ is the permissible stress when calculating wall thickness of pipes made of:
PE-HD (as in DIN 8074): σ = 5000 kN/m²;
PVC-U (as in DIN 8062): σ = 10000 kN/m²;
PP (as in DIN 8077): σ = 5000 kN/m²;
E_c is the 50 year creep modulus;
S_R is the ring stiffness.

The creep modulus determined as in subclause 5.3.2 shall not be used to calculate the ring stiffness as in subclause 4.2.1, but serves quality assurance purposes. Further, the profile should be checked for resistance to loading.

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