TECHNICAL REPORT

ISO/TR 10465-2

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Underground installation of flexible glass-reinforced pipes based on unsaturated polyester resin (GRP-UP) —

Part 2: Comparison of static calculation methods

Installation enterrée de canalisations flexibles renforcées de fibres de verre à base de résine polyester insaturée (GRP-UP) —

Partie 2: Comparaison de méthodes de calcul statique

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Contents

Page

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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

In exceptional circumstances, 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), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

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

ISO/TR 10465-2 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*.

This second edition cancels and replaces the first edition (ISO/TR 10465-2:1999), which has been technically revised to take into account changes made to methods in base documents ATV-A 127 and AWWA M-45 (see Introduction).

ISO 10465 consists of the following parts, under the general title *Underground installation of flexible glass-reinforced pipes based on unsaturated polyester resin (GRP-UP)*:

— *Part 1: Installation procedures* [Technical Specification]

— *Part 2: Comparison of static calculation methods* [Technical Report]

— *Part 3: Installation parameters and application limits* [Technical Report]

Introduction

Work in ISO/TC 5/SC 6 (now ISO/TC 138) on writing International 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 International 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, many WG 4 meetings have been held which have considered the following matters:

— procedures for the underground installation of GRP pipes;

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

— minimum design parameters;

— 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 to address these issues. It was therefore agreed that all parts of the code of practice should be made into a type 3 Technical Report, and this was the form in which this part of ISO 10465 was first published in 1999. Since then the ISO rules dealing with the classification of document types have been revised and this has resulted in the three parts of ISO 10465 now being published as either a Technical Specification or a Technical Report.

ISO 10465-1, published as Technical Report in 1993 and revised as a Technical Specification in 2007, 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.

This part of ISO 10465, published as a Technical Report in 1999 and revised in 2007, presents a comparison of the two primary methods used internationally for static calculations on underground GRP pipe installations.

These methods are

a) the ATV method given in ATV-A 127, *Guidelines for static calculations on drainage conduits and pipelines*, and

b) the AWWA method given in AWWA manual M-45, *Fiberglass pipe design*.

ISO 10465-3, published as a Technical Report in 2007, gives additional information, which is useful for static calculations primarily when using an ATV-A 127 type design system in accordance with this part of ISO 10465, on items such as:

parameters for deflection calculations;

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

soil moduli and pipe stiffness 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.

This Technical Report 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.

Underground installation of flexible glass-reinforced pipes based on unsaturated polyester resin (GRP-UP) —

Part 2:
Comparison of static calculation methods

1 Scope

This part of ISO 10465 presents a comparison of the ATV and AWWA methods for static calculations on underground GRP pipe installations. It is intended that this comparison will encourage the use of both procedures for GRP pipes conforming to International Standards.

It is not the intent of this part of ISO 10465 to cover all the details of the two methods. Some aspects are, of necessity, very complex, and for a full understanding the original documents need to be studied in detail. Rather, the intention is to give a general overview and comparison of the key elements so that the user can more easily understand and appreciate the differences between the two procedures and their similarities.

2 Normative references

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

ATV-A 127, *Guidelines for static calculations on drainage conduits and pipelines,* 3rd edition, August 2000 (German Association for Water Pollution Control)

AWWA M-45, *Fiberglass pipe design manual M-45*, 2005 (American Water Works Association)

3 Symbols and abbreviated terms

For the purposes of this document, the following symbols apply.

NOTE 1 This clause also contains symbols and abbreviations from ISO 10465-1 and ISO 10465-3 for completeness.

NOTE 2 Several identical symbols are used in ATV-A 127 and AWWA M-45 to represent different quantities, and where this occurs, the origin of the symbol is given in the rightmost column.

NOTE 3 The format of the symbols listed here has been aligned as far as practicable with the *ISO/IEC Directives*, part 2, namely they appear in Times New Roman italic font. This format may differ slightly from the format used in ATV-A 127 and AWWA M-45.

Symbol	Unit	Meaning
AQL	—	acceptable quality level
a'	—	effective relative projection
a_f	—	ageing factor (ATV)

a_f	—	distribution factor (AWWA)
B1, B2, B3, B4	—	embedment conditions
b	m	trench width at spring-line
b'	m	distance from trench wall to pipe (see Figure 1)
C_n	—	buckling scalar calibration factor
c_1, c_2, c_3, c_4	—	coefficients used to determine ζ
c_4	—	reduction factor
c_f	—	creep factor
$c_{h,qv}$, $c_{v,qh}$, $c_{v,qh*}$, $c_{h,qh}$, $c_{h,qh*}$, $c_{v,qv}$, c_{v*}, $c_{v,qh*}$, $c_{h,qh*}$, c_{v*}	—	deformation coefficients
D	mm	mean pipe diameter
D_f	—	shape factor
D_g	—	shape adjustment factor
D_L	—	deflection lag factor
D_{pr}	%	compaction (based on simple proctor)
d_e	m	external pipe diameter
d_i	m	internal pipe diameter
d_m	m	mean pipe diameter $\left[\left(d_e \times 1000\right) - e\right]$
d_v	mm	vertical deflection
d_{vA}	mm	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_p, $E_{t,wet}$	N/m^2	apparent flexural moduli of pipe wall
E', E_1, E_2, E_3, E_4, E'_s, E_s, $E_{s,\sigma}$, E_{20}	N/m^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	—	calculated safety factor (ATV)
FS	—	design factor = 2,5 (AWWA)
FS_b	—	bending safety factor
FS_{pr}	—	pressure safety factor
f_1	—	reduction factor for creep
f_2	—	reduction factor for ground water in pipe zone
G1, G2, G3, G4	—	soil groups
HDB	—	extrapolated pressure strain at 50 years
H_{EVD}	m	environmental depth of cover
h	m	depth of cover to top of pipe
h_{int}	m	depth at which load from wheels interact
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_f	—	impact factor (AWWA)
i_f	N/mm^2	installation factor
K^*	—	coefficient for bedding reaction pressure
K'	—	modulus of deformation
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 pressures in pipe-zone backfill, when backfill is at top of pipe (see ISO 10465-3:2007, Annex A)
k_{v2}	—	reduction factor to take into account the elastic-plastic soil mass law and preliminary deflections
k_x	—	bedding coefficient
L_1	m	load width parallel to direction of travel
L_2	m	load width perpendicular to direction of travel
$LLDF$	—	live load as a function of depth factor
M	—	sum of bending moments
M_p	—	multiple presence factor
M_s	N/m^2	composite constrained-soil modulus

M_{s1}	N/m^2	value of composite constrained-soil modulus from ISO 10465-3:2007, Table A.3
M_{s100}	N/m^2	composite constrained-soil modulus at 100 % SPD
M_{sb}	N/m^2	backfill soil constrained modulus
M_{sn}	N/mm^2	native soil constrained modulus
m_{qv}, m_{qh}, m_{qh*}	—	moment factors
N	—	sum of normal forces
n_{10}	—	number of blows
P	N	magnitude of wheel load
PN	—	nominal pressure (pipe characteristic)
P	bar	internal pressure
P_f	—	probability of failure
P_v	MPa (N/mm^2)	internal under-pressure
P_w	N/m^2	working pressure
$P(X)$	—	probability function
P_{50}	bar	long-term (50 year) failure pressure
p	N/m^2	soil stress resulting from traffic loads
p_E	N/mm^2	pressure due to prismatic soil load
p_e	N/mm^2	external water pressure
p_F	N/m^2	soil stress due to traffic load according to Boussinesq
p_o	N/m^2	soil pressure due to uniformly distributed surface 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_{cl}	MPa (N/mm^2)	critical buckling pressure under sustained load
q_{c*w}	N/mm^2	horizontal bedding reaction for pipe and contents
q_h, q_v	N/mm^2	horizontal or vertical soil pressure on pipe
q_{h*}	N/mm^2	horizontal bedding reaction pressure
q_{hLT}	N/mm^2	reduced long-term horizontal soil pressure
$q_{h,50}$	N/mm^2	long-term (50 year) horizontal soil pressure
q_{vLT}	N/mm^2	reduced long-term vertical soil pressure

$q_{v,50}$	N/mm²	long-term (50 year) vertical soil pressure
q_{vwa}	N/mm²	vertical load due to pipe and contents
R_h	—	depth-of-fill correction factor
R_w	—	water buoyancy reduction factor
r	—	rerounding factor (AWWA)
r	m	mean pipe radius (AWWA)
r_A, r_E	m	wheel radii (ATV)
r_c	—	rerounding coefficient
r_i	m	pipe internal radius
r_m	m	mean pipe radius
S_{Bh}	N/mm²	horizontal bedding stiffness
S_{Bv}	N/mm²	vertical bedding stiffness
S_b	—	long-term ring-bending strain capability of the pipe
S_c	—	soil support combining factor
S_k	N/mm²	characteristic stress
S_O	N/m²	long-term pipe stiffness
$S_{O,50}$	N/m²	long-term pipe stiffness
$\bar{S}_o$	N/m²	weighted long-term pipe stiffness
S_{OK}	N/m²	long-term (50 year) pipe stiffness
S_{OL}	N/m²	long-term (2 year) pipe stiffness
SPD	%	standard proctor density
S_p	N/m²	initial pipe stiffness
$S_{p,50}$	N/m²	long-term pipe stiffness
S_R	N/mm²	$S_p \times 8 \times 10^{-6}$
$S_{R,50}$	N/mm²	$S_{p,50} \times 8 \times 10^{-6}$
S_{Res}	N/mm²	standard deviation of strength of pipe
$S_{Res,B}$	N/mm²	standard deviation of strength of pipe below ground
S_S	N/mm²	standard deviation of stress in pipe
$S_{S,B}$	N/mm²	standard deviation of stress in pipe below ground
t_l	m	length of tyre footprint
t_w	m	width of tyre footprint

V_{RB}	—	system stiffness
V_S	—	stiffness ratio
W_c	N/m^2	vertical soil load on pipe
W_L	N/m^2	traffic load
X	—	safety index
y	%	coefficient of variation for initial tensile strength
y_R	%	coefficient of variation for tensile strength
z	%	coefficient of variation for initial ultimate deflection
α	°	half the bedding angle (see Figure 2)
α_B	—	reduction factor depending upon trench proportions and embedding conditions
α_{Bi}	—	value from ISO 10465-2:2007, Figure 5
α_D	—	snap-through coefficient
$\alpha\kappa$, $\alpha\kappa_i$, $\alpha\kappa_e$	—	correction factor for extreme curvature of inner or outer edge
β	°	half the horizontal support angle (see Figure 2)
β	°	(ATV) trench wall slope angle (see Figure 1)
γ_b	N/m^3	bulk density of backfill material
γ_w	N/m^3	density of pipe contents
δ	°	trench wall friction angle
δ_h	%	relative horizontal deflection
δ_v	%	relative vertical deflection
δ_{va}	%	negative relative vertical deflection due to traffic and vacuum load
δ_{vc}, δ_{vs}	%	negative relative vertical deflection due to soil load
δ_{v50}	%	long-term relative vertical deflection
δ_{vio}	%	positive relative vertical deflection due to backfilling in pipe zone
δ_{viv}	%	negative relative vertical deflection due to installation irregularities
δ_{vs50}	%	long-term negative relative vertical deflection due to soil load
δ_{vw}	%	negative relative vertical deflection due to weight of pipe

δ_w	%	relative vertical deflection due to traffic load
ε_b	—	bending strain caused by maximum permitted deflection
ε_{comp}	—	compressive strain due to vertical load
ε, ε_t, ε_f	—	calculated flexural strains in pipe wall
ε_{if}	—	flexural strain due to installation irregularities
ε_{max}, ε_R	—	maximum permissible strain due to pressure
ε_{PK}	—	initial bending tensile strain
ε_{PL}	—	long-term bending tensile strain
ε_{pr}	—	calculated strain in pipe wall due to internal pressure
$\bar{\varepsilon}_R$	—	weighted calculated value of outer fibre strain
ε_{tot}	—	total flexural strain
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
ε_{50}	—	long-term maximum bending strain caused by maximum permitted deflection
ζ	—	correction factor for horizontal bedding
η, η_t, η_f, η_{ff}	—	safety factors
η_{haf}	—	combined flexural safety factor
η_{hat}	—	combined tensile safety factor
$\eta_{t,PN}$	—	redefined safety factor for pipe to operate at PN
φ	°	soil internal friction angle
φ'	—	impact factor (ATV)
φ_s	—	variability factor for compacted soil
χ	—	coefficient of safety
χ_P	MN/m^3	unit weight (density) of pipe material
χ_s	N/m^3	unit weight (density) of soil
χ_w	N/m^3	unit weight (density) of water
κ, κ_β	—	reduction factor for distributed load according to silo theory when trench angle, β, is 90°

