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Timber structures — Methods of test for evaluation of long-term performance — Part 1: Wood-based products in bending

Structures en bois — Méthodes d'essai pour l'évaluation du comportement à long terme — Partie 1: Produits à base de bois en flexion

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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 document 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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ISO 24322 was prepared by Technical Committee ISO/TC 165, *Timber structures*.

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.

Introduction

This document sets out a framework to establish the duration of load and creep characteristics of timber structural products from test results on a sample drawn from a clearly defined reference population.

It is the intention that the document can be used on any structural product including but not limited to: sawn timber, glulam, structural composite lumber, I-beams, wood-based panels, poles and round timber. Whenever it is used, the document alerts the user to the basic requirements for the determination of consistent characteristic values. It permits the characterisation of duration of load and creep behaviour based on testing of commercial sized specimens.

Timber structures — Methods of test for evaluation of long-term performance — Part 1: Wood-based products in bending

1 Scope

This document gives methods of determination of duration of load and creep factors under bending actions at ambient temperatures for a defined population of structural timber products such as solid timber, LVL, OSB, plywood, particleboard, I-beams calculated from test values.

It presents methods for

a) determining the duration of load and creep factors for new timber products,

b) establishing whether a previously defined set of duration of load and creep factors can be applied to a tested product, and

c) an optional method for establishment of sensitivity of duration of load and creep factors to changes in environmental conditions.

NOTE 1 This document is intended to apply to wood-based products for which a duration of load factor or a creep factor is used in design.

NOTE 2 The effect of elevated temperature on the duration of load factor and creep factor that is derived using these methods for use with timber products can need additional consideration.

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 12122-1, *Structural timber — Determination of Characteristic values — Part 1: Basic principles*

3 Terms and definitions

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

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

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

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

3.1
characteristic value
value of a property taken to represent the property of a designated population using a process of sampling

Note 1 to entry: The sampling is as determined in accordance with ISO 12122-1.

3.2
creep
time-dependent increase of deformation of the material under a sustained load

3.3
duration of load
cumulative total time during which a load acts on a member

3.4
linear creep
time-dependent increase of deformation, which is linearly related to the load level

Note 1 to entry: Linear creep usually applies with low load levels.

3.5
non-linear creep
time-dependent increase of deformation, which is non-linearly related to the load level

Note 1 to entry: Non-linear creep usually applies with high load levels.

3.6
service class
class assigned to a structure based on the climatic conditions

Note 1 to entry: The service class system is mainly aimed at assigning strength values and for calculating deformations under defined environmental conditions.

Note 2 to entry: The climatic conditions are according to EN 1995-1-1.

4 Symbols (and abbreviated terms)

Symbols defined in the relevant ISO product or test standard shall be used.

In addition, the following apply:

C_R	is the average creep recovery within 30 days of unloading
F	is the total force applied to the specimen
D_f	is the fractional deflection after 90 days
F_{max}	is the short term maximum load applied in a single short-term test, where the term is used in a long-term test, it refers to the maximum load applied in the matched short-term test.
N_{90}	number of specimen failures at the end of 90 days
N_c	critical order statistic used to estimate the lower 5 % non-parametric tolerance limit based on the number of specimens under long-term load
SC1	is service class 1
SC2	is service class 2
SC3	is service class 3
S_L	is the stress level of a loading (%)
t	is time after loading in a long-term test
t_f	is time to failure in a long-term test
$X_{0,05}$	is the 5 % point estimate of the capacity of a short-term test group
a	is a deflection reading in a creep test

a_0	is a deflection reading before a load is applied in a creep test
a_1	is a deflection reading 1 min after the application of a load in a creep test
a_t	is a deflection reading time, t, after the application of a load in a creep test
c	is the intercept on a plot of $\log_{10}t$ versus S_L to evaluate the duration of load factor
e	is the intercept of an S_L versus t plot (= c/m)
f	is the slope of an S_L versus t plot (= $1/m$)
f_b	is the minimum applied bending stress
h	is the depth of the specimen
$k_{d,t}$	is duration of load factor after time, t
l	is the test span in a bending test
l_1	is the span of the deflection measurement yoke used in shear-free creep tests
m	is the slope on a plot of $\log_{10}t$ versus S_L to evaluate the duration of load factor
w	is the deformation in millimetres
Δ_a	is the initial deflection measured 1 min after loading
Δ_{30}	is the deflection measured 30 days after loading
Δ_{60}	is the deflection measured 60 days after loading
Δ_{90}	is the deflection measured 90 days after loading
Δ_c	is the total creep deflection accumulated over the long-term load test
Δ_i	is initial deflection gauge reading prior to loading
Δ_e	is deflection gauge reading just prior to unloading
Δ_r	is the total creep deflection recovered within 30 days after unloading
Δ_b	is deflection gauge reading within 30 days after unloading

5 Reference population

The population to which the duration of load and creep factors apply shall be fully described. The description shall reference all of the attributes that may affect either the strength or stiffness and restrict the pieces to the grouping for which the characteristic value is required. These include but are not be limited to:

a) reference to the relevant product standard or manufacturing specification;

b) species or species grouping;

c) designation of grade of the product;

d) size or size range of the product;

e) moisture condition of the product at the commencement of the tests;

f) detail of any adhesives used in the product including method and time of curing;

g) treatment of the product; or

h) period in which the product was manufactured.

The reference population shall be a grouping from which it is possible to draw a representative sample, and on which it is possible to perform tests on specimens to characterize the required properties.

Where the reference population includes a range of products (e.g. different thicknesses), the population may be characterised by testing the extremes of the range. Where the results of the extremes are significantly different, some other tests may be required to determine the nature of the variation within the range.

6 Sampling

6.1 Sampling method

The sampling method shall aim to produce a sample that is representative of the variants in the defined reference population that may affect the tested properties. The sampling shall minimise selection bias, and shall be appropriate to the purpose of the tests and the nature of the reference population.

The matched short-term and long-term specimens shall be clearly identified and marked so that the same matched face is loaded in both long-term and short-term tests.

The sampling method shall be documented. The documentation shall include details of the steps taken to ensure that each of the variants listed in the population as described in Clause 5 is included in the representative sample.

6.2 Matched groups within a sample

Matched test representative groups are required for comparative short- and long-term tests.

Matching is a technique that attempts to subdivide the initial sample population into two or more separate groups that possess near identical distributional form and scale for bending properties. Matching specimens for the purposes of testing for this document should be done with care, considering errors introduced by the process and the characteristics of the material under test.

Where two matched groups are required, specimens shall be matched in pairs (each specimen shall be matched to another specimen and shall be marked to enable the pair of matched specimens to be identified.

Where three matched groups are required, specimens shall be matched in threes (each specimen shall be matched to two other specimens and shall be marked to enable the three matched specimens to be identified.

The method of obtaining matched samples shall be documented.

The following methods of matching groups of specimens may be used:

a) Side matching for products with sufficient widths (e.g. panels, SCL)

b) End matching for width limited products (e.g. I-joists)

c) MOE matching for width and length limited products (e.g. solid timber)

6.3 Sample size

The sample shall be large enough to cover variants of the product that impact on the tested properties, and give statistical significance to the result.

Minimum sample sizes for short-term and long-duration tests are detailed in Clauses 9 and 10.

Materials with larger assumed or assigned population coefficient of variation, C_V, of the tested properties, should have a larger sample size.

Some product standards can define a minimum number of tests that shall be undertaken to determine characteristic values to be used with described products.

NOTE Annex A gives some guidance on selecting sample size.

For some populations, a number of different sub-groups within the population may need to be sampled (e.g. different cross-sectional sizes). In these cases, the size of each of the sub-groups can have to be sufficient to allow meaningful pooling of the results as indicated in Annex A.

Where characteristic values are to support limit states (or LRFD) design, the sample size should be appropriate for the statistical method selected to determine the 5th percentile value strength (full distribution or tail-fit). However, where the data is used to support a full reliability design method, the sample size should be appropriate to also enable the full statistical distribution of the property to be defined.

7 Sample conditioning prior to testing

Test specimens shall be conditioned prior to testing. The conditioning shall target moisture content that is compatible with the definition of the population and with the moisture conditions at the commencement of the long-duration tests specified in Clauses 9 and 10.

The test laboratory shall normally be maintained at the controlled environment, but when other conditions apply, they shall be reported.

8 Bending tests

8.1 Test method

8.1.1 General

Subject to the requirements of 8.1.2 to 8.1.4, the test data shall be derived in accordance with an appropriate test method for the properties and for the reference population.

For tests on some product types, discrimination of results on the basis of failure mode can be required to ensure that the results are compatible with objectives of the test program and the property being determined.

Test methods involve many variables that may affect results including loading configuration and rates, specimen positioning and measurement methods. The selection of these variables shall be appropriate to the objectives of the testing and may require some adjustments specified in 8.2.

8.1.2 Load location on specimens

The load locations on the bending test specimens shall be at random locations.

There should be no attempt to bias the test location.

NOTE A test at mid position of each specimen can be regarded as random position tests.

8.1.3 Load configuration

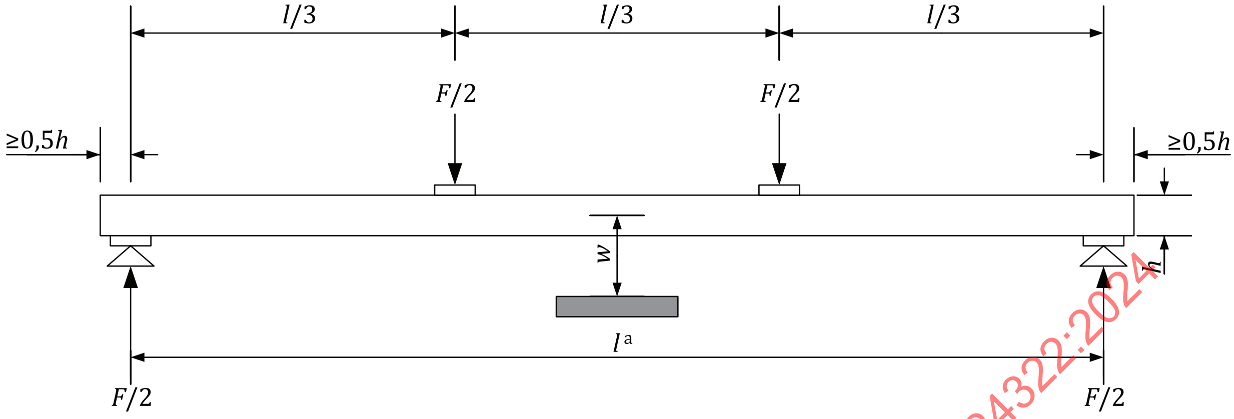
Tests shall be conducted using load points at 1/3 of the span as shown in Figure 1. Lateral restraints shall be used when necessary to maintain lateral stability.

Test specimens shall be cut to length as shown in Figure 1. The test spans shall be appropriate for the materials tested:

a) for members loaded in major axis bending (edgewise) the span is generally in the range 18 to 25 times the depth (h),

b) for members loaded in minor axis bending (flatwise) the span shall be less than 48 times the depth (*h*) and the specimen width shall not be less than 300 mm.,

The same span load positions and deformation measurement point and system shall be used for both short-term and long-term tests.



Key

l[a] Test span.

Figure 1 — Four-point bending test setup with apparent bending deflection measurement

Plates over supports to shall be of sufficient size to reduce crushing under a load of 0,5 of the average maximum load to less than 0,5 % of the central deflection. (This aims to reduce overestimation of the deflection measurements due to crushing under the loads and over the reactions.)

NOTE The expected length of bearing to satisfy this condition will be close to the depth of the member under test. During the first static test, the deformation over the supports can be measured to verify that the condition has been met.

8.1.4 Deformation measurements

The deformation measurement device shall have a resolution of 0,025 mm or 0,5 % of the deformation reading near the end of the linear response, whichever is greater.

8.1.5 Reporting failure results

The results of a bending test shall be reported as the maximum load attained by the specimen.

8.2 Short-term tests

8.2.1 Loading rate

The loading rate used in short-term tests shall target failure in approximately 1 min. Failure load shall not be reached in less than 10 s nor more than 10 min.

NOTE A loading rate of 0,003 × nominal thickness in mm/s is suitable for the testing.

8.2.2 Reporting

The results of each test shall include:

a) maximum load at failure;

b) moisture content of specimen;

c) orientation of the specimen;

d) time to failure.

8.2.3 Reference loads

The results of the short-term load tests give the reference load used to calculate the load levels to be used in the long-term tests:

— For long-term tests in accordance with Clause 9, the reference load is the average of the maximum loads from all of the short-term test specimens.

— For long-term tests in accordance with Clause 10, the reference load is the lower 5 % of the maximum loads from all of the short-term test specimens

8.3 Long-term tests

8.3.1 Loading levels

Loading levels shall be as specified in Clauses 9 and 10.

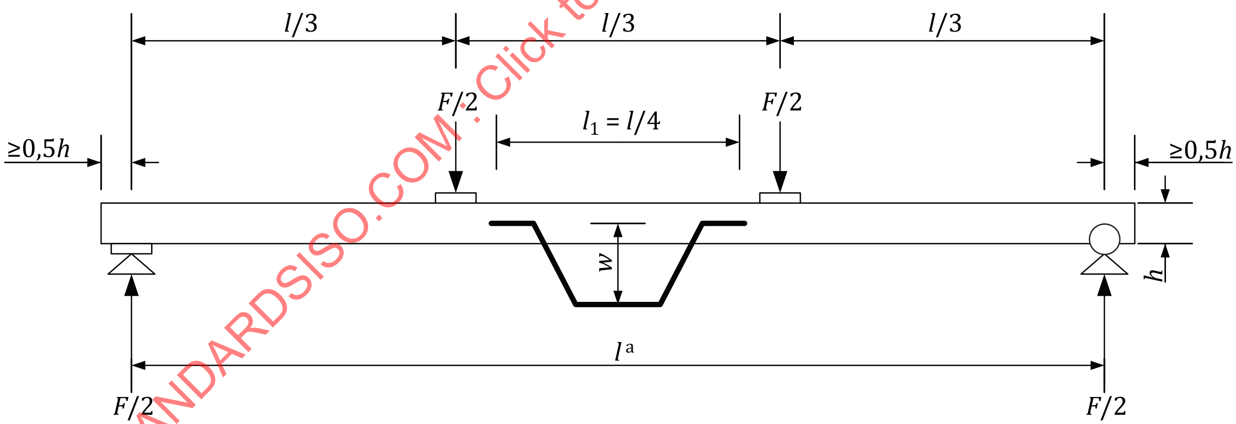
8.3.2 Initial loading rate

Long-term load shall be gradually applied so that the period of loading is no longer than 1 min.

8.3.3 Deformation measurements

Where deformations are measured in conjunction with long-term deflection models, the mid-span deflections shall be measured with reference to the supports along the same longitudinal line along the member, as shown in Figure 1.

If a shear-free creep is required, then it is possible to also measure shear-free deflection, as shown in Figure 2.



Key

l^a Test span.

Figure 2 — Four-point bending test setup with true bending (shear-free) deflection measurement

9 Evaluating new duration of load and creep factors

9.1 General

The procedure described in Clause 9 is based on the test method given in EN 1156. Its purpose is to evaluate duration of load factors k_d or creep factors k_c from bending tests.

Where testing is undertaken to evaluate the sensitivity of the product to changes in environmental conditions, the tests presented in Annex B should be compared with those conducted using Clause 9 in a SC1 environment.

9.2 Sampling

9.2.1 Service class

The minimum sample size specified in 9.2.2 is for a single service class. The service class or classes to be tested are chosen as the most appropriate considering the end-use of the material.

9.2.2 Sample size

The minimum sample size is given in Table 1.

Table 1 — minimum sample size for evaluating duration of load or creep effects

Test cases	For duration of load tests only	For creep tests only	For both creep and duration of load tests
Single service class, Linear creep expected	2 matched groups, each of 60 specimens (60 specimens short-term test and 60 specimens for DOL test)	2 matched groups, each of 10 specimens (10 specimens for short-term test and 10 specimens for creep test)	Two matched groups, each of 70 specimens. Altogether 140 specimens
Single service class, Non-linear creep expected	2 matched groups, each of 60 specimens (60 specimens short-term test and 60 specimens for DOL test)	3 matched groups, each of 10 specimens (10 specimens for short-term test and 10 specimens for creep test at load level 1 and 10 specimens for creep test at load level 2)	Two matched groups, each of 70 specimens and three matched groups, each of 10 specimens. Altogether 150 specimens
Single service class, and sensitivity with environmental change	3 matched groups, each of 60 specimens (60 specimens for short-term test, 60 specimens for DOL tested at constant humidity and 60 specimens tested at cyclic humidity)	3 matched groups, each of 10 specimens (10 specimens for short-term test, 10 specimens for creep test at constant humidity and 10 specimens tested at cyclic humidity)	Three matched groups, each of 70 specimens. Altogether 210 specimens

9.3 Specimen conditioning

The specimens shall be conditioned to the environment appropriate to the service class for the test:

a) SC1 – 20 °C and 65 % RH;

b) SC2 – 20 °C and 85 % RH;

c) SC3 – 20 °C and 95 % RH.

The reference condition is SC1 and if required, additional tests can be performed to evaluate performance for SC2 and SC3 conditioning.

9.4 Tests

9.4.1 General considerations for short-term tests

The short-term tests specified in Table 1 shall be conducted in accordance with 8.1 and 8.2. F_{max} shall be recorded as the maximum load attained by each individual specimen.

9.4.2 General considerations for the long-term tests

It is assumed that the material creep performance is linear with respect to the load. If there is doubt about this assumption, then creep tests shall be carried out at more than one stress level and this will require 10 additional test specimen for each additional stress level.

Place the second of the two matched test pieces on a creep test (or duration of load test) arrangement with the same surface in compression as in the short-term static bending test.

Ensure that the climatic conditions are identical to those prevailing during the short-term bending test. The climatic conditions during test shall be monitored continuously.

Add the load taking note of the starting time, t_0, and take care to avoid too rapid loading, especially at high stress levels. Immediately after loading, record the time of starting to the nearest minute.

9.4.3 Long-term duration of load tests

For the determination of duration of load factors, carry out a series of tests with loads corresponding to the values in Table 2. At least four stress levels shall be selected and the stress levels shall be determined so that the test results are adequate to appropriately evaluate the duration of load factor. At each stress level, carry out 10 tests. From the seventy or more test pieces, select each set of ten test pieces such that as far as possible, each test piece within a set comes from a different production site or production period. For all tests, record the time to failure in minutes expressed to the nearest 1 % of the elapsed time, t_f. The tests shall continue until at least 5 test pieces at each stress level have failed.

Table 2 — Stress levels for long-term duration of load tests

Service class	Percentage of short term max load F_{max} for each group of 10 specimens					
SC1 (20 °C and 65 %RH)	55 %	60 %	65 %	70 %	75 %	80 %
SC2 (20 °C and 85 %RH) SC3 (20 °C and 95 %RH)	50 %	55 %	60 %	65 %	70 %	75 %

9.4.4 Long-term creep tests

For the determination of creep factors, carry out a second series of tests at a single stress level. Where it is desired to carry out this determination of creep factor concurrently with the duration of load factor, a load corresponding to 25 % of F_{max}, as determined in accordance with 8.2.3, may be used. Alternatively, the load applied may correspond to the actual working load levels in practice. The applied load shall be the percentage of the average maximum load (stress level) of the matched short-term test results of 10 specimen.

The use of a single load level for the calculation of creep factor underlines the assumption that the material is linear viscoelastic up to levels applied. If there is doubt about the validity of this assumption for new materials or for higher levels of relative humidity for example, additional series of creep tests shall be carried out over a range of stress levels between 10 % and 40 % of F_{max}.

Carry out the seventy tests and additional 10 tests if more stress levels is necessary. Prior to loading the test piece, place the deflection measuring instrument in place. Record the reading as "zero" deflection, a_0, to the nearest 0,01 mm for whichever method of measuring is used. Apply the test load and record the deflection at midspan at 1 min after loading (a_1) to the nearest 0,1 mm for whichever method of measurement is used. For all tests, record the deflection, a_t, as a function of time, t.

NOTE It is recommended that deflections are measured according to the schedule presented in Table 3.

Deflection shall be recorded to the nearest 0,1 mm. The duration of the creep factor test shall be at least 26 weeks and preferably 52 weeks. The duration of the loading period should be decided on prior to the start of testing.

Table 3 — Recommended deflection measurement schedule for creep tests

Event	Time of measurement h:min
No load deformation immediately prior to loading	0:00
After loading is complete	0:01
	0:05
	0:10
	0:50
	1:40
	8:20
One day after loading	24:00
Each day after loading, ...	48:00, ...

9.5 Evaluation of test results

9.5.1 Duration of load factor

The duration of load factor at a given time is defined as the ratio of the stress level that results in failure at that time, to the short-term bending strength.

The duration of load factor k_d shall be determined by plotting the level of stress against $\log_{10}$ time to failure. The mean time to failure is calculated at each stress level for those test specimens which have failed. The test results of the test specimens which have not failed shall also be included in calculating the average time to failure. In this case, the time to failure of those test specimens is the duration of time of those test specimens from the beginning of loading to the end of the test. Calculate the linear regression line taking stress level as the independent variable, to provide Formula (1) of the form:

$$\log_{10} t = c - m S_L \quad (1)$$

where

c is the intercept on the vertical axis;

m is the slope;

S_L is the stress level, in percent;

t is the time to failure, in minutes ($t_f - t_0$).

Formula (1) is then rearranged to give the form:

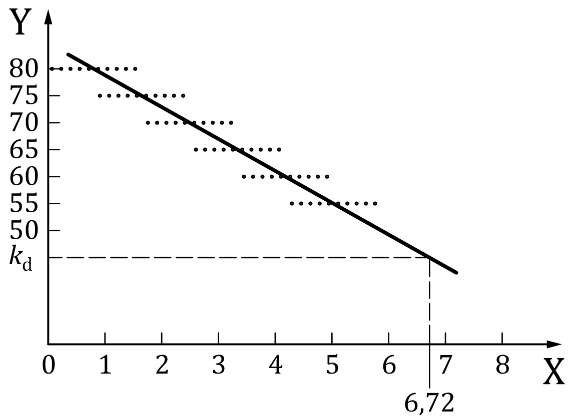
$$S_L = e - f \log_{10} t = k_{d,t} \quad (2)$$

where

$e = c/m$

$f = l/m$

The extrapolated stress level for a particular life is then calculated using Formula (2) and expressed to three significant figures. An example for a 10-year life ($\log_{10} t = 6{,}72$) is illustrated in Figure 3.



Key

X mean time to failure in $\log_{10}$ min

Y stress level in percent

Figure 3 — Determination of duration of load factor, $k_{d,t}$, from test results

The symbol k_d is related to the time of loading and service class to which it applies. An example of a predicted k_d value at 10 years calculated from duration of load testing carried out under SC1 conditions is as follows:

$$k_{d,10Y,SC1}$$

For separate tests that are performed in the major axis and minor axis bending, separate load duration factors are also to be calculated.

9.5.2 Creep factor

The creep factor is defined as the ratio of the increase in deflection with time under load to the initial elastic deflection: The value of the creep factor will therefore change with time under load, level of stressing (if not in the linear range), and climate. It is dimensionless and a relative measure. Hence the creep factor, k_c for a certain period of time, *t*, is given by:

$$k_c = \frac{a_t - a_1}{(a_1 - a_0)} \tag{3}$$

where

a_t is the total deflection, in millimetres at time, *t*, min;

a_1 is the deflection measure in, millimetres after 1 min of loading;

a_0 is the deflection measure, in millimetres of unloaded test specimen positioned in the creep test arrangement;

$a_1 - a_0$ is the initial elastic deflection, in millimetres as measured after 1 min of load application.

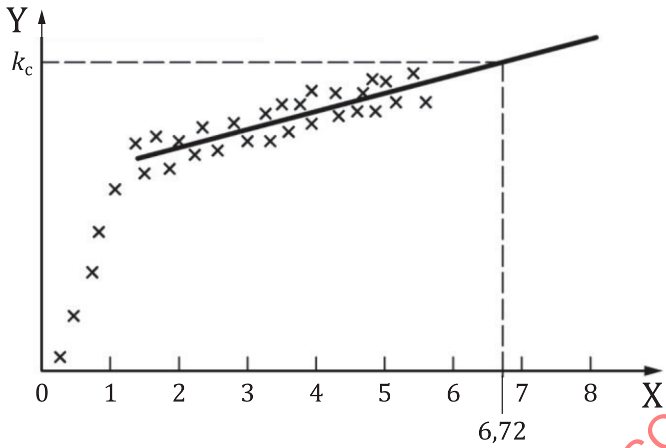
The creep factor k_c is relative to the time of loading, service class to which it applies, as well as the level of stress used in its determination. An example of a predicted k_c value at 10 years calculated from creep testing carried out under SC1 conditions and at a stress level of 25 % is as follows:

$$k_{c,10Y,SC1,25\,\%}$$

To determine for any one stress level the value of the creep factor at ten years, first calculate the mean value of k_c for the ten test specimens at different periods of time during the loading. Plot the $\log_{10}$ of the mean value of k_c against $\log_{10}$ time in minutes under load for each time period as illustrated in Figure 4.

To determine an estimate of k_c for the given load time, take the regression line through the measured points, but excluding those below 10 min of loading. Then project to a time period corresponding to the time span required. As an example, the derivation of k_c at 10 years is illustrated in Figure 4.

Where the regression coefficient calculated on the data for loading times longer than 10 min, is not above 0,9, alternative mathematical models should be used to predict long-term deflection.



Key

X time under load in $\log_{10}$ min

Y $\log_{10}$ of creep factor

Figure 4 — Determination of creep factor k_c at 10 years from test results [Figure copied from EN 1156]

Where separate tests have been performed in both longitudinal and transverse directions, separate values of the creep factor shall be determined.

10 Confirmation of duration of load and creep factors

10.1 General

Clause 10 uses test results to confirm whether the duration of load and creep factors for a tested wood-based product match solid timber models for long-term strength and deformation. The procedure described in this clause is based on the test method given in ASTM D6815 standard specification for evaluation of duration of load and creep effects of wood and wood-based products.

NOTE Some appropriate products for these tests are defined in ISO 12465, ISO 16894, and ISO 22390.

10.2 Sampling

A population of test materials shall be randomly sampled from representative production of the product under evaluation. A sample consisting of at least 28 pairs of matched specimens (see 6.2) of the same cross-sectional dimension shall be prepared into two groups, one for short-term bending tests, and the other for long-term creep-rupture bending tests.

Additional sets of test specimens should be considered from the initial sampling if further testing is contemplated.

10.3 Tests required

10.3.1 Short-term bending tests

Short-term bending tests shall be conducted in accordance with 8.2 unless specifically noted otherwise. Loads shall be applied in the product orientation that represents the intended use of the product.

For joist-form materials, the span to depth ratio shall be as specified in applicable test standards. The minimum test specimen cross section shall be 60 mm in depth and 25 mm in width.

NOTE For solid timber sized products, span to depth ratios typically used for flexural tests range between 17 and 21.

For sheathing-form materials, the test span shall be not less than 48 times specimen thickness or 600 mm, whichever is greater.

Moisture content shall be measured immediately after destructive testing. Measurement of moisture content shall be in accordance with ISO 3130.

The sample standard deviation and the lower five percent point estimate of the short-term test group (5 % PE) shall be determined in accordance with ISO 12122-1 ($X_{0,05}$).

10.3.2 Long-duration bending tests

The test setup for creep-rupture bending tests shall be the same as short-term bending tests prescribed in 10.3.1.

After loading, the specimens shall be subjected to the constant stress, as determined in accordance with Formula (6) for a minimum period of 90 days. During this period, mid-span deflection readings shall be taken for each test specimen in accordance with Figure 1, until the 90-day time period has elapsed or until the occurrence of a failure. At a minimum, the deflection readings shall be taken at approximately 1 min after the application of the constant load (initial deflection), and at the end of 1 h, day 1, day 7, day 14, day 30, day 60, and day 90. When better characterization of the creep rate is desired, more frequent deflection measurements shall be taken. Additional deflection readings are required when the test extends beyond 90 days. When a specimen failure occurs, time-to-failure shall be recorded.

Moisture content of the long-term specimens shall be measured at the termination of the long-term test. Measurement of moisture content shall be in accordance with ISO 3130. The average moisture content of all the long-term test specimens shall not deviate more than ±2 % from the average moisture content of all short-term test specimens.

NOTE Conditioning the short-term and long-term test material for at least 30 days in the anticipated test environment conditions generally provides conformity with the ±2 % moisture content change.

The test environment temperature and relative humidity shall be recorded daily. The daily average temperature of the test environment shall meet the following requirements:

a) not decrease more than 5 °C below the temperature at which the short-term tests were conducted, and

b) at no time shall the test environment reach a temperature less than 0 °C.

NOTE In experiments where the temperature falls below the limit prescribed in a) above, it can be possible to demonstrate the validity of the data by continuing the experiment for an additional time period at least equal to the amount of time the temperature was below the prescribed limit.

The specimens selected for these tests shall be tested at a constant stress level, f_b, as determined in accordance with Formula (6).

$$f_b = 0{,}55 \times (5\,\%\,\text{PE}) \tag{6}$$

where

f_b minimum applied bending stress;

5 % PE the lower five percent point estimate, as determined from the short-term bending tests in 10.3.1.

The creep rate, fractional deflection, D_f, and the total number of failures at 90 days (N_{90}) or greater shall be used to evaluate the acceptance of the product.

10.4 Acceptance criteria

The product is considered acceptable for using the duration of load and creep factors applicable to solid timber if the following three criteria are all satisfied:

a) adequate strength over the test duration,

b) decreasing creep rate, and

c) a limited fractional deflection.

10.4.1 Adequate strength

The total number of failures at 90 or more days shall be less than the critical order statistic, N_c, of the lower 5 % non-parametric tolerance limit with 75 % confidence, as shown in Formula (7).

$$N_{90} < N_c \tag{7}$$

where:

N_{90} number of specimen failures at the end of the 90-day test period;

N_c critical order statistic used to estimate the lower 5 % non-parametric tolerance limit based on the number of specimens under long-term load.

For example, if 53 specimens are used in the creep-rupture tests, $N_c = 2$ and no more than one specimen shall fail within the 90-day period ($N_{90} \leq 1$) for the product to be accepted as meeting the adequate strength criterion. Alternatively, if 28 specimens are tested, $N_c = 1$, and no failures shall occur ($N_{90} = 0$). If the requirement of this Clause is not met and the number of failures at 90 days is greater than or equal to the critical order statistic ($N_{90} \geq N_c$), the product under evaluation fails to meet the adequate strength criterion.

If the number of failures at 90 days is equal to the critical order statistic ($N_{90} = N_c$) defined in this Clause, additional testing may be conducted. In this case the sample population shall be increased by sampling an additional set of matched specimens in accordance with 10.2 sufficient to allow the use of a higher non-parametric order statistic. The additional specimens shall be tested for another 90-day test duration. The adequate strength requirement of this Clause is met when, at the end of the additional testing, the combined number of specimen failures during these two test series (N_{90} combined) is less than the critical order statistic (N_c combined) based on the combined number of specimens evaluated (N combined).

NOTE From ISO 12122-1, the order statistic for the lower 5 % tolerance limit with 75 % confidence, N_c, for various sample populations, N, is as follows:

N	28	53	78	102
N_c	1	2	3	4

10.4.2 Decreasing creep rate

10.4.2.1 All specimens that do not fail during the 90 days constant load time period shall show a decreasing creep rate. To determine a decreasing creep rate, the change in creep deflection shall be calculated between a minimum of three equally spaced time segments. The change in calculated creep deflection shall progressively decrease for each specimen. For the three equal time periods of 0 to 30 days, 30 to 60 days, and 60 to 90 days, the decreasing creep rate can be expressed in Formula (8):

$$\Delta_{30} - \Delta_{a} > \Delta_{60} - \Delta_{30} > \Delta_{90} - \Delta_{60} \tag{8}$$

where

Δ_a initial deflection (measured 1 min after application of the load in accordance with 10.3.2);

Δ_{30}, Δ_{60}, Δ_{90} deflections measured on 30th, 60th, and 90th day, respectively.

NOTE To better define the creep rate, additional segments with a shorter frequency (for example six 15-day segments) can be used.

If the creep rate for a given specimen is not decreasing at the end of the 90-day period, the time period shall be extended for a minimum of 30 additional days. The change in calculated creep rate for the additional time segment(s) after 90 days shall progressively decrease relative to the preceding segment.

NOTE The creep rate may fluctuate due to environmental changes in relative humidity or temperature, or both. Extending the test beyond the 90-day period in a controlled environment may demonstrate that the products were not exhibiting tertiary behaviour at the end of the time period.

10.4.3 Fractional deflection, D_f

Fractional deflection after ninety (90) days for each surviving specimen shall not be greater than 2,0, as shown in Formula (9).

$$D_f = \frac{\Delta_{90}}{\Delta_a} \leq 2{,}0 \tag{9}$$

where

Δ_a initial deflection (measured 1 min after application of the load in accordance with 10.3.2), and

Δ_{90} deflection measured on 90th day.

10.5 Retest option

If a product fails to meet the strength criterion of 10.4.1, the product shall not be allowed to use the duration of load or creep adjustments for solid timber. A retest at any stress level lower than that specified in Formula (6) is not permitted to satisfy the strength criterion of 10.4.1.

If a product satisfies the strength criterion of 10.4.1 in the original test at the stress level specified in Formula (6), but fails to meet either or both of the deflection-based criteria of 10.4.2 and 10.4.3, the product proponent shall be allowed to conduct a retest at a reduced stress level. The reduced stress level shall be defined by the user. The user shall be permitted to repeat this procedure until the acceptance criteria of 10.6 are satisfied. However, if a product fails to meet the strength criterion of 10.4.1 during any retest at a stress level less than that specified in Formula (6), the product is not allowed to use the duration of load or creep adjustments for solid timber and no further retesting shall be permitted.

10.6 Acceptance criteria for retest at lower stress level

The acceptance criteria for the retest(s) shall include the three acceptance criteria from 10.4 and the additional requirements specified in this clause.

10.6.1 Average fractional deflection

The average fractional deflection after 90 days shall be less than or equal to 1,6.

10.6.2 Average creep-recovery

The average creep recovery within 30 days of unloading shall be greater than or equal to twenty percent (20 %), as shown in Formula (10).

$$C_R = \frac{\Delta_r}{\Delta_c} = 1 - \frac{(\Delta_b - \Delta_i)}{(\Delta_e - \Delta_a)} \geq 0{,}20 \quad (10)$$

where:

C_R	creep-recovery, unit-less;
Δ_r	the total creep deflection recovered within 30 days after unloading, mm;
Δ_c	the total creep deflection accumulated over the long-term load test, mm;
Δ_a	deflection gauge reading after 1 min of loading, mm,
Δ_i	initial deflection gauge reading prior to loading, mm;
Δ_e	deflection gauge reading just prior to unloading, mm;
Δ_b	deflection gauge reading within 30 days after unloading, mm.

10.6.3 Average residual strength and stiffness

The specimens from the long-term loading retest shall be tested in short-term bending in accordance with 10.3.1. The average residual strength and stiffness of the test specimens shall be greater than or equal to ninety percent (90 %) of that measured in the short-term bending tests.

NOTE The selection of the reduced stress level is defined by the user, and is a careful selection with the desire to assure that the product can meet all six acceptance criteria (see 10.4.1, 10.4.2, 10.4.3, 10.6.1, 10.6.2, and 10.6.3).

10.7 Interpretation of retests

If the retest proves that the product meets all the acceptance criteria defined in 10.4 and 10.6 as applicable, all time-dependent member and connection properties shall be reduced by the percent change in stress level used in the retest(s).

11 Test report

As a minimum, the report shall include the following information:

a) a reference to this document, i.e. ISO 24322:2024.

b) Description of the reference population, including species, grade (or grade combination), specimen geometry, and grain orientation, moisture content and other specific process parameters involved in its manufacture.

c) Description of the sampling and matching protocol used.

d) Descriptions of the test equipment, test methodology, reference to material test standards used.

e) Description and frequency of calibration procedures.

f) Records of test environmental conditions for short-term and long-term tests.