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BSI Standards Publication

Plastics piping systems — Glass-reinforced thermosetting plastics (GRP) based on unsaturated polyester resin (UP) — Guidance for the structural analysis of buried GRP-UP pipelines

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National foreword

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Plastics piping systems - Glass-reinforced thermosetting plastics (GRP) based on unsaturated polyester resin (UP) - Guidance for the structural analysis of buried GRP-UP pipelines

Systèmes de canalisations en plastiques - Plastiques thermodurcissables renforcés de verre (PRV) à base de résine polyester non saturé (UP) - Guide pour l'analyse structurale de conduites PRV-UP enterrées

Kunststoff-Rohrleitungssysteme - Glasfaserverstärkte duroplastische Kunststoffe (GFK) auf der Basis von ungesättigtem Polyesterharz (UP) - Anleitung für die statische Berechnung von erdverlegten GFK-UP-Rohrleitungen

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Foreword

This document (CEN/TS 14807:2013) has been prepared by Technical Committee CEN/TC 155 “Plastics piping systems and ducting systems”, the secretariat of which is held by NEN.

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This document supersedes CEN/TS 14807:2004.

The following is a list of the major technical changes that have been made since the previous edition:

a) revised wording to reflect the revisions to GRP product standards EN 1796 and EN 14364;

b) revised wording to improve clarity of presentation.

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Introduction

The purpose of this document is to provide guidance for the selection of a suitable structural analysis procedure for buried glass-reinforced thermosetting plastics (GRP) pipes. The design approach should be founded on accepted engineering principles and have been demonstrated through field experience. The procedure should satisfy the requirements of GRP pipes and should provide dependable long-term performance.

The limiting performance criteria for buried glass-reinforced thermosetting plastics (GRP) pipes are different than other pipe products, including thermoplastics pipes. Consequently, any recommendations on the use of GRP products should take these differences into consideration. Additionally, the method of structural analysis should accommodate these limiting performance criteria, so guidance on suitable design limits are given. Any structural analysis procedure may be used provided it includes the assessment of short and long-term deflection and buckling resistance. Established structural analysis procedures, although found satisfactory for other materials, may not meet the needs of GRP.

1 Scope

This Technical Specification, which is a guidance document for use with a structural analysis procedure for below ground installations, covers limits applicable to glass-reinforced thermosetting plastics (GRP) pipes used for the conveyance of liquids under pressure or gravity conditions.

This document does not specify a particular structural analysis procedure but gives guidance on the selection of a structural analysis procedure. It concludes that any established structural analysis procedure may be used provided it includes the assessment of short and long-term deflection and buckling resistance.

Products complying to the applicable GRP product standards EN 1796 or EN 14364, which are not subject to internal pressure, are suitable as long as the analysis shows that the long-term deflection of the installed pipes is limited to 6 %, which is the basic assumption of the GRP pipe product standards. Products complying with the applicable system standards (EN 1796 or EN 14364), which are subject to internal pressure, are suitable as long as the analysis shows that the initial deflection of the installed pipes does not exceed 3 %.

NOTE The approach followed when preparing a general structural analysis procedure does not depend on the nominal size(s) of the pipe(s).

A suitable structural analysis procedure should normally be capable of being used for pipes operating at different temperatures provided that the corresponding temperature re-rating factors for the relevant pipe properties are applied, as specified in the referring standard(s). Nevertheless, high service temperatures may require an additional analysis of the longitudinal stresses and strains and/or a special design of the joints.

Normal structural analysis procedures are intended to cover normal soil installation conditions. Pipes to be designed for installations in abnormal or unusual conditions, e.g. in quick soils or a marine sea-bed, may require special engineering. Some structural analysis procedures may include axial effects depending upon the type of joint used.

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 805, *Water supply - Requirements for systems and components outside buildings*

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

EN 1796:2013, *Plastics piping systems for water supply with or without pressure - Glass-reinforced thermosetting plastics (GRP) based on unsaturated polyester resin (UP)*

EN 14364:2013, *Plastics piping systems for drainage and sewerage with or without pressure - Glass-reinforced thermosetting plastics (GRP) based on unsaturated polyester resin (UP) - Specifications for pipes, fittings and joints*

ISO 7685, *Plastics piping systems - Glass-reinforced thermosetting plastics (GRP) pipes - Determination of initial specific ring stiffness*

ISO 10928, *Plastics piping systems - Glass-reinforced thermosetting plastics (GRP) pipes and fittings - Methods for regression analysis and their use*

ISO 10466, *Plastics piping systems - Glass-reinforced thermosetting plastics (GRP) pipes - Test method to prove the resistance to initial ring deflection*

ISO 10471, *Glass-reinforced thermosetting plastics (GRP) pipes - Determination of the long-term ultimate bending strain and the long-term ultimate relative ring deflection under wet conditions*

ISO 10952, *Plastics piping systems - Glass-reinforced thermosetting plastics (GRP) pipes and fittings - Determination of the resistance to chemical attack for the inside of a section in a deflected condition*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

NOTE For a more complete listing of terms and definitions for GRP pipes, see EN 1796:2013 and EN 14364:2013.

3.1
nominal pressure
PN
alphanumerical designation for pressure classification purposes, which has a numerical value equal to the resistance of a component of a piping system to internal pressure, when expressed in bars

Note 1 to entry: The designation for reference or marking purposes consists of the letters PN plus a number.

3.2
nominal size
DN
alphanumerical designation of size of component, which is a convenient integer approximately equal to a manufacturing dimension in millimetres and which can apply to either the internal diameter (DN-ID) or the external diameter (DN-OD)

Note 1 to entry: The designation for reference or marking purposes consists of the letters DN-ID or DN-OD plus a number.

3.3
nominal stiffness
SN
alphanumerical designation for stiffness classification purposes, which has the same numerical value as the minimum initial value required, when expressed in newtons per square metre (N/m^2)

Note 1 to entry: The designation for reference or marking purposes consists of the letters SN plus a number.

3.4
specific ring stiffness
S
physical characteristic of the pipe, expressed in newtons per square metre

Note 1 to entry: It is a measure of the resistance to ring deflection per metre length under external load and is defined by Formula (1):

$$S = \frac{E \times I}{d_m{}^3} \tag{1}$$

where

E is the apparent modulus of elasticity as determined in a ring stiffness test, in newtons per square metre (N/m^2);

I is the second moment of area in the longitudinal direction per metre length, in metres to the fourth power per metre, (m^4/m) i.e.

$$I = \frac{e^3}{12} \quad (2)$$

where

e is the wall thickness, in metres (m);

d_m is the mean diameter of the pipe, in metres (m).

3.5
initial specific ring stiffness
S_0
value of S obtained when tested in accordance with ISO 7685, in newtons per square metre (N/m^2)

3.6
re-rating factor
R_{RF}
multiplication factor that quantifies the relation between a mechanical, physical or chemical property at the service condition compared to the respective value at 23 °C and 50 % relative humidity (R.H.)

3.7
non-pressure pipe or fitting
pipe or fitting subject to an internal pressure not greater than 1 bar

3.8
pressure pipe or fitting
pipe or fitting having a nominal pressure classification which is greater than 1 bar and which is intended to be used with the internal pressure equal to or less than its nominal pressure when expressed in bars

3.9
buried pipeline
pipeline which is subjected to the external pressure transmitted from soil loading, including traffic and superimposed loads and, possibly, the pressure of a head of water

3.10
non-buried pipeline
pipeline which is subjected to negative and positive pressure, forces resulting from its supports, environmental conditions, e.g. snow and wind, and possibly pressure of a head of water

3.11
design service temperature
maximum sustained temperature at which the system is expected to operate, expressed in degrees Celsius (°C)

3.12
minimum long-term design pressure
$P_{x,d}$
least value for mean long-term burst failure pressure, expressed in bars, which is evaluated in accordance with the procedures described in ISO 10928 and includes a design factor of safety, FS_d

Note 1 to entry: It is one of the parameters used to determine the minimum initial design pressure.

3.13
minimum long-term failure pressure
P_x**,min**
least value for long-term burst failure pressure, expressed in bars, which is evaluated in accordance with the procedures described in ISO 10928 and includes a factor of safety, FS_{min}

Note 1 to entry: It is one of the parameters used to determine the minimum initial design pressure.

3.14
minimum initial relative ring deflection before bore cracking occurs
y_2**,bore,min**$/d_{\text{m}}$
initial relative deflection, expressed as a percentage (%), at 2 min which a test piece is required to pass without bore cracking when tested in accordance with ISO 10466

3.15
minimum initial relative ring deflection before structural failure occurs
y_2**,struct,min**$/d_{\text{m}}$
initial relative deflection, expressed as a percentage (%), at 2 min which a test piece is required to pass without structural failure when tested in accordance with ISO 10466

3.16
minimum long-term relative ultimate ring deflection
$y_{\text{u,wet,min,}x}/d_{\text{m}}$
required minimum extrapolated value, expressed as a percentage (%), at 50 years derived from the ultimate deflection regression line obtained from long-term deflection tests performed under wet conditions in accordance with ISO 10471

4 Requirements

There are many procedures used for the structural analysis of buried pipelines. When considering the applicability of a particular structural analysis procedure for the design of a GRP pipeline the following requirements shall be met:

a) The method shall be for flexible pipelines.

b) Several methods are covered by EN 1295 [1] [2]. In addition, ISO/TR 10465-2 [6], which is felt more appropriate, covers design methods specifically written for GRP-UP pipes.

c) The analysis procedure used shall be based on accepted engineering principles and have a proven record of use for GRP pipelines.

d) The procedure shall cover initial and long-term deformation and buckling resistance.

e) The method of analysis shall assess the pipeline using the performance criteria covered by the applicable GRP-UP system standard so that proper installation limits are established.

f) If the structural analysis procedure includes taking into account re-rounding due to internal pressure, then the analysis shall be reconciled with the guidelines given in ISO/TR 10465-2 [6] and ISO/TR 10465-3 [7], as re-rounding has been incorporated into the requirements of the GRP-UP product standards (EN 1796 and EN 14364).

5 Classification and designation

5.1 Product classification

Product standards EN 1796 (for Water) and EN 14364 (for Sewage), classify pipes on the basis of nominal size DN, nominal stiffness SN and nominal pressure PN.

5.2 Deflection limits

The product standards referred to in 5.1, specify the minimum mechanical properties that a pipe shall possess to be suitable for the particular application. These requirements are based on several assumptions, the main one being that the product is designed on a strain basis and not stress. Another key assumption is that the requirements are intended to ensure that there is an intrinsic factor of safety built into the product such that it remains safe in use for over 50 years even, in the case of pressure pipes when installed with an initial deflection of 3 % before pressurisation and in the case of non-pressure pipes when deflected long-term to 6 %. The GRP-UP product standards specify minimum initial test deflection requirements when tested in accordance with ISO 10466 (see Table 1 or Table 2 as applicable) and the minimum long-term test deflection requirement when tested in accordance with ISO 10471 (see Table 3):

Table 1 — Minimum initial ring deflections before bore cracking ($y_{2,\mathrm{bore,min}}/d_{\mathrm{m}}$)

Nominal stiffness (SN)	630	1 250	2 500	5 000	10 000
No sign of bore cracking at a % deflection of:	22,7	18	14,3	11,3	9

Table 2 — Minimum initial ring deflection before structural failure ($y_{2,\mathrm{struct,min}}/d_{\mathrm{m}}$)

Nominal stiffness (SN)	630	1 250	2 500	5 000	10 000
No structural failure at a % deflection of:	37,8	30	23,9	18,9	15

Table 3 — Minimum long-term relative ultimate ring deflection under wet conditions ($y_{\mathrm{u,wet,min},x}/d_{\mathrm{m}}$)

Nominal stiffness (SN)	630	1 250	2 500	5 000	10 000
Minimum extrapolated % long-term ring deflection:	22,7	18	14,3	11,3	9

The deflection values in Table 3 are based on the assumption that the maximum allowable long-term deflection when buried in the ground is 6 %. The manufacturer of the pipes may however specify a long-term deflection different to this assumed value. In such cases the requirements in Table 3 should be adjusted proportionately, e.g. if the manufacturer's value is 3 % then the required values would be 50 % of those in Table 3 while a manufacturer's deflection value of 8 % would result in required values of 133 % of those in Table 3.

The ultimate ring deflection values given in Table 3 induce the same flexural strain in all the stiffness classes. Therefore, the long-term ultimate ring deflection determined for one stiffness can be converted into strain and this in turn can be converted into an ultimate ring deflection for any other stiffness class.

If the pipeline is for sewerage then the standards require that the levels of deflection in Table 3 also be met when tested in accordance with ISO 10952, using a strong sulphuric acid solution.

Comparing these minimum values to the maximum permitted long-term deflection of 6 % there can be seen to be adequate safety to ensure durability.

5.3 Internal pressure

GRP-UP pipes made to the standards mentioned in 5.1 shall be designed to ensure a factor of safety of at least the applicable value given in Table 4, against failure at 50 years. To achieve this assurance products should be subjected to long-term testing in accordance with EN 1447 [3] and the results of these tests analysed in accordance with ISO 10928. The values in Table 4 have been determined using the procedure described in ISO/TR 10465-3, which takes into account the installed conditions likely to be encountered, and assumes, for a pipe subject to internal pressure, that the mean initial deflections will not exceed 3 %. A value of 3 % for initial pipe deflection before pressurising was chosen for the calculations in ISO/TR 10465-3 [7], because this is a common requirement for pressure pipes. Due to re-rounding, the deflection is reduced and the long-term calculation is based upon this reduced deflection (the amount of re-rounding is directly related to internal pressure, with full re-rounding achieved at a pressure of 30 bars). As the internal pressure increases, the deflection, and hence the strain from flexure, reduces.

The values in Table 4 satisfy the requirements that the mean long-term combined tensile factor of safety, from flexure and internal pressure, shall not be less than 1,6 for a pipe installed in the ground with a mean initial deflection of 3 % and a probability of failure not greater than 10^{-4} when the pipe is operating at an internal pressure equal to its nominal pressure rating. The product standards require that the pipes shall be designed using the procedure in ISO 10928 and the factors of safety in Table 4 to ensure:

a) that the minimum long-term failure pressure $P_{x,\mathrm{min}}$ is at least $FS_{,\mathrm{min}}$ times PN, expressed in bars, and

b) that the minimum long-term design pressure $P_{x,\mathrm{d}}$ is at least $FS_{,\mathrm{d}}$ times PN, expressed in bars.

Table 4 — Minimum long-term factors of safety FS_{min} and FS_{d}

Factor of safety	PN 32	PN 25	PN 20	PN 16	PN 12,5	PN 10	PN 6	PN 4	PN 2,5
FS_{min}	1,3	1,3	1,4	1,45	1,5	1,55	1,6	1,65	1,7
FS_{d}	1,6	1,6	1,7	1,8	1,85	1,9	2,0	2,05	2,1

5.4 Buckling resistance

The pipe property contributing to buckling resistance is its stiffness and the product standards mentioned in 5.1 contain a table similar to Table 5, which details the range of nominal stiffnesses covered by the standard and the applicable value for the minimum initial specific ring stiffness, $S_{0,\mathrm{min}}$, determined in accordance with ISO 10466.

The product standards detailed in 5.1 permit initial stiffnesses other than those given in Table 5 to be supplied, subject to agreement between the purchaser and the pipe manufacturer. The selected structural analysis procedure shall clearly state whether initial or long-term stiffness values are to be used for a particular condition. The selected structural analysis method will specify the procedure to be used to determine the buckling resistance of the installed pipe.

Table 5 — Minimum initial specific ring stiffness values

SN	$S_{0,\mathrm{min}}$ N/m^2
630	630
1 250	1 250
2 500	2 500
5 000	5 000
10 000	10 000

5.5 Temperature effects

The properties mentioned in 5.2 to 5.4 are all determined at (23 ± 5) °C and the values are applicable to products used at temperatures up to, and including, 35 °C. For service temperatures over 35 °C type tests shall be carried out, at least at the design service temperature, to establish re-rating factors for all properties used in design.

5.6 Installation

Pipes should be installed in accordance with the guidance in CEN/TS 14578 [4] which is based on and should be used in conjunction with ISO/TS 10465-1 [5], which contains useful information that can be used in appropriate structural analysis procedures. The applicable functional requirements detailed in EN 805 and EN 1610 shall also be met.

5.7 Summary

Use a structural analysis procedure that meets the requirements of Clause 4.

Classify and specify products which conform to standards EN 1796 and/or EN 14364.

Ensure that the predicted long-term deflection of non-pressure pipes does not exceed 6 % or as recommended by the manufacturer (see 5.3). This is normally ensured on site by limiting the initial deflection to not more than 3 %.

Ensure that the short-term deflection of pressure pipes does not exceed 3 %.

It is recommended to take into account the re-rounding effect of internal pressure. The GRP-UP product standards mentioned in 5.1 have allowed for re-rounding when arriving at the specified pressure factors of safety described in 5.3. Any structural analysis procedure shall reconcile its procedures with those used by the GRP-UP product standards.

ISO/TR 10465-2 [6] and ISO/TR 10465-3 [7] detail the assumptions used in the re-rounding of GRP-UP pipe as used in EN 1796 and EN 14364.

Obtain from the manufacturer details of the factor for converting initial stiffness values to long-term values.

For operating temperatures over 35 °C obtain from the pipe manufacturer either the re-rating factors appropriate to each property or assurance that the product he intends to supply is suitable for the operating temperature.

Install the pipes in accordance with 5.6.

Bibliography

[1] EN 1295-1, *Structural design of buried pipelines under various conditions of loading - Part 1: General requirements*

[2] CEN/TR 1295-2, *Structural design of buried pipelines under various conditions of loading - Part 2: Summary of nationally established methods of design*

[3] EN 1447, *Plastics piping systems - Glass-reinforced thermosetting plastics (GRP) pipes - Determination of long-term resistance to internal pressure*

[4] CEN/TS 14578, *Plastics piping systems for water supply or drainage and sewerage - Glass-reinforced thermosetting plastics (GPR) based on unsaturated polyester resin (UP) - Recommended practice for installation*

[5] ISO/TS 10465-1, *Underground installation of flexible glass-reinforced pipes based on unsaturated polyester resin (GRP-UP) - Part 1: Installation procedures*

[6] ISO/TR 10465-2, *Underground installation of flexible glass-reinforced pipes based on unsaturated polyester resin (GRP-UP) - Part 2: Comparison of static calculation methods*

[7] ISO/TR 10465-3, *Underground installation of flexible glass-reinforced pipes based on unsaturated polyester resin (GRP-UP) - Part 3: Installation parameters and application limits*

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