TECHNICAL REPORT

ISO/TR 10465-3

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Underground installation of flexible glass-reinforced thermosetting resin (GRP) pipes —

Part 3:
Installation parameters and application limits

Installation enterrée de canalisations flexibles en plastique renforcé de fibres de verre/résine thermodurcissable (PRV) —

Partie 3: Paramètres d'installation et limites d'application

Reference number
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Contents

International Organization for Standardization
Case postale 56 • CH-1211 Genève 20 • Switzerland
Internet iso@iso.ch

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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 main task of ISO technical committees is to prepare International Standards, but in exceptional circumstances a technical committee may propose the publication of a Technical Report of one of the following types:

— type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;

— type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;

— type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example).

Technical Reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

ISO/TR 10465-3, which is a Technical Report of type 2, was prepared by Technical Committee ISO/TC 138, *Plastics pipes, fittings and valves for the transport of fluids*, Subcommittee SC 6, *Reinforced plastics pipes and fittings for all applications*.

The reasons which led to the decision to publish this document in the form of a type 2 Technical Report are explained in the introduction.

ISO/TR 10465 consists of the following parts, under the general title *Underground installation of flexible glass-reinforced thermosetting resin (GRP) pipes:*

— *Part 1: Installation procedures*

— *Part 2: Comparison of static calculation methods*

— *Part 3: Installation parameters and application limits*

This document is not to be regarded as an International Standard. It is proposed for provisional application so that experience may be gained on its use in practice. Comments should be sent to the secretariat of TC 138/SC 6.

Introduction

Work in ISO/TC 5/SC 6 (now ISO/TC 138) on writing standards for the use of glass-reinforced plastics (GRP) pipes and fittings was approved at the subcommittee meeting in Oslo in 1979. An *ad hoc* group was established and the responsibility for drafting various standards was later given to a Task Group (now ISO/TC 138/SC 6).

At the SC 6 meeting in London in 1980, Sweden proposed that a working group be formed to develop documents regarding a code of practice for GRP pipes. This was approved by SC 6, and Working Group 4 (WG 4) was formed for this purpose. Since 1982, twenty-eight WG 4 meetings have been held which have considered the following areas:

— procedures for the underground installation of GRP pipes;

— pipe/soil interaction with pipes having different stiffness values;

— minimum design features;

— an overview of various static calculation methods.

During the work of WG 4, it became evident that unanimous agreement could not be reached within the working group on the specific methods to be employed. Therefore WG 4 agreed that all documents should be made into a three-part type 2 Technical Report, of which this is part 3.

Part 1 describes procedures for the underground installation of GRP pipes. It concerns particular stiffness classes for which performance requirements have been specified in at least one product standard, but it can also be used as a guide for the installation of pipes of other stiffness classes.

Part 2 presents a comparison of the two primary methods used internationally for static calculations on underground GRP pipe installations (ATV-A 127 and AWWA M-45).

Part 3 gives additional information, which is useful for static calculations when using an ATV-A 127 type design system in accordance with part 2 of this Technical Report, on items such as:

— parameters for deflection calculations;

— soil parameters, strain coefficients and shape factors for flexural-strain calculations;

— soil moduli and pipe stiffnesses for buckling calculations with regard to elastic behaviour;

— parameters for rerounding and combined-loading calculations;

— the influence of traffic loads;

— the influence of sheeting;

— safety factors.

Underground installation of flexible glass-reinforced thermosetting resin (GRP) pipes —

Part 3:
Installation parameters and application limits

1 Scope

This part of ISO/TR 10465 gives information on parameters and application limits for the installation of GRP pipes. It is particularly relevant when using an ATV-A 127 type design system.

Explanations of the long-term safety factors incorporated in the GRP system standards, based on simplified probability methods, are given in annex G.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO/TR 10465. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO/TR 10465 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO/TR 10465-1:1993, *Underground installation of flexible glass-reinforced thermosetting resin (GRP) pipes — Part 1: Installation procedures.*

ISO/TR 10465-2:1999, *Underground installation of flexible glass-reinforced thermosetting resin (GRP) pipes — Part 2: Comparison of static calculation methods.*

ASTM D 1586:1984, *Standard test method for penetration test and split-barrel sampling of soils.*

ASTM D 2166:1991*, Standard test method for unconfined compressive strength of cohesive soil.*

ATV-A 127, *Guidelines for static calculations on drainage conduits and pipelines* (December 1988).

AWWA M-45, *Fiberglass pipe design manual M-45* (1997).

BS 1377 (all parts)*, Methods of test for soils for civil engineering purposes.*

DIN 19565-1:1989, *Centrifugally cast and filled polyester resin glass fibre reinforced (UP-GF) pipes and fittings for buried drains and sewers; dimensions and technical delivery conditions.*

OENORM B 4419-1:1985, *Erd- und Grundbau; Untergrunderkundung durch Sondierungen; Rammsondierungen.*

OENORM B 5012-1:1990, *Statische Berechnung erdverlegter Rohrleitungen im Siedlungs- und Industriewasserbau; Grundlagen.*

WRc, Water Research Centre, Swindon, UK: *Pipe materials selection manual — Water supply,* 2nd edition, June 1995.

3 Terminology

Pipeline installation terminology can vary around the world so, where such terms are used in this part of ISO/TR 10465, they will either be described or reference will be made to part 1 or 2, where the relevant descriptions can be found.

4 Symbols and abbreviated terms

For the purposes of this part of ISO/TR 10465, the following symbols apply:

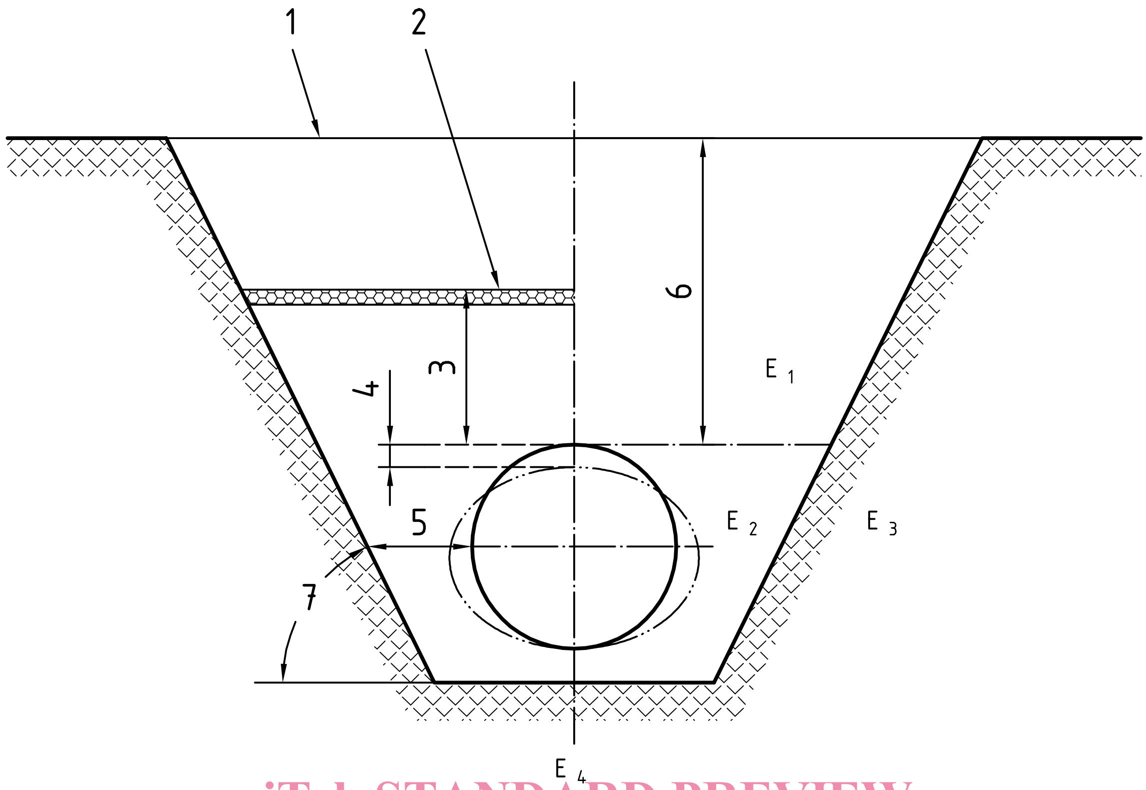
NOTE This clause also contains symbols and abbreviations from parts 1 and 2 for completeness.

Symbol	Unit	Meaning
a_f	—	Ageing factor
a_f	—	Distribution factor
B'	—	Support factor
b	m	Trench width at spring-line
b'	m	Distance from trench wall to pipe (see Figure 1)
c_4	—	Reduction factor
c_f	—	Creep factor
c_h, c_v	—	Deformation coefficients
D_f	—	Shape factor
D_g	—	Shape adjustment factor
D_L	—	Deflection lag factor
d_e	m	External pipe diameter
d_m	mm	Mean pipe diameter $[(d_e \times 1\,000) - e]$
d_v	mm	Vertical deflection
d_{vA}	m	Maximum permissible long-term deflection
d_{vR}	mm	Vertical deflection at rupture
$(d_v/d_m)_{permissible}$	%	Maximum permissible relative vertical deflection
$(d_v/d_m)_{initial}$	%	Initial vertical deflection
$(d_v/d_m)_{50}$	%	Long-term (50-year) vertical deflection
$(d_v/d_m)_{ult}$	%	Ultimate long-term vertical deflection
E, E_o, $E_{t,wet}$	N/m^2	Apparent flexural moduli of pipe wall
E', E_1, E_2, E_3, E_4, E'_s, E'_t, E_s	N/mm^2	Soil deformation moduli
E_{TH}	N/m^2	Tensile hoop modulus
e	mm	Pipe wall thickness
e	—	Base of natural logarithms (2,718 281 8)
F	—	Compaction factor
F_A, F_E	kN	Wheel loads
FS	—	Safety factor
FS_b	—	Bending safety factor
FS_{pr}	—	Pressure safety factor
HDB	—	Extrapolated pressure strain at 50 years
H_{EVD}	m	Environmental depth of cover

Symbol	Unit	Meaning
h	m	Depth of cover to top of pipe
h_w	m	Height of water surface above top of pipe
I	m^4/m	Second moment of area in longitudinal direction per unit length (of a pipe)
i_o	—	Initial ovalization
i_f	N/mm^2	Installation factor
K^*	—	Coefficient for bedding reaction pressure
K_1, K_2	—	Ratio of horizontal to vertical soil pressure in soil zones 1 and 2
K_3	—	Ratio of horizontal to vertical soil pressure in pipe-zone backfill, when backfill is at top of pipe (see annex A)
k_x	—	Bedding coefficient
M	—	Sum of bending moments
M_s	N/mm^2	Constrained-soil modulus
m_{qv}, m_{qh}, m^*_{qh}	—	Moment factors
N	—	Sum of normal forces
n_{10}	—	Number of blows
P	bar	Internal pressure
PN	—	Nominal pressure
$P(x)$	—	Probability function
P_f	—	Probability of failure
P_v	MPa (N/mm^2)	Internal underpressure
P_W	N/m^2	Working pressure
p_a	N/m^2	External water pressure
p_E	N/mm^2	Pressure due to prismatic soil load
p_F	N/m^2	Pressure due to traffic load according to Boussinesq
p_o	N/mm^2	Soil pressure due to distributed load
p_V	N/mm^2	Soil pressure resulting from traffic load
q_a	MPa (N/mm^2)	Permissible buckling pressure
q_c	MPa (N/mm^2)	Critical buckling pressure
q_{cs}	MPa (N/mm^2)	Short-term critical buckling pressure
q_{cl}	MPa (N/mm^2)	Critical buckling pressure under sustained load
q_{cw}	MPa (N/mm^2)	Critical buckling pressure due to water
q_h, q_v	N/mm^2	Horizontal and vertical soil pressure on pipe
q_h^*	N/mm^2	Horizontal bedding reaction pressure
$q_{h,50}$	N/mm^2	Long-term (50-year) horizontal soil pressure
q_{hLT}	N/mm^2	Reduced long-term horizontal soil pressure
q_{c*w}	N/mm^2	Horizontal bedding reaction for pipe and contents
$q_{v,50}$	N/mm^2	Long-term (50-year) vertical soil pressure
q_{vLT}	N/mm^2	Reduced long-term vertical soil pressure
q_{vwa}	N/mm^2	Vertical load due to pipe and contents
R_w	—	Water buoyancy reduction factor
r	—	Rerounding factor

Symbol	Unit	Meaning
r_A, r_E	m	Wheel radii
r_c	—	Rerounding coefficient
S_{Bh}	N/mm^2	Horizontal bedding stiffness
S_{Bv}	N/mm^2	Vertical bedding stiffness
S_b	—	Long-term strain
S_c	—	Soil support combining factor
S_k	N/mm^2	Characteristic stress
S_p	N/m^2	Initial pipe stiffness
$S_{p,50}$	N/m^2	Long-term pipe stiffness
S_R	N/mm^2	$S_p \times 8 \times 10^{-6}$
$S_{R,50}$	N/mm^2	$S_{p,50} \times 8 \times 10^{-6}$
s_{Res}	N/mm^2	Standard deviation of strength of pipe
$s_{Res,A}$	N/mm^2	Standard deviation of strength of pipe above ground
$s_{Res,B}$	N/mm^2	Standard deviation of strength of pipe below ground
s_S	N/mm^2	Standard deviation of stress in pipe
$s_{S,A}$	N/mm^2	Standard deviation of stress in pipe above ground
$s_{S,B}$	N/mm^2	Standard deviation of stress in pipe below ground
SPD	%	Standard Proctor density
V_{RB}	—	System stiffness
V_S	—	Stiffness relation
W_c	N/m^2	Vertical soil load on pipe
W_L	N/m^2	Traffic load
X	—	Safety index
y_R	%	Coefficient of variation for tensile strength
y_{ult}	%	Coefficient of variation for ultimate deflection
α	° (degrees)	Half the bedding angle (see Figure 2)
β	° (degrees)	Half the horizontal support angle (see Figure 2)
χ	—	Reduction factor applied to prismatic soil load to allow for friction
χ_β	—	Reduction factor applied to prismatic soil load to allow for friction and taking into account trench angle (β in ATV and ω in this part of ISO/TR 10465)
χ_o	—	Reduction factor applied to a uniformly distributed load to allow for friction
$\chi_{o\beta}$	—	Reduction factor applied to a uniformly distributed load to allow for friction and taking into account trench angle (β in ATV but ω in this part of ISO/TR 10465)
δ	° (degrees)	Trench wall friction angle
δ_d	mm	Maximum permitted long-term installed deflection
δ_v	%	Relative vertical deflection
δ_{vio}	%	Relative vertical deflection due to backfilling in pipe zone
δ_{viv}	%	Relative vertical deflection due to installation irregularities
δ_{vs}	%	Relative vertical deflection due to soil load
δ_{vw}	%	Relative vertical deflection due to weight of pipe

Symbol	Unit	Meaning
δ_W	%	Relative vertical deflection due to traffic load
ε_{comp}	—	Compressive strain due to vertical load
ε, ε_t, ε_f	—	Calculated flexural strains in pipe wall
ε_{max}	—	Maximum permissible strain due to pressure
ε_{pr}	—	Calculated strain in pipe wall due to internal pressure
ε_v	—	Flexural strain due to total vertical load
ε_{vio}	—	Flexural strain due to backfilling in pipe zone
ε_{vw}	—	Flexural strain due to weight of pipe
ε_W	—	Flexural strain due to pipe contents
γ_b	MN/m^3	Bulk density of backfill material
γ_w	MN/m^3	Density of pipe contents
η, η_t, η_f, η_{ff}	—	Safety factors
η_{haf}	—	Combined flexural safety factor
η_{hat}	—	Combined tensile safety factor
φ	° (degrees)	Soil internal friction angle
κ, κ_ω	—	Reduction factor for distributed load according to silo theory when trench angle (ω) is 90°
κ_o, $\kappa_{o\omega}$	—	Reduction factor for distributed load according to silo theory when trench angle (ω) is not 90°
λ_B	—	Concentration factor in soil next to pipe
λ_{max}	—	Maximum concentration factor
λ_R, λ_{RG}, λ_{max}	—	Concentration factors for soil above pipe
μ_{Res}	N/mm^2	Mean value of pipe strength (resistance)
$\mu_{Res,A}$	N/mm^2	Mean value of strength (resistance) of pipe above ground
$\mu_{Res,B}$	N/mm^2	Mean value of strength (resistance) of pipe below ground
μ_S	N/mm^2	Mean value of stress in pipe
$\mu_{S,A}$	N/mm^2	Mean value of stress in pipe above ground
$\mu_{S,B}$	N/mm^2	Mean value of stress in pipe below ground
ρ	MN/m^3	Density of pipe-wall material
ρ_D	g/cm^3	Density
σ_c	N/mm^2	Calculated compressive stress in pipe wall
σ_t	N/mm^2	Calculated tensile stress in pipe wall
ν_s	—	Poisson's ratio for soil
ω	° (degrees)	Trench wall angle (see Figure 1) (designated β in ATV-A 127)
ξ	—	Correction factor for horizontal bedding



Key

1 Ground level
2 Water table
3 Height of water surface above top of pipe, h_w
4 Vertical deflection, d_v
5 Distance from trench wall to pipe, b'
6 Depth of cover to top of pipe, h
7 Trench wall angle, ω

NOTE 1 The AWWA M-45 design manual uses E'_b in zone E_2.

NOTE 2 The AWWA M-45 design manual uses E'_n in zone E_3 and E_4.

NOTE 3 E_1 is the backfill above the pipe zone (E_2) material.

NOTE 4 E_2 is the embedment material to the side of the pipe.

NOTE 5 E_3 is the *in situ* trench wall material.

NOTE 6 E_4 is the *in situ* material underlying the pipe zone material (foundation material).

NOTE 7 In ATV-A 127, β is used for the trench wall angle instead of ω.

Figure 1 — Symbols and terminology

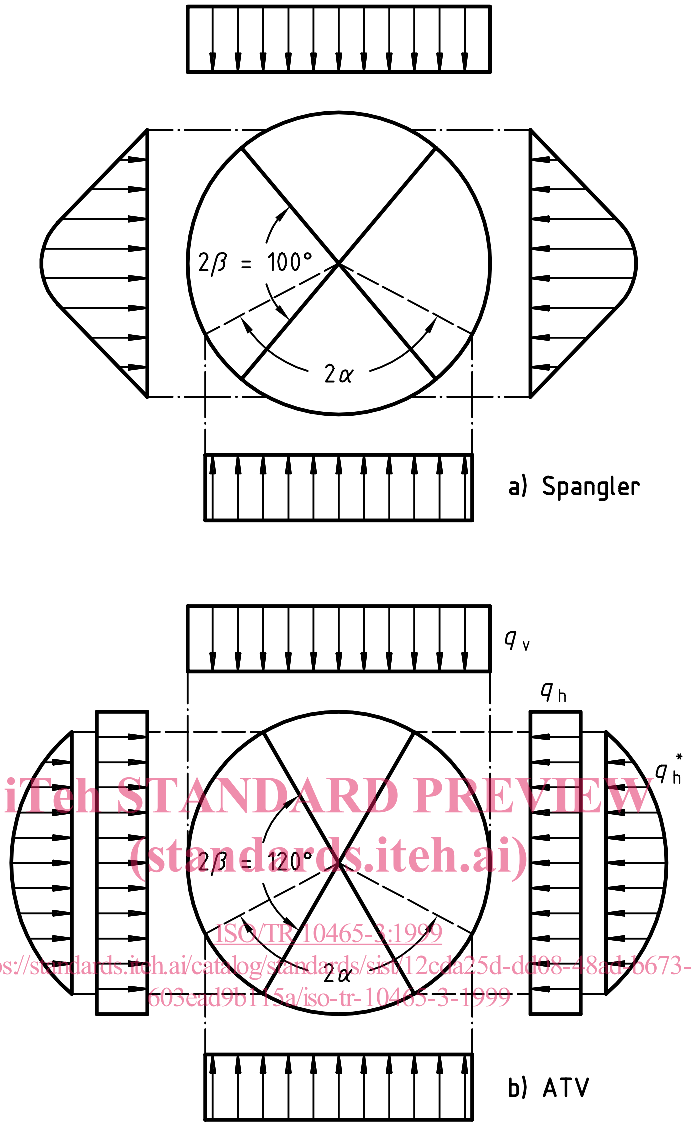


Figure 2 — Soil distribution according to Spangler and ATV-A 127

5 Parameters for deflection calculations when using an ATV-A 127 type design system

This clause covers the soil parameters and deflection coefficients recommended for use when calculating the initial or long-term deflection in accordance with ATV-A 127.

NOTE In the following calculations, deflections having a negative value indicate a reduction in vertical diameter.

5.1 Initial deflection

Measurement of the initial deflection shortly after installation, when the effects of traffic loads are not present, is a very easy way of assessing the quality of the installation. The initial deflection should therefore be determined under these loading conditions.

ATV-A 127 and the AWWA M-45 design manual do not address the effects of installation irregularities, deflection resulting from the pipe's own weight, or the reduction in deflection due to upwards ovalization of the pipe when the pipe zone backfill is compacted. It is recommended that, in deflection calculations, these effects be considered in addition to the effects of soil load and superimposed loads. This recommendation is made because these effects have been found to be significant in practice, especially for pipes having a DN greater than 2000.

5.1.1 Deflection due to vertical soil load and superimposed loads, but excluding traffic loads

The relative vertical deflection δ_v, given by $\delta_{vs} = \frac{d_v}{d_m}$ (% deflection when multiplied by 100), is determined using equation (1):

NOTE This deflection has a negative value, which indicates a reduction in vertical diameter.

$$\delta_{vs} = \frac{d_v}{d_m} = \left[c_{v1} + \left(c_{v2} \times K^*\right)\right] \times \left(q_v - q_h\right) \times \frac{1}{S_R} \tag{1}$$

where

d_v is the vertical deflection of the pipe, in mm;

d_m is the mean diameter of the pipe, $(d_e \times 1\,000) - e$, in mm;

e is the pipe wall thickness;

$$K^* = \frac{c_{h1}}{V_{RB} - c_{h2}} \tag{2}$$

c_{v1}, c_{v2}, c_{h1}, c_{h2} are deflection coefficients (see annex C);

$$V_{RB} = S_R / S_{Bh} \tag{3}$$

$$S_R = S_p \times 8 \times 10^{-6} \quad \text{(in N/mm}^2\text{)} \tag{4}$$

S_p is the initial pipe stiffness, in N/m^2;

$$S_{Bh} = c_4 \times \xi \times E_2 \quad \text{(in N/mm}^2\text{)} \tag{5}$$

c_4 = 0,6 in ATV-A 127

ξ is a correction factor, given by:

$$\xi = \frac{1{,}44}{f + (1{,}44 - f)\, E_2 / E_3} \tag{6}$$

$$\text{in which } f = \frac{\left(\frac{b}{d_e} - 1\right)}{1{,}154 + 0{,}444\left(\frac{b}{d_e} - 1\right)} \leqslant 1{,}44 \tag{7}$$

NOTE The correction factor ξ takes into account the difference in the soil moduli of the pipe embedment material and the native soil, as well as the width of the trench. The above equations are those given in ATV-A 127 for a support angle of 120°, but it is recommended that the equations and values given in annex D be used. Annex D covers a wider range of support conditions than the 120° covered by equation (6). Despite appearances, the equations in annex D for 120° produce a very similar answer to that obtained using equation (6).

E_2 is the modulus of the soil in the pipe zone (zone E_2), in N/mm^2 (see Figure 1);

E_3 is the modulus of the native soil in zone E_3, in N/mm^2 (see Figure 1);

q_v is the vertical pressure due to the soil loads, calculated using equation (8):

$$q_v = (\kappa \times \gamma_b \times h + \kappa_o \times p_o) \times \lambda_{RG} \quad \text{(in N/mm}^2\text{)} \tag{8}$$

NOTE Equation (8) uses values in MN/m^2 and N/mm^2 which are numerically equivalent.

h is the depth of cover, in m;

γ_b is the bulk density of the backfill above the pipe, in MN/m^3;

p_o is the soil pressure due to the distributed load at the surface, in N/mm^2;

κ and κ_o are trench friction coefficients (see ISO/TR 10465-2 or ATV-A 127, as well as annex F of this document);

q_h is the horizontal pressure due to soil loads, calculated using equation (9):

$$q_h = K_2[(\kappa \times \gamma_b \times h + \kappa_o \times p_o) \times \lambda_B + (\gamma_b \times d_e/2)] \quad \text{(in N/mm}^2\text{)} \tag{9}$$

NOTE Equation (9) uses values in MN/m^2 and N/mm^2, which are numerically equivalent.

K_2 is the ratio of the horizontal to the vertical soil pressure in soil zone 2 (see annex A);

λ_B is a concentration factor (see annex B), given by:

$$\lambda_{rg} = \left(\frac{\lambda_r - 1}{3} \times \frac{b}{d_e}\right) + \frac{4 - \lambda_R}{3} \tag{10}$$

NOTE Experience shows that the limits given for λ_{RG} for GRP pipes in ATV-A 127 are not normally reached.

b is the trench width, in m;

d_e is the outside diameter of the pipe, in m;

λ_R is a concentration factor for the the soil above the pipe (see annex B).

5.1.2 Deflection due to weight of pipe

When the pipe diameter is DN 2000 or greater and the nominal stiffness of the pipe is less than SN 2000, then account should be taken of the relative deflection resulting from the pipe's own weight, calculated using equation (11):

$$\delta_{vw} = -2{,}3 \times e \times \rho \times 10^{-4} \times \frac{1}{S_R} \tag{11}$$

where

e is the pipe wall thickness, in mm;

ρ is the density of the pipe-wall material, in MN/m^3.

NOTE This deflection has a negative value, which indicates a reduction in vertical diameter.

5.1.3 Deflection due to compaction of pipe zone backfill (initial ovalization)

When the pipe zone backfill material is compacted, the horizontal soil pressure generated causes the pipe to ovalize in the vertical direction. The magnitude of this relative vertical deflection can be calculated using equation (12):

$$\delta_{vio} = K_3 \times \gamma_b \times \frac{d_e}{24 \times S_R} \tag{12}$$