INTERNATIONAL STANDARD

ISO 16534

Second edition
2020-06

Thermal insulating products for building applications — Determination of compressive creep

Produits isolants thermiques destinés aux applications du bâtiment — Détermination du fluage en compression

Reference number
ISO 16534:2020(E)

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Published in Switzerland

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee Committee ISO/TC 163, *Thermal performance and energy use in the built environment*, Subcommittee SC 1, *Test and measurement methods,* in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 88, *Thermal insulating materials and products,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 16546:2012), which has been technically revised. The main changes compared to the previous edition are as follows:

— modification of Figure 1;

— editorial modifications.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Thermal insulating products for building applications — Determination of compressive creep

1 Scope

This document specifies the equipment and test method for determining the compressive creep of specimens under various conditions of stress.

This document is applicable to thermal insulating products.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 29469, *Thermal insulating products for building applications — Determination of compression behaviour*

ISO 29768, *Thermal insulating products for building applications — Determination of linear dimensions of test specimens*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
thickness
linear dimension measured perpendicular to the planes of length and width

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

3.3
deformation
X
reduction in *thickness* (3.1) of the test specimen

3.4
relative deformation
ε
ratio of the *deformation* (3.3) of the test specimen X, and its *thickness* (3.1) d_s, measured in the direction of loading

3.5
compressive creep
X_{ct}
increase in *deformation* (3.3) of the test specimen over time whilst under a constant stress, at specified conditions of temperature and humidity

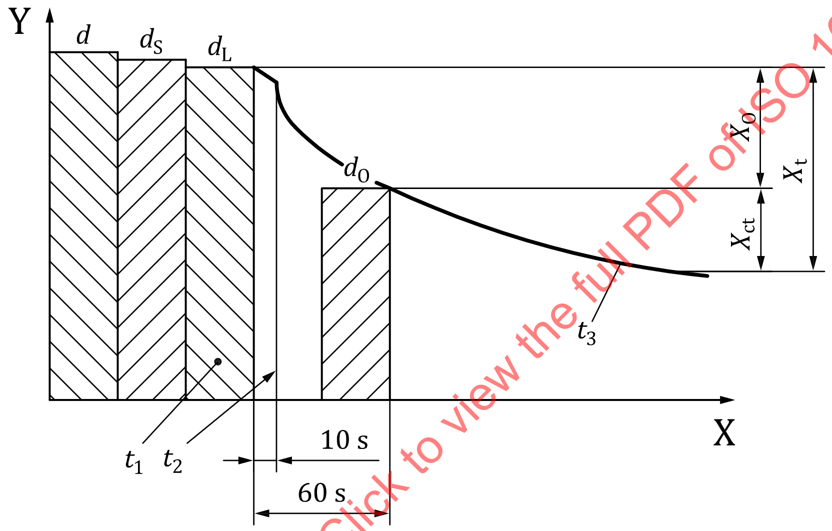
$$X_{ct} = X_t - X_0$$

where

X_t is the deformation at time t;

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

Note 1 to entry: An illustration of the different *thicknesses* (3.1) and deformations is given in Figure 1.



Key

d original product thickness

d_s initial thickness of the test specimen

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

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

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

X_{ct} increase in deformation of the test specimen over time whilst under a constant stress, at specified conditions of temperature and humidity

X_t total the deformation at selected time t_3

t_1 time when dead wright is applied

t_2 time when selected load is uniformly applied

t_3 deformation at selected time

Y thickness

X time

In the illustration, d_L is used as a reference value for deformation measurements. If d_s is used as the reference value, the illustration can be used, omitting the column for d_L (see 8.3).

Figure 1 — Illustration of the different thicknesses and deformations

4 Symbols

Symbol	Description
d	original product thickness
d_S	thickness of the test specimen
d_L	thickness of the test specimen under the basic compressive stress of the loading device ('dead weight')
d_0	thickness of the test specimen 60 s after the beginning of the loading process
d_t	thickness of the test specimen at a given time, t

5 Principle

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

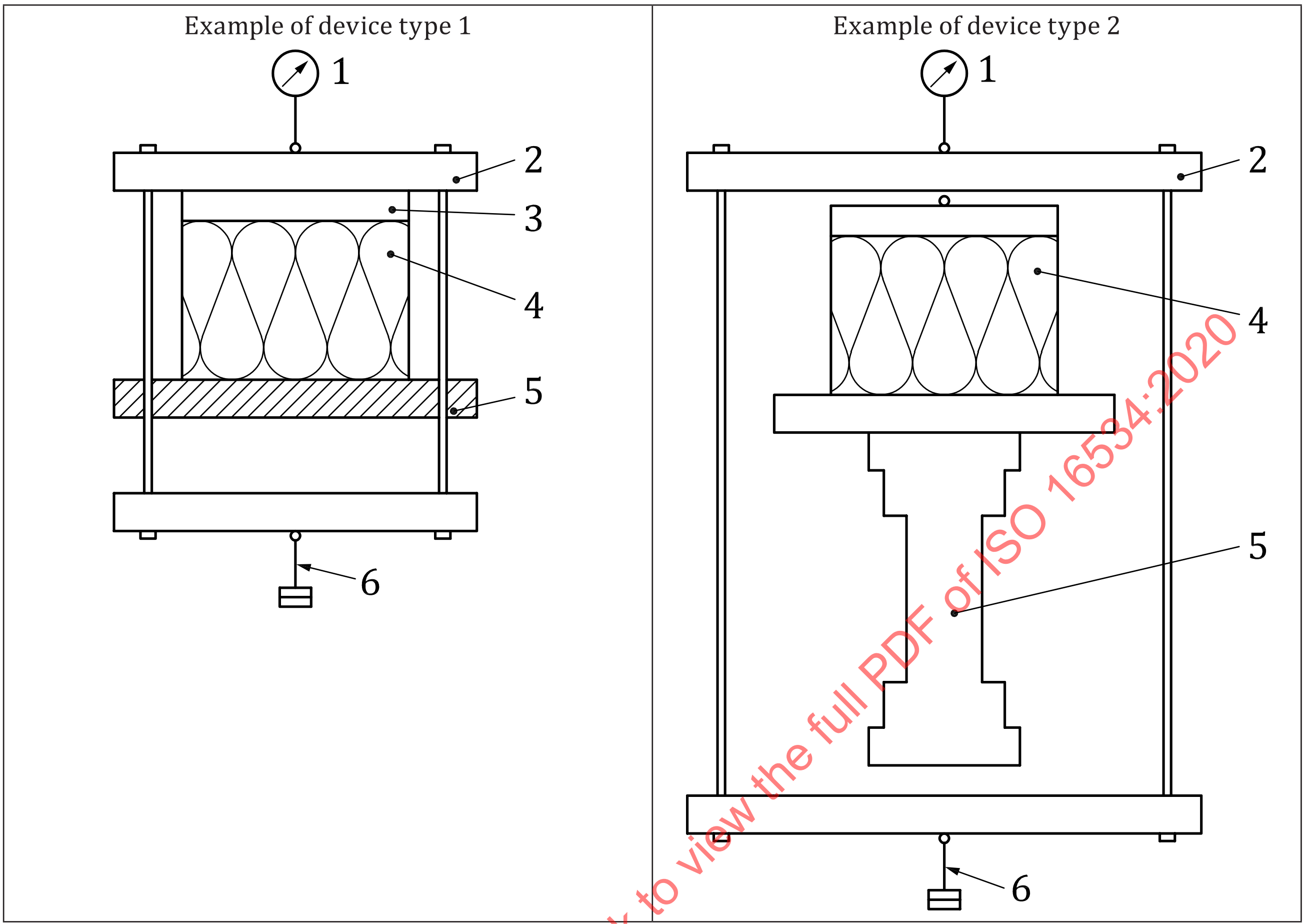
6 Apparatus

6.1 Loading device, consisting of two flat plates, one of which shall be movable, arranged so that they compress the test specimen in a vertical direction. The movable plate shall be guided 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 %.

6.2 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.

6.3 Suitable damping measures, to ensure the effects of external vibration are minimized (e.g. a substantial foundation and anchoring of the apparatus support).

Examples of the testing 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 support beam

6 loading by weights

Figure 2 — Examples of test apparatus

7 Test specimens

7.1 Selection of test specimens

The test specimens for determining the compressive creep shall be taken from the same sample, with the same preparation as the test specimens used for the compression test as specified in ISO 29469.

The method for selecting the test specimens shall be as specified in the relevant product standard.

NOTE In the absence of a product standard or any other technical specification, the method for selection of the test specimens can be agreed between parties.

7.2 Dimensions of test specimens

The thickness of test specimens shall be equal to the original product thickness. The width of the test specimens shall not be less than their thickness. Products with facings or integral moulded skins which are intended to be 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 test specimens shall be cut squarely and have sides with the following recommended dimensions:

— 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 dimensions of test specimens shall be the same as used in the compression test as described in ISO 29469. These are specified in the relevant product standard or agreed between parties.

The linear dimensions shall be determined in accordance with ISO 29768, to an accuracy of 0,5 %.

The upper and lower faces of each test specimen shall be flat and parallel with a tolerance no greater than 0,5 % of its side length, up to a maximum of 0,5 mm.

7.3 Number of test specimens

The number of test specimens shall be as specified in the relevant product standard. If the number is not specified, then at least three specimens shall be used for each compressive stress selected from 8.2.

NOTE In the absence of a product standard or any other technical specification, the number of specimens can be agreed between parties, provided the minimum requirement of three specimens are met.

7.4 Preparation of test specimens

The specimens shall be cut so that the direction of loading applied to the product will correspond to the direction in which the compressive forces are applied to the product in use.

The test specimens shall be cut by methods that do not change the original structure of the product.

If the test specimen is not flat and parallel, it shall be ground flat and parallel or a suitable coating shall be applied to prepare the surface for the test. If a coating is applied, any creep which occurs within the coating shall be taken into account by deducting the creep of the coating.

Special methods of preparation, when needed, can be provided in the relevant product standard.

7.5 Conditioning of test specimens

The test specimens shall be conditioned for at least 24 h at (23 ± 2) °C and (50 ± 5) % relative humidity (RH). In case of dispute, the time for conditioning (equilibrium of moisture content) shall be as specified in the relevant product standard.

In tropical countries, the local environment can necessitate different conditioning and testing conditions. In such cases, the conditioning shall be performed at (27 ± 2) °C and (65 ± 5) % RH and be stated clearly in the test report.

8 Procedure

8.1 Test conditions

The test shall be carried out at (23 ± 2) °C and (50 ± 5) % RH.

Other conditions can be given in the relevant product standard or can be agreed between parties.

In tropical countries, the local environment may necessitate different conditioning and testing conditions. In such cases, the testing shall be performed at (27 ± 2) °C and (65 ± 5) % RH and be stated clearly in the test report.

8.2 Stress selection

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

To verify one defined level of stress only this level shall be used.

The alternative stresses for the creep test, σ_c, shall be based on the compressive strength, σ_m, or on the compressive stress, σ_{10}, at 10 % strain measured in accordance with ISO 29469, 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.

8.3 Test procedure

If the thickness of a test specimen, d_s, is to be determined without using the loading device, it shall be measured to an accuracy of 0,1 mm, in accordance with ISO 29768.

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

The stress imposed by the 'dead weight' shall be less than 10 % of the minimum stress selected for the test.

If the thickness of the test specimen, d_s, is determined using the loading device, the specimen should be preloaded by applying a pressure of (250 ± 10) Pa and the thickness measured to an accuracy of 0,01 mm. This value shall then be used as the reference value for the deformation measurements.

If a significant deformation occurs under the pressure of 250 Pa, then a load corresponding to 50 Pa may be used, assuming that such load is specified in the relevant product standard. In this case the thickness, d_s, should be determined under the same load.

Apply the selected stress 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 loading has started.

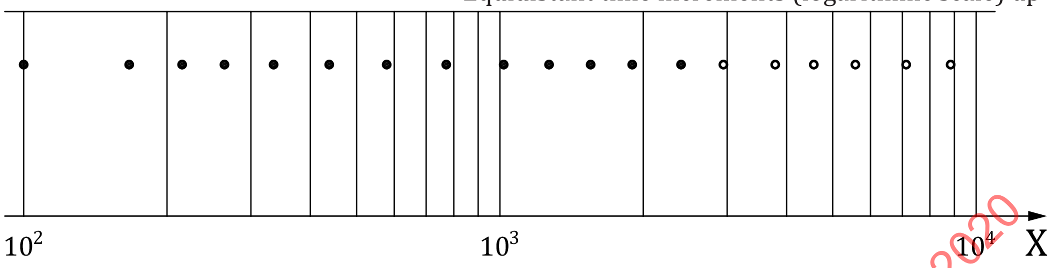
Determine the deformation, X_t, to the nearest 0,01 mm at the following times after loading:

1 min, 1 h, 5 h, and then at the following intervals after loading has started: (1, 2, 4, 7, 9, 11, 14, 18, 24, 32, 42, 53, 65 and 80) days, and once between 90 days and 100 days.

NOTE These times, expressed in hours, are equidistant time increments in a logarithmic time scale.

If the test is continued after 90 days (see 8.4), readings shall be made at equidistant time increments (logarithmic scale). An example for appropriate reading time increments is given in Figure 3 and Table 1.

When the product to be tested incorporates a facing which is difficult to remove or if a coating has been applied for testing 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 placed on the edges of the material, if the intention is to assess the material itself.



Key

- • readings for the required test duration of 90 days (see 8.3)
- ○ readings for a test duration longer than 90 days (see 8.4)
- X time, *t*, in h

Figure 3 — Reading time: examples for time intervals for deformation measurement

Table 1 — Reading times: examples for time intervals for deformation measurement

Week	Day	Time	Duration in h	Day of the week
1st	0	10:00	0 (loading)	Monday
1st	0	10:01	0,017	Monday
1st	0	11:00	1,0	Monday
1st	0	15:00	5,0	Monday
1st	1	10:00	24	Tuesday
1st	2	10:00	48	Wednesday
1st	4	14:00	100	Friday
1st	7	10:10	168	Monday
2nd	9	10:00	216	Wednesday
2nd	11	10:00	264	Friday
2nd	14	10:00	336	Monday
2nd	18	10:00	432	Friday
3rd	24	10:00	576	Thursday
4th	32	10:00	768	Friday
6th	42	10:00	1 008	Monday
7th	53	10:00	1 272	Friday
9th	65	10:00	1 560	Wednesday
11th	80	10:00	1 920	Thursday
14th	100	10:00	2 400	Wednesday
17th	123	10:00	2 952	Friday
22nd	156	10:00	3 744	Wednesday
27th	190	10:00	4 560	Tuesday
33rd	231	10:00	5 544	Monday
42nd	295	10:00	7 080	Tuesday
52nd	365	10:00	8 760	Tuesday

8.4 Duration of test

The compressive creep shall be measured at time intervals given in 8.3 over a period of at least 90 days. The duration of the test shall be as specified in the relevant product standard or shall be agreed between the parties. The total duration of testing depends on the required extrapolation time, which shall be determined in accordance with Annex A.

9 Calculation and expression of results

The deformation value, X_t, shall be tabled for each test specimen.

Calculate the relative deformation, ε_t, as a percentage, for each test specimen, using Formula (1):

$$\varepsilon_t = \frac{X_t}{d_s} \times 100 \quad (1)$$

where

X_t is the deformation at time t, in mm;

d_s is the thickness of the test specimen, in mm.

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 semi-log (time) or a log/log diagram. The calculation of creep deformation and the formula for its extrapolation is given in Annex A. See Annex B for an example of a linear regression analysis.

10 Accuracy of measurement

Following the experience from a “round robin test” where comparable test equipment and test specimen preparation were used, the accuracy for compressive creep, ε_{ct}, and total deformation, ε_t, when measured under a static load can be estimated as given below:

— Repeatability limit, r, with a probability of 95 %: approximately 0,5 %;

— Reproducibility limit, R, with a probability of 95 %: approximately 1,2 %.

NOTE The above-mentioned terms are applied as described in ISO 5725-2.

11 Test report

The test report shall include the following information:

a) Reference to this International Standard, i.e. ISO 16534:2020;

b) Product identification:

1) product name, factory, manufacturer or supplier;

2) production code number;

3) type of product;

4) packaging;

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

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

c) Test procedure:

1) pre-test history and sampling (e.g. person taking the sample, place of sampling);

2) conditioning;

3) any deviations from Clauses 7 and 8;

4) date of testing;

5) conditioning and testing conditions in tropical countries, if applicable;

6) dimensions and number of test specimens;

7) kind of surface treatment (grinding or type of coating);

8) general information relating to the test (strength, σ_m, or stress, σ_{10}, measured in accordance with ISO 29469 and the chosen stresses, σ_c);

9) any other events which may have affected the results;

d) Results:

1) the tabled deformation values and the diagrams X_t versus t in semi-log or log/log form for each test specimen, and the mean values for the chosen stresses;

2) results according to Annex A for each stress level, if any;

3) the statistical parameters a, b, and r^2;

4) factors m and b of the Findley equation;

5) the creep deformation, X_{ct}, together with the linear regression analysis in a log/log diagram;

6) the relative deformation, ε, and the extrapolation curve in a semi-log diagram.

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

Annex A
(normative)

Calculation method

A.1 General

This annex specifies a calculation method for the determination of a long-term deformation value of thermal insulating products due to compressive creep. In case of positive validation of another mathematical model, that model shall be incorporated by amendment or revision of this annex.

This method may be used to define a permissible load in practical applications and/or to define the compressive behaviour of a certain product.

When tested in accordance with this document, in order to make a reliable extrapolation of the behaviour of thermal insulating products with time, the results of many tests and experience are required. This experience is not available for all products. For many plastic foam products, such experience has been well established and verified however, for other products, tests are still running and no mathematical model has yet been validated.

A validation shall be based on measurements over a period of at least five years for different products within the same product family. Based on these measurements, different mathematical models shall be evaluated by using measured values from periods of up to two years and comparing the extrapolation with the data obtained over a period of five years.

This annex provides a permissible extrapolation, with a maximum extrapolation up to 30 times the testing time.

To validate the characteristic form of a curve based on the mathematical model, it should be similar to that obtained by the measured values.

Even with an extrapolation up to 30 times the testing time, it is recommended that a safety factor should be applied for the determination of long-term allowable stress and the corresponding deformation.

A.2 Principle

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

$$X_t = X_0 + m \times t^b \qquad \text{(A.1)}$$

where m and b are material constants.

Formula (A.1) can be written in a logarithmic form, as follows:

$$\log (X_t - X_0) = \log m + b \times \log t \qquad \text{(A.2)}$$

Hence it follows that $\log m$ is the intercept of the coordinate and b is the slope of the straight line defined by this formula. These constants shall be calculated by a regression analysis based on the measured deformation as a function of time.

A.3 Procedure

A.3.1 Using the values for the thickness of the test specimens, d_s and d_L, and deformation values, X_0 and X_t, at the corresponding time, t, measured in accordance with this document, the terms log t, X_{ct}, log X_{ct} shall be calculated starting with the value read after seven days (=168 h).

This period of seven days may be reduced if the measured data show a linear behaviour in a log/log diagram corresponding to Formula (A.2).

A.3.2 For the linear regression analysis, the following statistical terms shall be determined.

General formula for the linear regression line:

$$y = a + b \times x \tag{A.3}$$

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

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

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

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

$$Q_{xy} = \sum x_t y_t - \left[\left(\sum x_t \right) \times \left(\sum y_t \right) / n \right] \tag{A.8}$$

$$s_R^2 = \left[Q_y - \left(Q_{xy}^2 / Q_x \right) \right] / (n-2) \tag{A.9}$$

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

$$r^2 = Q_{xy}^2 \; / \left(Q_x \times Q_y \right) \tag{A.11}$$

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

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

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

where

n is the number of values;

x_t is the time, log t;

y_t is the creep deformation, log X_{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 squares of deviations, referring to x values;

Q_y is the sum of squares of deviations, referring to y values;

Q_{xy} is the sum of the deviations;

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 of the ordinate;

b is the slope of the line;

y represents log $(X_t - X_0)$;

x represents log t:

A.4 Calculation of long-term deformation

By using Formula (A.1), with b from Formula (A.13), and by putting $m = 10^a$, a long-term deformation at any time, t, can be calculated. Extrapolation is permissible up to 30 times of the testing time, provided that $r^2 \geq 0{,}9$ (see example in Annex B).

Annex B
(informative)

Example of a linear regression analysis

Tables B.1 and B.2 provide the measured values for the deformation of three single test specimens for a single compressive stress. These are recorded after various time periods. In this example, the results are analysed using a linear regression technique, as described in Annex A to obtain the mean values of the test specimens.

The calculated statistical values are:

$x_m = 3{,}238\ 72$

$y_m = -0{,}868\ 83$

$Q_x = 7{,}770\ 76$

$Q_y = 0{,}277\ 14$

$Q_{xy} = 1{,}444\ 65$

$s_R^2 = 0{,}000\ 41$

$s_R = 0{,}020\ 20$

$r^2 = 0{,}969\ 08$ ($r^2 > 0{,}9$)

$r = 0{,}984\ 42$

$b = 0{,}185\ 91$

$a = -1{,}470\ 94$

Figure B.1 shows a straight-line regression analysis for the values of log X_{ct} versus log t, with $m = 0{,}033\ 81$ and $b = 0{,}185\ 91$.

For example, the long-term deformation value of the test specimens for 10 years (about 87 600 h), is to be calculated using Formula (A.1), with m and b as given above:

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

$X_{87\ 600} = 0{,}50$ mm