Underground tanks of glass-reinforced plastics (GRP) —

Determination of factor α and factor β

The European Standard EN 978 : 1997 has the status of a British Standard

ICS 23.020.10

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National foreword

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– present to the responsible European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

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Summary of pages

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Unterirdische Tanks aus textilglasverstärkten Kunststoffen (GFK) — Bestimmung des Faktors α und des Faktors β

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Foreword

This European Standard has been prepared by Technical Committee CEN/TC 210, GRP tanks and vessels, 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of an identical text or by endorsement, at the latest by January 1998, and conflicting national standards shall be withdrawn at the latest by January 1998.

This standard is drafted in support of EN 976-1 and EN 976-3, *Horizontal cylindrical tanks for the non-pressure storage of liquid petroleum based fuels — Part 1: Requirements and test methods for single wall tanks* and *Part 3: Requirements and test methods for double wall tanks*, in order to assess the structural stability and the environmental behaviour of the tank.

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1 Scope

This European Standard specifies a test method for the determination of the factor α and the factor β of test specimens of tanks of glass reinforced thermosetting resins for the underground storage of liquids.

2 Normative references

This European 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 publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

prEN 976-1 *Underground tanks of glass-reinforced plastics (GRP) — Horizontal cyclindrical tanks for the non pressure storage of liquid petroleum based fuels — Part 1: Requirements and test methods for single wall tanks*

3 Definitions

For the purposes of this standard the following definitions apply:

3.1 factor α

Ratio of the initial deformation of material under load and the deformation under the same constant load, extrapolated to a given period.

3.2 factor β

Ratio between the beam stiffness after storage in water of 50 °C for 1000 h and the initial beam stiffness determined in dry condition at 23 °C after postcuring of the sample.

4 Principle

From the cylindrical part of the tank a series of segments is taken in the circumferential direction.

Depending on the tank construction, the segments can consist of a solid GRP wall, or in the case of a rib construction a representative part of the rib construction as well as the part between the ribs, and in the case of a sandwich construction a sandwich wall segment.

From this series a portion of the segments is subjected to a creep test under defined loading conditions and the rest of the segments are subjected to a water immersion test.

From the results of these tests the factor α and the factor β are determined.

5 Apparatus

5.1 Testing machine

A device that is capable of applying a controlled rate of compression, while applying the load without shock.

The accuracy of loading shall be ± 0,5 % of the maximum indicated load.

5.2 Four point test rig (see figures 2 and 3)

Two supporting rods, one fixed and one with pivoting ball bearings, and a loading cam with two loading rods with pivoting ball bearings.

The supporting and loading rods shall have a diameter of 30 mm.

The supporting length L_1 is 0,5 × D rounded up to the next highest 100 mm and the loading length L_2 is 0,25 × D rounded up to the next highest 50 mm, where D is the internal diameter of the tank.

The width of the supporting and loading rods shall be at least equal to the test specimen width.

When testing a rib construction, the shape of the loading rods shall be adapted to the width of the test specimen (see figure 1).

5.3 Measuring device

The device for measuring the deflection can be a device adjusted to the loading cam (see figure 2) or a separate item, where the resting points are as near as possible to the loading rods of the cam (see figure 3). The device shall be capable of measuring to the nearest 0,01 mm.

NOTE. It is preferred to measure the deflection of the midpoint in relation to the loading points and not in relation to the supporting points in order to avoid the influence of shear from the specimen sections between the loading and supporting point. Especially in the case of a sandwich construction this might lead to an unrealistic value of the stiffness.

5.4 Oven for post curing

A temperature controlled oven, with forced air circulation, with a volume great enough to contain the test specimens and capable of keeping the temperature at the value specified in **6.3.2** within 5 K.

5.5 Waterbath

A waterbath of such dimensions that it is able to contain the test specimens and capable of keeping the water at (50 ± 2) °C.

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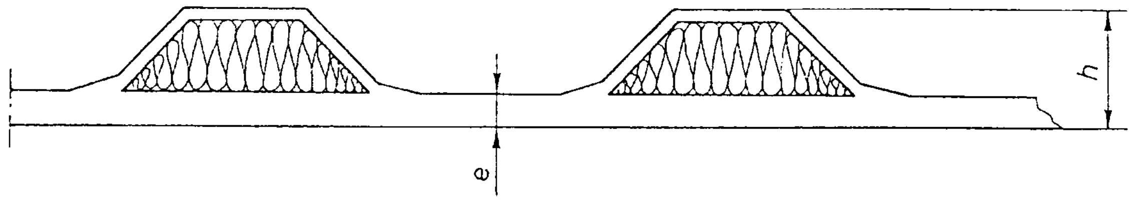
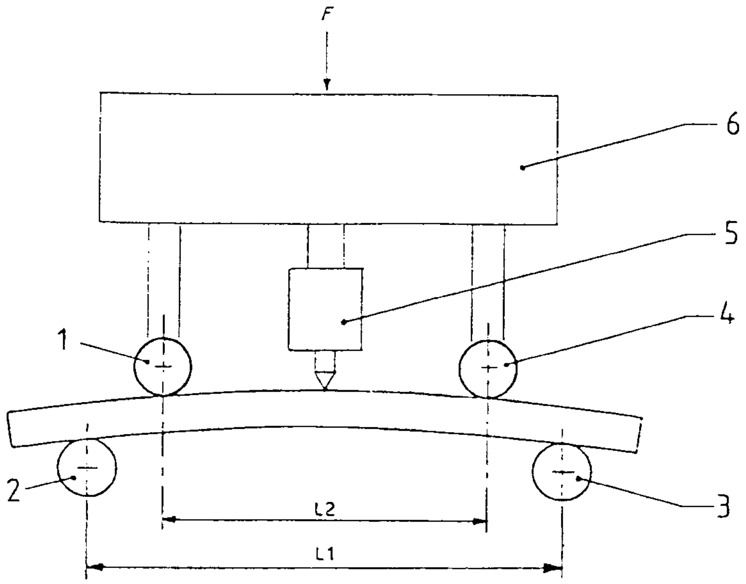


Figure 1. Side-view of test specimen with rib



1 Loading rod diameter 30 mm with ball bearings

2 Supporting rod diameter 30 mm fixed

3 Supporting rod diameter 30 mm with ball bearings

4 Loading rod diameter 30 mm with ball bearings

5 Measuring device

6 Loading cam

Figure 2. Four point test rig

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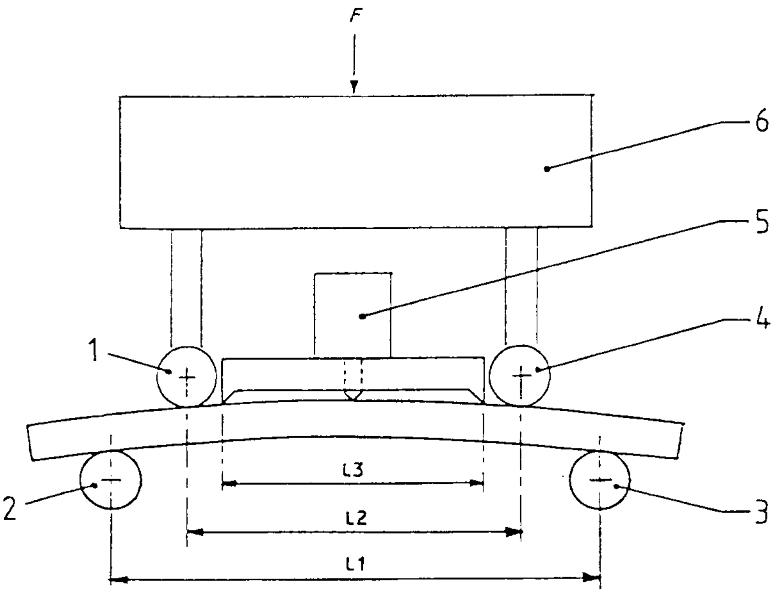

1 Loading rod diameter 30 mm with ball bearings
2 Supporting rod diameter 30 mm fixed
3 Supporting rod diameter 30 mm with ball bearings
4 Loading rod diameter 30 mm with ball bearings
5 Measuring device
6 Loading cam

Figure 3. Four point test rig with separate measuring device

6 Test specimens

6.1 Number of test specimens

For the determination of the factor α and the factor β the following numbers of test specimens are necessary:

a) tanks with a sandwich structure and solid wall tanks (to determine α_s and β_s as required by EN 976-1):

– two series of two test specimens;

b) tanks with a rib construction:

– two series of two test specimens including one rib (to determine α_s and β_s as required by EN 976-1);

– two series of two test specimens taken between the ribs (to determine α_t and β_t as required by EN 976-1).

6.2 Shape and size of test specimens

6.2.1 The test specimens are ring segments taken in the circumferential direction from the cylindrical part of the tank.

6.2.2 The ring segments have a chord length of $(0{,}5 \times D + 100)$ mm, where D is the internal diameter of the tank.

6.2.3 The width of the test specimen shall be:

a) for solid wall tanks: at least 100 mm;

b) for tanks with a rib construction (see figure 1):

– between the ribs: at least 100 mm;

– with the rib: heart-to-heart between the ribs; the rib shall be in the centre of the specimen width;

c) for tanks with a sandwich structure: at least 100 mm.

7 Procedure

7.1 Determination of the initial beam stiffness

7.1.1 ***Test specimens***

– From a solid tank wall or a tank with a sandwich construction take four test specimens with shape and sizes according to **6.2**.

– From a tank with a rib construction take two series each of four test specimens with shape and sizes according to **6.2**, one series of specimens taken between the ribs and one series with a rib section.

7.1.2 ***Determination of the thickness and the height of the test specimens***

Determine, by a series of eight measurements, equally spaced over the length of the test specimen, the thickness (e) of the solid or sandwich specimen and the overall height (h) of the test specimen with the rib section in millimetres.

The overall height is the height of the rib including the thickness of the tank wall.

From the data calculate per test specimen the average thickness (e_m) and/or the average height (h_m) in millimetres.

7.1.3 ***Test conditions***

Before testing the test specimens are conditioned at (23 ± 5) °C and (50 ± 5) % relative humidity for at least 16 h and at most 72 h. The test shall be carried out at the same temperature and humidity conditions.

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7.1.4 ***Test with the four point bending rig and standard measuring device*** (figure 2)

a) Mount the test rig in the test machine.

b) Adjust the supporting and loading rods to the correct span.

c) Install the test specimen in the test rig with the convex side up and adjust the measuring device.

d) Perform a bending test with a constant speed, in millimetres per minute, of approximately

$$1{,}4 \times 10^{-4}\,\frac{L_2{}^2}{e_m}\text{, or } 1{,}4 \times 10^{-4}\,\frac{L_2{}^2}{h_m}$$

where:

e_m is the average wall thickness, in millimetres;

h_m is the average total height of the specimen with rib, in millimetres;

L_2 is the distance between the loading rods, in millimetres.

Register the force/deformation curve and adjust the scale so that the curve is at an angle of approximately 45° with the axis.

e) End the test when the deformation y, in millimetres, has reached a value of

$$4{,}5 \times 10^{-4}\,\frac{L_2{}^2}{e_m}\text{, or } 4{,}5 \times 10^{-4}\,\frac{L_2{}^2}{h_m}$$

f) Calculate for each test specimen the beam stiffness S, in newton square millimetres, using the following equation:

$$S = \frac{(L_1 - L_2)L_2{}^2}{32} \times \frac{F}{y}$$

where:

F is the force corresponding to the deformation y, in newtons;

y is the deformation, in millimetres;

L_1 is the supporting span, in millimetres;

L_2 is the loading span, in millimetres.

g) Calculate per series the average stiffness.

7.1.5 ***Test with the four point bending rig and the special measuring device*** (figure 3)

a) Mount the test rig in the testing machine (see **5.1**).

b) Adjust the supporting and loading rods at the right span.

c) Install the test specimen in the test rig with the convex side up.

d) Install the special measuring device onto the specimen.

e) Perform a bending test with a constant speed of deformation in millimetres per minute of approximately

$$1{,}4 \times 10^{-4}\,\frac{L_3{}^2}{e_m}\text{, or } 1{,}4 \times 10^{-4}\,\frac{L_3{}^2}{h_m}$$

where:

e_m is the average wall thickness, in millimetres;

h_m is the average total height of the specimen with rib, in millimetres;

L_3 is the span between the measuring points, in millimetres.

Register the force/deformation curve and adjust the scale so that the curve is at an angle of approximately 45° with the axis.

f) End the test when the deformation y, in millimetres, has reached a value of

$$4{,}5 \times 10^{-4}\,\frac{L_3{}^2}{e_m}\text{, or } 4{,}5 \times 10^{-4}\,\frac{L_3{}^2}{h_m}$$

g) Calculate for every test specimen the beam stiffness S, in newton square millimetres, using the following equation:

$$S = \frac{(L_1 - L_2)L_3{}^2}{32} \times \frac{F}{y}$$

where:

F is the force value corresponding to the deformation y, in newtons;

y is the deformation, in millimetres;

L_1 is the supporting span, in millimetres;

L_2 is the loading span, in millimetres;

L_3 is the measuring span, in millimetres.

h) Calculate per series the average stiffness.

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7.2 Determination of factor a

7.2.1 *Test specimens*

Two test specimens per series for which the initial beam stiffness has been determined in accordance with **7.1**.

7.2.2 *Test conditions*

The test conditions are in accordance with **7.1.3**.

7.2.3 *Test with a four point bending rig*

a) Set the dial gauge to zero with only the load from the measuring device and the loading cam on the test specimen.

b) Apply carefully load F (from which the mass of the loading cam has been subtracted) to the loading cam with approximately the same speed as the speed of the determination of the stiffness of the test specimen on the bending rig (**7.1.4** or **7.1.5**).

c) With the full load resting on the test specimen, measure the deformation after 6 min (= 0,1 h), 24 h, 50 h, 100 h, 200 h, 500 h and 1000 h.

d) From the series of measured deformations (y_t) beginning at 24 h and the corresponding times, calculate y_x using the method of least squares for the equation:

$$\log y_x = A + B \log x$$

where:

$A = \log y_{0,1h}$

B = the gradient

x = the specified extrapolation period in hours.

e) For each test specimen, calculate factor a using the equation:

$$a = \frac{y_{0,1h}}{y_x}$$

where:

$y_{0,1h}$ is the deformation, in millimetres, after 6 min loading;

y_x is the extrapolated value of the deformation, in millimetres, at the specified extrapolation period x.

f) Calculate the average value of factor a for the two test specimens of the same sample

7.3 Determination of factor β

7.3.1 *Test specimens*

Two test specimens for which the initial beam stiffness has been determined in accordance with **7.1**.

7.3.2 *Post curing*

Expose the test specimens in the oven in accordance with **5.4** under the following conditions:

– tanks with sandwich construction: depending on the core material of the sandwich construction 4 h at (800 ± 2) °C or 16 h at (60 ± 2) °C;

– all other constructions: time and temperature to be agreed between the interested parties according to the materials used.

7.3.3 *Treatment of the test specimens*

Before further testing all the cut sides of test specimens may be sealed with an elastic coating which can resist a temperature of 50 °C in water.

7.3.4 *Determination of the beam stiffness after post curing*

Determine on each test specimen the beam stiffness (S_1) in newton square millimetres, in accordance with **7.1**.

7.3.5 *Exposure to water of 50 °C*

Expose the test specimens for 1000 h in tap water of (50 ± 2) °C.

Dry the test specimens after this exposure.

7.3.6 *Determination of the beam stiffness after exposure in water*

Determine after the exposure in water in accordance with **7.3.5** the beam stiffness (S_2), in newton square millimetres, for each test specimen.

7.3.7 *Calculation of the factor β*

Calculate for each test specimen factor β using the equation:

$$\beta = \frac{S_2}{S_1}$$

where:

S_1 is the beam stiffness after post curing, in newton square millimetres;

S_2 is the beam stiffness after 1000 h in water of 50 °C, in newton square millimetres.

Calculate the average value of factor β for the two test specimens of the same sample.

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8 Test report

The test report shall at least indicate:

a) a reference to this European Standard;

b) a complete identification of the test specimen:

- name of the producer and production place;
- build-up of the material, name and type of the material;
- tank marking, including production code;
- dimensions of the test specimens.

c) for each specimen e_m and/or h_m, in millimetres;

d) for the four point bending test: L_1 and L_2, in millimetres:

e) post curing conditions;

f) the individual names for:

- initial beam stiffness (S);
- factor α;
- beam stiffness (S_1) after post curing;
- beam stiffness (S_2) after exposure in water of 50 °C for 1000 h;
- factor β;

g) the average values for α and β;

h) any deviation from the test procedure specified in this European Standard;

i) any details which have not been provided for by this procedure and any accidental circumstances which might have affected the results;

j) the date(s) of testing.

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