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Thermal-insulating materials — Determination of compressive creep

Matériaux d'isolation thermique — Détermination du fluage en compression

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Foreword

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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.

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 20392 was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 10, *Cellular plastics*.

Thermal-insulating materials — Determination of compressive creep

1 Scope

This International Standard specifies equipment and procedures for determining the compressive creep of test specimens under various conditions of stress. It is applicable to thermal-insulation products.

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.

ISO 844, *Rigid cellular plastics — Determination of compression properties*

ISO 1923, *Cellular plastics and rubbers — Determination of linear dimensions*

3 Terms and definitions

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

3.1
thickness
linear dimension measured perpendicular to the length and width plane

3.1.1
thickness d
original product thickness

3.1.2
thickness d_S
initial thickness of the test specimen

3.1.3
thickness d_L
thickness of the test specimen under the basic compressive stress of the loading device (“dead weight”)

3.1.4
thickness d_0
thickness of the test specimen 60 s after the beginning of loading

3.1.5
thickness d_t
thickness of the test specimen at a given time t

3.2
compressive stress
σ_c
ratio of the compressive force to the initial cross-sectional area of the test specimen

3.3
deformation
X
reduction in thickness of the test specimen

3.4
relative deformation
ε
ratio of the deformation X of the test specimen and its thickness d_s, measured in the direction of the load

3.5
compressive creep
X_{ct}
increase, with time, in the deformation of the test specimen under a constant stress under specified conditions of temperature and humidity

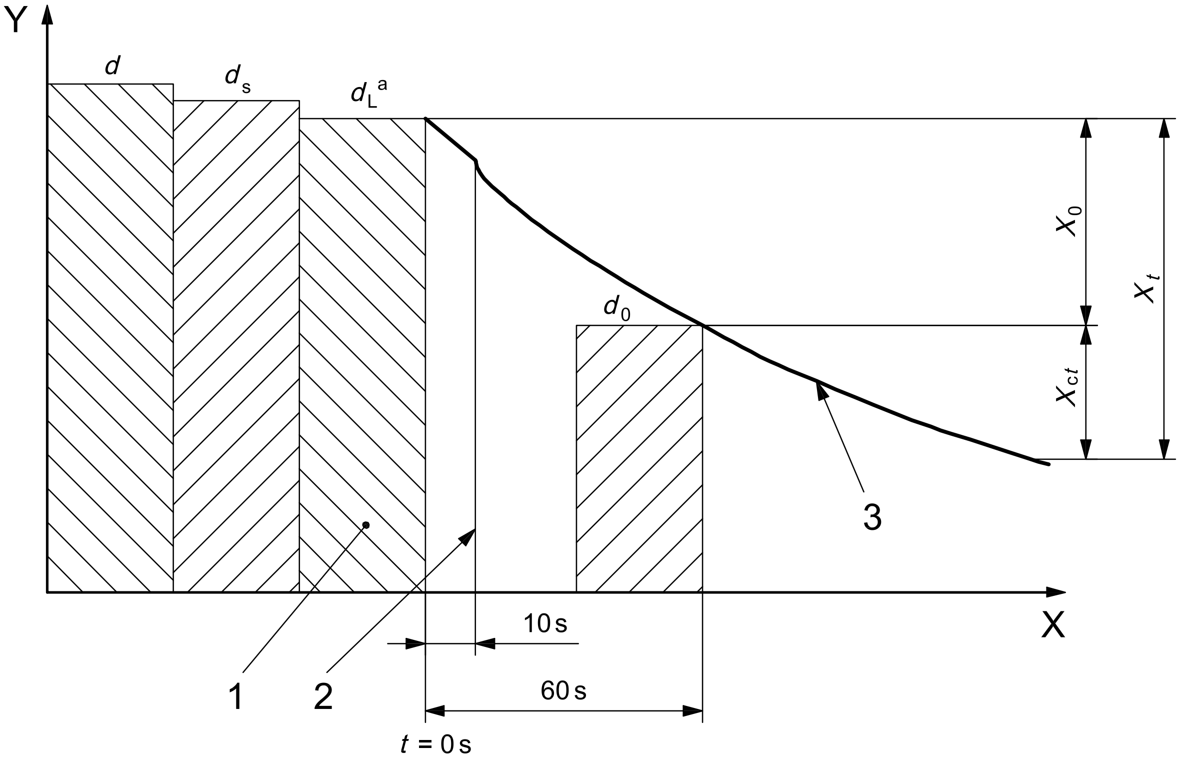
NOTE $X_{ct} = X_t - X_0$

where

X_t is the deformation at time t;

X_0 is the initial deformation (60 s after the beginning of loading).

An illustration of the different thicknesses and deformations is given in Figure 1.



Key

X time, t

Y thickness

1 thickness under the “dead weight” of the loading device (< 10 % of the smallest chosen stress for the creep test)

2 point when load is applied for the compressive-creep test

3 deformation curve

[a] In the illustration, d_L is used as the reference value for the measurements of deformation. If d_s is used as the reference value, the illustration can be used with the omission of the column for d_L (see 7.3).

Figure 1 — Illustration of the various thicknesses and deformations

4 Principle

The compressive creep is determined by measuring the increase in deformation of a test specimen under a constant compressive stress and specified conditions of temperature, humidity and time.

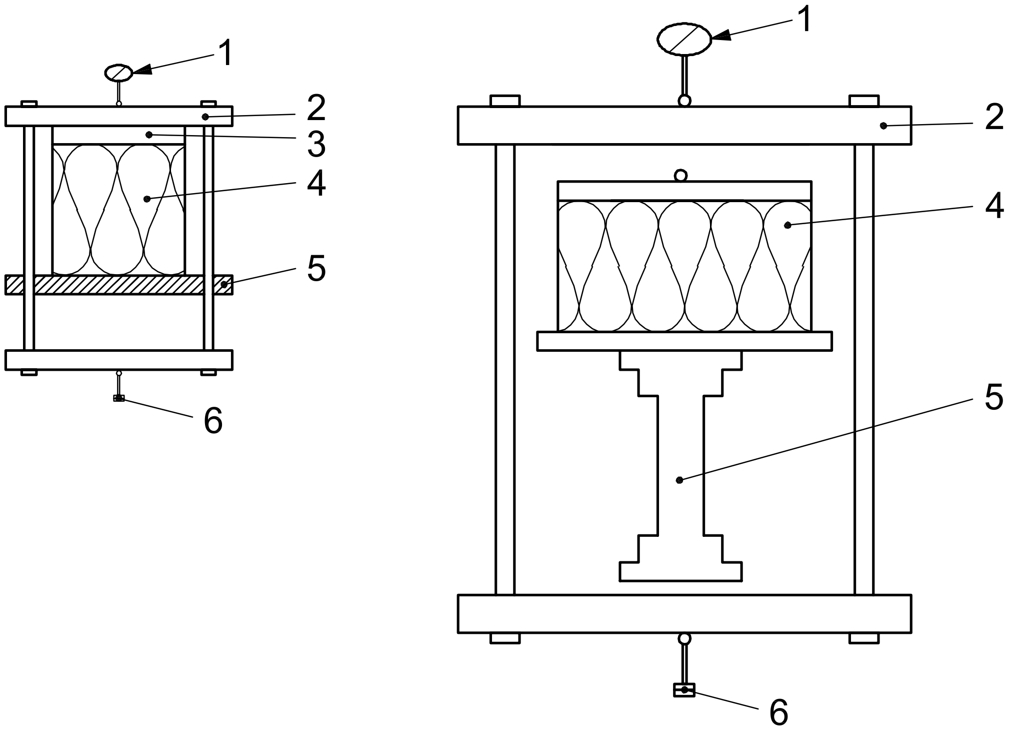
5 Apparatus

5.1 Loading device, consisting of two flat plates, one of which shall be movable, so arranged that they compress the test specimen in the vertical direction. The movable plate shall be mounted in such a manner as to be self-aligning. The plates shall be capable of being loaded smoothly and without distortion so that, during the test, the static stress does not change by more than ± 5 %.

5.2 Measuring device (e.g. dial gauge), capable of determining the distance between the two plates, i.e. the deformation of the test specimen, to an accuracy of 0,01 mm.

5.3 Suitable damping facilities, to minimize the effects of external vibration, e.g. a substantial base supporting the apparatus.

Examples of test apparatus are given in Figure 2.



Key

1 displacement transducer or dial gauge

2 loading bridge

3 load-distribution plate (movable, self-aligning)

4 test specimen

5 base supporting apparatus

6 weights providing the load

Figure 2 — Examples of test apparatus

6 Test specimens

6.1 Preparation

The test specimens for determining the compressive creep shall be taken from the same test sample, with the same preparation, as the test specimens used for the determination of compression properties in accordance with ISO 844.

NOTE Special methods of preparation, when needed, may be given in the relevant product standard.

6.2 Dimensions

The test specimens shall be right prisms with a square base. The thickness of the specimens shall be the original product thickness. The length and width of the specimen base shall not be less than their thickness. Products with facings or integrally moulded skins which are retained in use shall be tested with these faces or skins intact.

Test specimens shall not be layered to produce a greater thickness for testing.

The length and width of the test specimen base are normally specified in the relevant product standard. If not, they shall be agreed between the interested parties, in which case the recommended dimensions are:

50 mm × 50 mm or

100 mm × 100 mm or

150 mm × 150 mm or

200 mm × 200 mm or

300 mm × 300 mm.

The length and width of the test specimen base shall be measured in accordance with ISO 1923 to an accuracy of 0,5 %.

The tolerance on parallelism between the upper and lower faces of the test specimens and the tolerance on the flatness of the upper and lower faces shall not be greater than 0,5 % of the test specimen length or width, with a maximum of 0,5 mm.

If a test specimen is not flat, it shall be ground flat or a suitable coating applied to prepare the surface for the test. If it is coated, no significant creep shall occur in the coating or, if creep does occur in the coating, this shall be taken into account by deducting it from the measurements.

6.3 Number

The number of test specimens shall be as specified in the relevant product standard. If the number is not specified, then at least three test specimens shall be used for each of the compressive stresses selected in 7.2.

In the absence of a product standard, the number of test specimens may be agreed between the interested parties.

6.4 Conditioning

The test specimens shall be conditioned for at least 24 h under the test conditions. In cases of dispute, the time for conditioning (equilibration of moisture content) shall be as specified in the relevant product standard.

7 Procedure

7.1 Test conditions

The test shall be carried out at

(23 ± 2) °C and (50 ± 10) % relative humidity

or

(23 ± 5) °C and 50^{+20}_{-10} % relative humidity

or

(27 ± 5) °C and 65^{+20}_{-10} % relative humidity

unless other conditions are given in the relevant product standard.

7.2 Stress selection

The test shall be carried out at three or more different stresses.

The alternative stresses, σ_c, for the creep investigation shall be based on either the compressive strength, σ_m, or the compressive stress, σ_{10}, at 10 % deformation measured in accordance with ISO 844, and shall be calculated as follows:

$\sigma_c = 0{,}15 \times \sigma_m$ or $\sigma_c = 0{,}15 \times \sigma_{10}$

$\sigma_c = 0{,}20 \times \sigma_m$ or $\sigma_c = 0{,}20 \times \sigma_{10}$

$\sigma_c = 0{,}25 \times \sigma_m$ or $\sigma_c = 0{,}25 \times \sigma_{10}$

$\sigma_c = 0{,}30 \times \sigma_m$ or $\sigma_c = 0{,}30 \times \sigma_{10}$

$\sigma_c = 0{,}35 \times \sigma_m$ or $\sigma_c = 0{,}35 \times \sigma_{10}$

If appropriate, other values of σ_c may be chosen.

7.3 Test procedure

If the thickness of a test specimen, d_s, is determined without using the loading device, it shall be measured to the nearest 0,1 mm in accordance with ISO 1923.

Place the test specimen carefully in the loading device under the “dead weight” of the loading device. The thickness under this load, d_L, is considered as the reference value for the measurements of deformation. Determine d_L to the nearest 0,01 mm.

The stress imposed by the “dead weight” shall be less than 10 % of the lowest stress selected for the test.

If the thickness of the test specimen, d_s, is determined using the loading device, the specimen shall be preloaded with a pressure of (250 ± 10) Pa and the thickness measured to the nearest 0,01 mm. This value shall then be used as the reference value for measurements of deformation. If significant deformation occurs under the pressure of 250 Pa, then a load corresponding to 50 Pa may be used assuming it is specified in the relevant product standard. In this case, the thickness d_s shall be determined under the same load.

Apply the first of the selected stresses uniformly to the test specimen within (10 ± 5) s. Determine the initial deformation, X_0, to the nearest 0,01 mm (60 ± 5) s after the beginning of loading.

Determine the deformation, X_t, to the nearest 0,01 mm at the following times after loading: 0,1 h, 1 h, 5 h and then at 1 day, 2 days, 4 days, 7 days, 9 days, 11 days, 14 days, 18 days, 24 days, 32 days, 42 days, 53 days, 65 days, 80 days and at at least one additional time between 90 days and 100 days.

NOTE These times, when expressed in hours, give equal time increments on a logarithmic time scale.

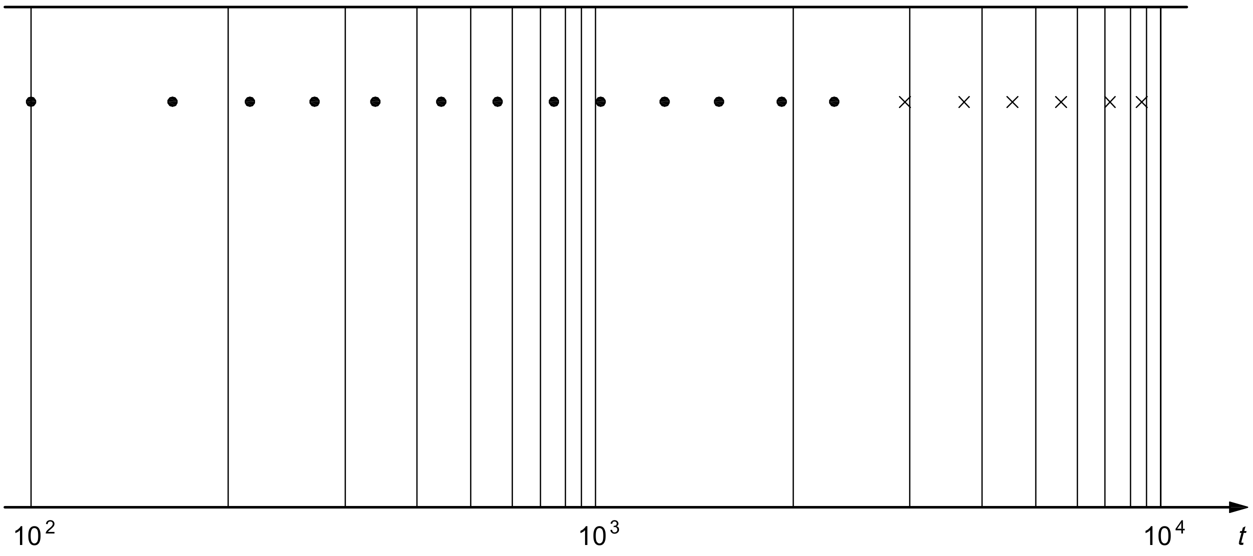
If the test is continued after 90 days, readings shall be made at equal time increments (on a logarithmic scale). An example of a suitable test schedule is given in Table 3 and shown in Figure 3.

If a coating has been added for test purposes, the compressive creep may be measured by the relative movement of the flat plates of the loading device. Alternatively, it may be measured from the relative movement of reference points on the edges of the specimen.

Tabulate the measured deformation values, X_t, for each test specimen separately.

Table 1 — Example of schedule for taking deformation readings

Day	Time	Test duration h	Day of week
0	10:00 a.m.	0 (loading)	Mon
0	10:01 a.m.	0,017	Mon
0	11:00 a.m.	1,0	Mon
0	3:00 p.m.	5,0	Mon
1	10:00 a.m.	24	Tues
2	10:00 a.m.	48	Wed
4	2:00 p.m.	100	Fri
7	10:00 a.m.	168	Mon
9	10:00 a.m.	216	Wed
11	10:00 a.m.	254	Fri
14	10:00 a.m.	336	Mon
18	10:00 a.m.	432	Fri
24	10:00 a.m.	576	Thurs
32	10:00 a.m.	768	Fri
42	10:00 a.m.	1 008	Mon
53	10:00 a.m.	1 272	Fri
65	10:00 a.m.	1 560	Wed
80	10:00 a.m.	1 920	Thurs
100	10:00 a.m.	2 400	Wed
123	10:00 a.m.	2 952	Fri
156	10:00 a.m.	3 744	Wed
190	10:00 a.m.	4 560	Tues
231	10:00 a.m.	5 544	Mon
295	10:00 a.m.	7 080	Tues
365	10:00 a.m.	8 760	Tues



Key

- • readings for the required test duration of 90 days (see 7.3)
- x readings for a test duration longer than 90 days (see 7.4)
- t time (h)

Figure 3 — Equal time increments (on logarithmic scale) up to 10 000 h

7.4 Duration of test

The compressive creep shall be measured at time intervals (see 7.3) over a period of at least 90 days. The total test time depends on the time to which the measurements will have to be extrapolated (the long-term deformation time), which shall be determined in accordance with Annex A.

8 Calculation and expression of results

Calculate the relative deformation, ε_t, as a percentage, for each test specimen using the equation

$$\varepsilon_t = \frac{X_t}{d_\text{s}} \times 100$$

where

X_t is the deformation, in millimetres, at time t;

d_s is the initial thickness, in millimetres, of the test specimen.

The relative deformation for each test specimen and the mean value of the three relative deformations for each stress level shall be plotted in a linear/logarithmic (time) or a logarithmic/logarithmic diagram.

The calculation of the creep deformation and the equation for its extrapolation is given in Annex A.

9 Precision

It has not been possible to include a statement on the precision of the measurements in this edition of this International Standard, but it is intended to include such a statement when the standard is next revised.

10 Test report

The test report shall include the following information:

a) a reference to this International Standard;

b) product identification:

   1) the name of the product, the factory where it was manufactured and the manufacturer or supplier,

   2) the production code number,

   3) the type of product,

   4) the type of packaging,

   5) the form in which the product arrived at the laboratory,

   6) any other information as appropriate, e.g. nominal thickness, nominal density;

c) test procedure:

   1) details of pre-test history and sampling, e.g. who sampled and where,

   2) details of conditioning,

   3) details of any deviations from the requirements specified in Clauses 6 and 7,

   4) the dates of testing,

   5) the dimensions of the test specimens and the number tested,

   6) details of any surface treatment to which the test specimens were subjected (grinding or coating),

   7) general information relating to the test (strength σ_m or stress σ_{10} measured in accordance with ISO 844 and the chosen stresses σ_c),

   8) details of any events which may have affected the results;

d) results:

   1) the tabulated deformation values and the plots of X_t versus t in semi-logarithmic or log/log form for each specimen and the mean deformation value for each of the chosen stresses,

   2) the results in accordance with Annex A for each stress level:

      i) the statistical parameters a, b and r^2,

      ii) the factors m and b in the Findley equation,

      iii) the value of the creep deformation X_{ct}, together with the linear regression analysis plotted as a log/log plot,

      iv) the relative deformation ε and the extrapolation line plotted as a semi-logarithmic plot.

Information about the apparatus and the identity of the technician should be available in the laboratory, but need not be recorded in the test report.

Annex A
(normative)

Calculation of long-term compressive creep

A.1 General

This annex specifies an extrapolation method for the calculation of a value for the long-term deformation of thermal-insulation products due to compressive creep. The method may be used to define a permissible load in practical applications and/or to characterize the compressive behaviour of a given product.

In order to make a reliable extrapolation of the behaviour of thermal-insulation products with time when they are tested in accordance with this International Standard, the results of many tests are required. The necessary results are not yet available for all products. The extrapolation method given in this annex is well established and has been validated for various plastic foam products. For other products, tests are still running, and no mathematical model has yet been validated. In the event of validation of another mathematical model, that model will be incorporated in this annex by amendment or revision.

Validation shall be based on measurements made over a period of at least 5 years on different products within a given product family. Based on these measurements, different mathematical models shall be evaluated by using measured values from periods of up to 2 years and comparing the extrapolation with the data obtained over the five years' measurements.

For the method described in this annex to be used with a particular product, the shape of the curve given by the mathematical model shall be similar to that given by the measured values.

The method gives a maximum extrapolation of up to 30 times the test duration. Even with an extrapolation of only 30 times the test duration, it is recommended that a safety factor be included in any long-term permissible load calculated and in the corresponding permissible deformation.

A.2 Principle

The method is based on a mathematical function, called the Findley equation [1] [Equation (A.1)], which allows the description of the creep behaviour of thermal insulating products, provided that the linear regression analysis according to Equation (A.2) fits with a coefficient of determination $r^2 > 0{,}9$.

$$X_t = X_0 + mt^b \tag{A.1}$$

where m and b are constants dependent on the material concerned.

Equation (A.1) can be written in a logarithmic form:

$$\log\left(X_t - X_0\right) = \log m + b \log t \tag{A.2}$$

It follows that $\log m$ is the intercept on the ordinate axis and b is the slope of the straight line defined by this equation. The constants m and b are calculated by regression analysis of the measured deformation as a function of time.

A.3 Procedure

A.3.1 Using the values obtained for the thickness of the test specimen, d_S and d_L, and the deformation values X_0 and X_t, measured in accordance with this International Standard, calculate the values of log$t$, X_{ct} and logX_{ct}, starting with the value read after 7 days (= 168 h).

This period of 7 days may be reduced if the measured data show linear behaviour when plotted as a double-logarithmic plot in accordance with Equation (A.2).

A.3.2 For the linear regression analysis, determine the following statistical functions:

$$y = a + bx \quad \text{(general equation for the linear regression line)} \tag{A.3}$$

$$X_m = \sum x_t / n \tag{A.4}$$

$$Y_m = \sum y_t / n \tag{A.5}$$

$$Q_x = \sum x_t^2 - \frac{\left(\sum x_t\right)^2}{n} \tag{A.6}$$

$$Q_y = \sum y_t^2 - \frac{\left(\sum y_t\right)^2}{n} \tag{A.7}$$

$$Q_{xy} = \sum x_t y_t - \frac{\sum x_t \sum y_t}{n} \tag{A.8}$$

$$s_R^2 = \frac{Q_y - Q_{xy}^2 / Q_x}{n-2} \tag{A.9}$$

$$s_R = \sqrt{s_R^2} \tag{A.10}$$

$$r^2 = Q_{xy}^2 / Q_x Q_y \tag{A.11}$$

$$r = \sqrt{r^2} \tag{A.12}$$

$$b = Q_{xy} / Q_x \tag{A.13}$$

$$a = y_m - b x_m \tag{A.14}$$

where

n is the number of values;

x_t is the time, log$t$;

y_t is the creep deformation, logX_{ct};

x_m is the mean value of x_t;

y_m is the mean value of y_t;

Q_x is the sum of the squares of the deviations for the x-values;

Q_y is the sum of the squares of the deviations for the y-values;

Q_{xy} is the sum of the deviations for both the x-values and y-values;

s_R^2 is the variance;

s_R is the standard deviation;

r^2 is the coefficient of determination;

r is the correlation coefficient;

a is the intercept at the ordinate axis;

b is the slope of the line.

A.4 Calculation of a long-term deformation

Using Equation (A.1) with b from Equation (A.13) and putting $m = 10^a$, the long-term deformation at any time t can be calculated. Extrapolation is permissible up to 30 times the test duration, providing $r^2 > 0{,}9$ (see example in Annex B).

Annex B
(informative)

Example of a linear regression analysis

Table B.1 gives the measured values of the deformation of three individual test specimens at one compressive stress. These were recorded after various periods of time. In this example, the results are analysed using a linear regression technique, as described in Annex A, using the mean values for the three test specimens.

The calculated statistical values are:

x_m = 3,238 72

y_m = – 0,868 83

Q_x = 7,770 76

Q_y = 0,271 4

Q_{xy} = 1,444 65

s_R^2 = 0,000 41

s_R = 0,020 20

r^2 = 0,969 08

r = 0,984 42

b = 0,185 91

a = 1,470 94

Figure B.1 shows the result of a linear regression analysis on the values of logX_{ct} versus log$t$ with m = 0,033 81 and b = 0,185 91.

The long-term deformation value for the test specimens at e.g. 10 years (about 87 600 h) is calculated using Equation (A.1) with m and b as given above:

$$X_{87\,600} = X_0 + 0{,}033\,81 \times 87\,600^{0{,}185\,91} = 0{,}50 \text{ mm}$$

The relative deformation (see Clause 8) is given by:

$$\varepsilon_t = \frac{X_t}{d_\text{s}} \times 100$$

Thus

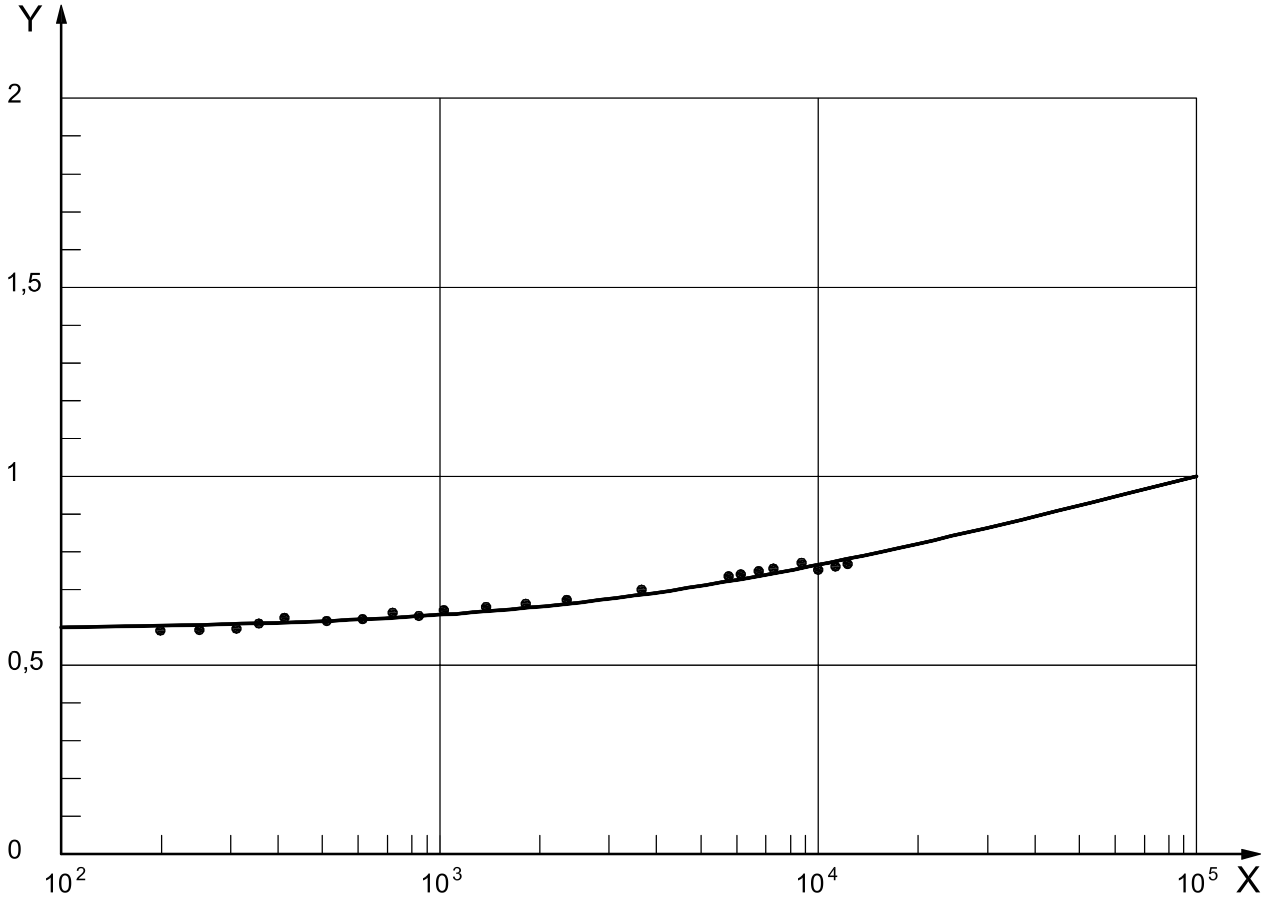
$$\varepsilon_{87\,600} = \frac{0{,}5}{50{,}2} \times 100 = 1{,}0 \text{ \%}$$

In Figure B.2, the relative deformation, ε_t, is plotted against time as a semi-logarithmic plot. In this plot, the measured values are depicted as points, and the curve has been extrapolated to 100 000 h (about 11,4 years).

Table B.1 — Measured values of the deformation of three individual test specimens at one compressive stress

Test specimen	No. 1	No. 2	No. 3
Thickness d_S, mm	50,20	50,20	50,20
Thickness d_L, mm	50,19	50,24	50,24
Deformation X_0, mm	0,22	0,23	0,21

Time t	log$t$	Deformation X_t			Relative deformation ε_t			Mean of ε_t	Compressive creep X_{ct}			Mean of X_{ct}	logX_{ct}
		Specimen			Specimen				Specimen				
h		No. 1	No. 2	No. 3	No. 1	No. 2	No. 3	%	No. 1	No. 2	No. 3	mm	
167	2,222 72	0,31	0,31	0,29	0,61	0,61	0,58	0,601	0,09	0,08	0,08	0,082	−1,086 19
215	2,332 44	0,31	0,31	0,30	0,61	0,63	0,59	0,608	0,09	0,08	0,09	0,085	−1,068 88
287	2,457 88	0,31	0,32	0,30	0,62	0,64	0,60	0,621	0,09	0,09	0,09	0,092	−1,036 21
357	2,552 67	0,32	0,33	0,31	0,64	0,65	0,62	0,637	0,10	0,10	0,10	0,100	−1,000 00
431	2,634 48	0,33	0,33	0,32	0,66	0,66	0,63	0,652	0,11	0,10	0,11	0,107	−0,969 27
527	2,721 81	0,33	0,34	0,32	0,66	0,67	0,64	0,657	0,11	0,11	0,11	0,110	−0,958 61
623	2,794 49	0,34	0,34	0,32	0,67	0,68	0,64	0,663	0,12	0,11	0,11	0,113	−0,946 92
719	2,856 73	0,34	0,35	0,33	0,68	0.69	0,66	0,677	0,12	0,12	0,12	0,120	−0,920 82
863	2,936 01	0,34	0,35	0,32	0,67	0,70	0,64	0,672	0,12	0,12	0,11	0,118	−0,929 35
1 007	3,003 03	0,35	0,36	0,34	0,70	0,71	0,67	0,692	0,13	0,13	0,13	0,127	−0,895 06
1 439	3,158 06	0,36	0,37	0,35	0,72	0,73	0,69	0,715	0,14	0,14	0,14	0,139	−0,855 94
1 943	3,288 47	0,36	0,38	0,35	0,73	0,75	0,70	0,725	0,14	0,15	0,14	0,144	−0,841 64
2 447	3,388 63	0,37	0,38	0,36	0,74	0,76	0,72	0,740	0,15	0,15	0,15	0,152	−0,819 11
3 215	3,507 18	0,38	0,39	0,37	0,75	0,78	0,73	0,752	0,16	0,16	0,16	0,158	−0,802 26
4 127	3,615 63	0,38	0,40	0,37	0,77	0,79	0,74	0,765	0,16	0,17	0,16	0,164	−0,784 27
4 487	3,651 96	0,39	0,40	0,37	0,77	0,80	0,74	0,771	0,17	0,17	0,16	0,167	−0,777 28
5 015	3,700 27	0,39	0,40	0,38	0,78	0,80	0,75	0,775	0,17	0,17	0,17	0,169	−0,772 11
5 855	3,767 53	0,39	0,40	0,38	0,78	0,80	0,76	0,780	0,17	0,17	0,17	0,172	−0,765 31
6 527	3,814 71	0,40	0,41	0,38	0,79	0,81	0,76	0,787	0,18	0,18	0,17	0,175	−0,756 14
8 159	3,911 64	0,40	0,40	0,38	0,79	0,80	0,76	0,783	0,18	0,17	0,17	0,173	−0,761 12
10 007	4,000 30	0,40	0,41	0,39	0,80	0,81	0,77	0,792	0,18	0,18	0,18	0,178	−0,749 58
11 519	4,061 41	0,40	0,41	0,39	0,80	0,81	0,77	0,794	0,18	0,18	0,18	0,179	−0,747 15
12 959	4,112 57	0,41	0,41	0,39	0,81	0,82	0,78	0,800	0,19	0,18	0,18	0,182	−0,739 93

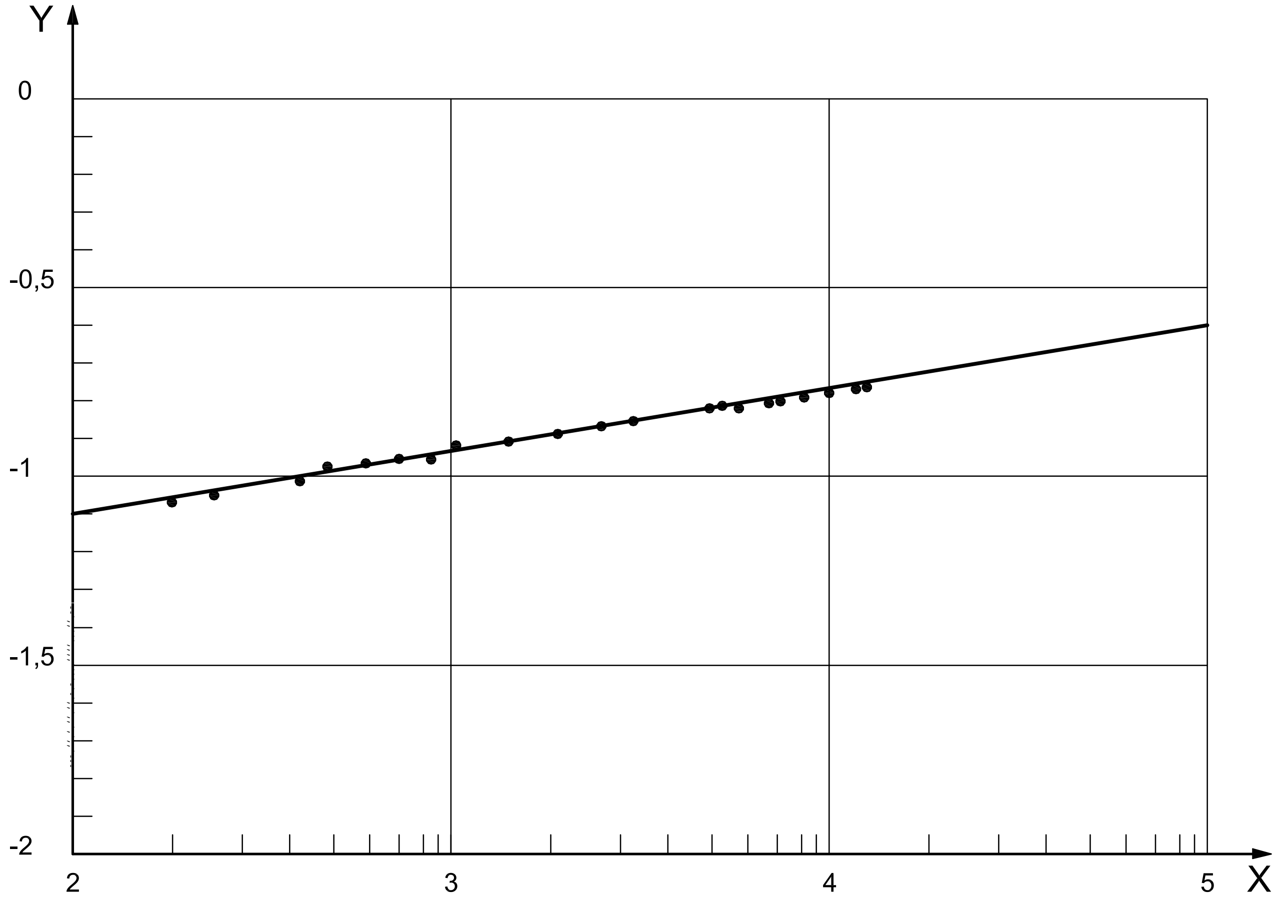


Key

X time, t (h)

Y relative deformation, ε (%)

Figure B.1 — Creep deformation — Regression analysis



$\log X_{ct} = -1{,}470\ 9 + 0{,}185\ 91 \log t$
$r^2 = 0{,}969\ 08$

Key

X log$t$ (t in hours)

Y logX_{ct} (X_{ct} in millimetres)

Figure B.2 — Long-term compressive-creep behaviour — Measured values and calculated extrapolation

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[1] FINDLEY, W.N. *Creep Characteristics of Plastics*, Symposium on Plastics, American Society of Testing and Materials, 1944

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