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**Timber structures — Determination  
of characteristic values —**

**Part 6:  
Large components and assemblies**

*Structures en bois — Détermination des valeurs caractéristiques —  
Partie 6: Composants assemblés*

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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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](http://www.iso.org/directives)).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on 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 the following URL: [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

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

A list of all parts in the ISO 12122 series can be found on the ISO website.

## Introduction

This document sets out a framework for establishing characteristic values from test results on a sample drawn from a clearly defined reference population of large components and assemblies. The characteristic value is an estimate of the property of the reference population with a consistent level of confidence prescribed in the standard.

This document is to be used in conjunction with ISO 12122-1.

Since this document is dedicated to large components and assemblies, it has to deal with a specific statistical issue, namely that the characteristic values are to be derived from a very small number of test results.

In some cases, characteristic values determined in accordance with this document may be modified to become a design value.

[Annex A](#) presents a commentary on the provisions in this document.

[Annex B](#) presents examples of the use of the statistical methods.

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# Timber structures — Determination of characteristic values —

## Part 6: Large components and assemblies

### 1 Scope

This document specifies methods of determination of characteristic values for a defined population of large components and assemblies, calculated from test values.

It establishes two methods for the determination of characteristic values:

- a) direct calculation from test values;
- b) calculation from a resistance model, which is firstly calibrated from test results, including calculation of error terms.

### 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, *Timber structures — Determination of characteristic values — Part 1: Basic requirements*

### 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:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

#### 3.1

##### large components and assemblies

parts of a timber structure consisted of at least two members, assembled together by connections

### 4 Symbols

$E(.)$	mean value of $(.)$
$Var(.)$	variance of $(.)$
$V$	coefficient of variation [ $V = (\text{standard deviation})/(\text{mean value})$ ]
$V_X$	coefficient of variation of $X$
$V_\delta$	estimator for the coefficient of variation of the error term $\delta$

$\underline{X}$	array of $j$ basic variables $X_1 \dots X_j$
$\underline{X}_m$	array of mean values of the basic variables
$\underline{X}_n$	array of nominal values of the basic variables
$g_{rt}(\underline{X})$	resistance function (of the basic variables $X$ ) used as the resistance model
$k_n$	characteristic fractile factor
$m_X$	mean of the $n$ sample results
$n$	number of experiments or numerical test results
$r$	resistance value
$r_e$	experimental resistance value
$r_{ee}$	extreme (maximum or minimum) value of the experimental resistance [i.e. value of $r_e$ that deviates most from the mean value $r_{em}$ ]
$r_{ei}$	experimental resistance for specimen $i$
$r_{em}$	mean value of the experimental resistance
$r_k$	characteristic value of the resistance
$r_m$	resistance value calculated using the mean values $\underline{X}_m$ of the basic variables
$r_n$	nominal value of the resistance
$r_t$	theoretical resistance determined from the resistance function $g_{rt}(\underline{X})$
$r_{ti}$	theoretical resistance determined using the measured parameters $\underline{X}$ for specimen $i$
$s$	estimated value of the standard deviation $\sigma$
$s_\delta$	estimated value of $\sigma_\delta$
$\delta$	error term
$\delta_i$	observed error term for test specimen $i$ obtained from a comparison of the experimental resistance $r_{ei}$ and the mean value corrected theoretical resistance $br_{ti}$
$\eta_k$	reduction factor applicable in the case of prior knowledge
$\sigma$	standard deviation $\left[ \sigma = \sqrt{\text{variance}} \right]$

## 5 Reference population

### 5.1 General

The reference population is the population of large components or assemblies that the test program is designed to represent. Prior to the carrying out of tests, a test plan shall be documented. It shall contain the objectives of the test and all specifications necessary for the selection or production of the

test specimens, the execution of the tests and the test evaluation. The test plan shall cover the following details of the reference population, including structural context for the loading of the specimens:

- objectives and scope;
- prediction of test results;
- specification of test specimens and sampling;
- description of expected restraint and boundary conditions in normal service;
- loading specifications;
- testing arrangement;
- measurements;
- evaluation and reporting of the tests.

The objective of the tests shall be clearly stated, e.g. the required properties, the influence of certain design parameters varied during the test and the range of validity. Limitations of the test and required conversions (e.g. scaling effects) shall be specified.

## 5.2 Prediction of test results

All properties and circumstances that can influence the prediction of test results should be taken into account, including:

- geometrical parameters and their variability;
- geometrical imperfections;
- material properties;
- parameters influenced by fabrication and execution procedures;
- scale effects of environmental conditions taking into account, if relevant, any sequencing.

The expected modes of failure and/or calculation models, together with the corresponding variables, should be described. If there is a significant doubt about which failure modes can be critical, then the test plan should be developed on the basis of accompanying pilot tests.

Attention shall be given to the fact that a structural assembly can possess a number of fundamentally different failure modes.

## 6 Sampling

Test specimens shall be constructed, or obtained by sampling, in such a way as to represent the conditions of the real structure.

Factors that shall be taken into account include:

- dimensions and tolerances;
- material and fabrication of prototypes;
- number of test specimens;
- sampling procedures;
- restraints.

The objective of the sampling procedure is to obtain a statistically representative sample.

Attention should be drawn to any difference between the test specimens and the product population that could influence the test results.

## 7 Sample conditioning

Test samples shall be conditioned to represent the reference population as detailed in ISO 12122-1.

## 8 Test data

### 8.1 Loading specifications

The loading and environmental conditions to be specified for the test shall include:

- loading points;
- expected loading time history;
- restraints;
- temperatures;
- relative humidity;
- loading by deformation or force control, etc.

Load sequencing shall be selected to represent the anticipated use of the structural assembly, under both normal and severe conditions of use. Interactions between the structural response and the apparatus used to apply the load shall be taken into account where relevant.

Where structural behaviour depends upon the effects of one or more actions that will not be varied systematically, then those effects shall be specified by their representative values.

### 8.2 Testing arrangement

The test equipment shall be relevant for the type of tests and the expected range of measurements. Special attention shall be given to measures to obtain sufficient strength and stiffness of the loading and supporting rigs, and clearance for deflections, etc.

### 8.3 Test measurements

Prior to the testing, all relevant properties to be measured for each individual test specimen shall be listed.

## 9 Evaluation of characteristic values for structural properties

### 9.1 General principles

Two methods are described in this document:

- direct evaluation of characteristic values from test results (see [9.2](#));
- evaluation of characteristic values from a model including error calculation (see [9.3](#)).

NOTE 1 Both methods are acceptable, but if there are less than 10 test results, the second method is preferred, since the first method can lead to conservative characteristic values with a low number of test results.

When evaluating test results, the behaviour of test specimens and failure modes should be compared with theoretical predictions. When significant deviations from the predicted behaviour occur, an

explanation shall be sought: this might involve additional testing, perhaps under different conditions, or modification of the theoretical model.

The result of a test evaluation shall be considered valid only for the specifications and load characteristics considered in the tests. If the results are to be extrapolated to cover other design parameters and loading, additional information from previous tests or from theoretical bases shall be used.

The derivation of a characteristic value from tests (see 9.2) should take into account:

- a) the scatter of test data;
- b) statistical uncertainty associated with the number of tests;
- c) prior statistical knowledge.

NOTE 2 [Annex A](#) gives additional explanation about variability of test results.

If the response of large components or assemblies depends on influences not sufficiently covered by the tests such as

- time and duration effects,
- scale and size effects,
- different environmental, loading and boundary conditions, and
- resistance effects,

then a behaviour model shall be derived and shall take such influences into account as appropriate (see 9.3).

## 9.2 Direct evaluation of characteristic value

### 9.2.1 Sampling factor $k_n$

A sampling factor is used in the evaluation of characteristic value detailed in both 9.2 and 9.3. The values for this factor shall be drawn from [Table 1](#).

When using the direct evaluation of the characteristic value from the test results, the 5 percentile value of a property,  $X$ , shall be found by using either a normal distribution fitted through the test data as indicated in 9.2.1 or a log-normal distribution fitted through the test data as indicated in 9.2.2.

**Table 1 — Values of  $k_n$  for the 5 % characteristic value**

$n$	1	2	3	4	5	6	8	10	20	30	$\infty$
$V_X$ known	2,31	2,01	1,89	1,83	1,80	1,77	1,74	1,72	1,68	1,67	1,64
$V_X$ unknown	—	—	3,37	2,63	2,33	2,18	2,00	1,92	1,76	1,73	1,64

### 9.2.2 Normal distribution

The characteristic value shall be calculated using [Formula \(1\)](#).

$$X_k = m_X \{1 - k_n V_X\} \quad (1)$$

The value of  $k_n$  shall be obtained from [Table 1](#) using either of the following two cases:

- The row “ $V_X$  known” shall be used if the coefficient of variation of the structural property of the reference population,  $V_X$ , or a realistic upper bound of it, is known from prior knowledge.

- The row “ $V_X$  unknown” shall be used if the coefficient of variation  $V_X$  is not known from prior knowledge and so, needs to be estimated from the sample using [Formulae \(2\)](#) and [\(3\)](#):

$$s_X = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (x_i - m_X)^2} \tag{2}$$

$$V_X = \frac{s_X}{m_X} \tag{3}$$

**9.2.3 Log-normal distribution**

The characteristic value shall be calculated using [Formulae \(4\)](#) and [\(5\)](#).

$$X_k = \exp[m_Y - k_n s_Y] \tag{4}$$

where:

$$m_Y = \frac{1}{n} \sum_i \ln(x_i) \tag{5}$$

The value of  $k_n$  shall be obtained from [Table 1](#) using either of the following two cases:

- The row “ $V_X$  known” shall be used if the coefficient of variation of the structural property of the reference population,  $V_X$ , or a realistic upper bound of it, is known from prior knowledge with  $s_Y$  as given in [Formula \(6\)](#).

$$s_Y = \sqrt{\ln(V_X^2 + 1)} \approx V_X \tag{6}$$

- The row “ $V_X$  unknown” shall be used if the coefficient of variation  $V_X$  is not known from prior knowledge and so  $s_Y$  is estimated from the sample as given in [Formula \(7\)](#).

$$s_Y = \sqrt{\frac{1}{n-1} \sum_i (\ln x_i - m_Y)^2} \tag{7}$$

**9.3 Statistical determination of resistance models**

In [9.3](#), the procedures (methods) for calibrating resistance models and for deriving characteristic values from tests are defined. Use will be made of available prior information (knowledge or assumptions).

Based on the observation of actual behaviour in tests and on theoretical considerations, a “resistance model” shall be developed, leading to the derivation of a resistance function. The validity of this model shall be then checked by means of a statistical interpretation of all available test data. If necessary, the resistance model shall be adjusted until sufficient correlation is achieved between the theoretical values and the test data.

Deviation in the predictions obtained by using the resistance model shall also be determined from the tests. This deviation shall be combined with the deviations of the other variables in the resistance function in order to obtain an overall indication of deviation. These other variables shall include:

- deviation in material strength and stiffness;
- deviation in geometrical properties.

The characteristic resistance shall be determined by taking account of the deviations of all the variables.

### 9.3.1 General

For this evaluation procedure, the following assumptions are made:

- a) the resistance function is a function of a number of independent variables  $X$ ;
- b) a sufficient number of test results is available;
- c) all relevant geometrical and material properties are measured;
- d) there is no correlation (statistical dependence) between the variables in the resistance function;
- e) all variables follow either a normal or a log-normal distribution.

NOTE Adopting a log-normal distribution for a variable has the advantage that no negative values can occur.

### 9.3.2 Procedure

- a) Step 1: Develop a resistance model.

Develop a resistance model for the theoretical resistance,  $r_t$ , of the large components or assemblies considered, represented by the resistance function given in [Formula \(8\)](#):

$$r_t = g_{rt}(X) \quad (8)$$

The resistance function shall cover all relevant basic variables,  $X$ , that affect the resistance at the relevant limit state.

All basic parameters shall be measured for each test specimen,  $I$ , and shall be available for use in the evaluation.

- b) Step 2: Compare experimental and theoretical values.

Substitute the actual measured properties into the resistance function to obtain theoretical values  $r_{ti}$  and to form the basis of a comparison with the experimental values,  $r_{ei}$ , from the tests.

The points representing pairs of corresponding values,  $(r_{ti}, r_{ei})$ , shall be plotted on a diagram, as indicated in [Figure 1](#).

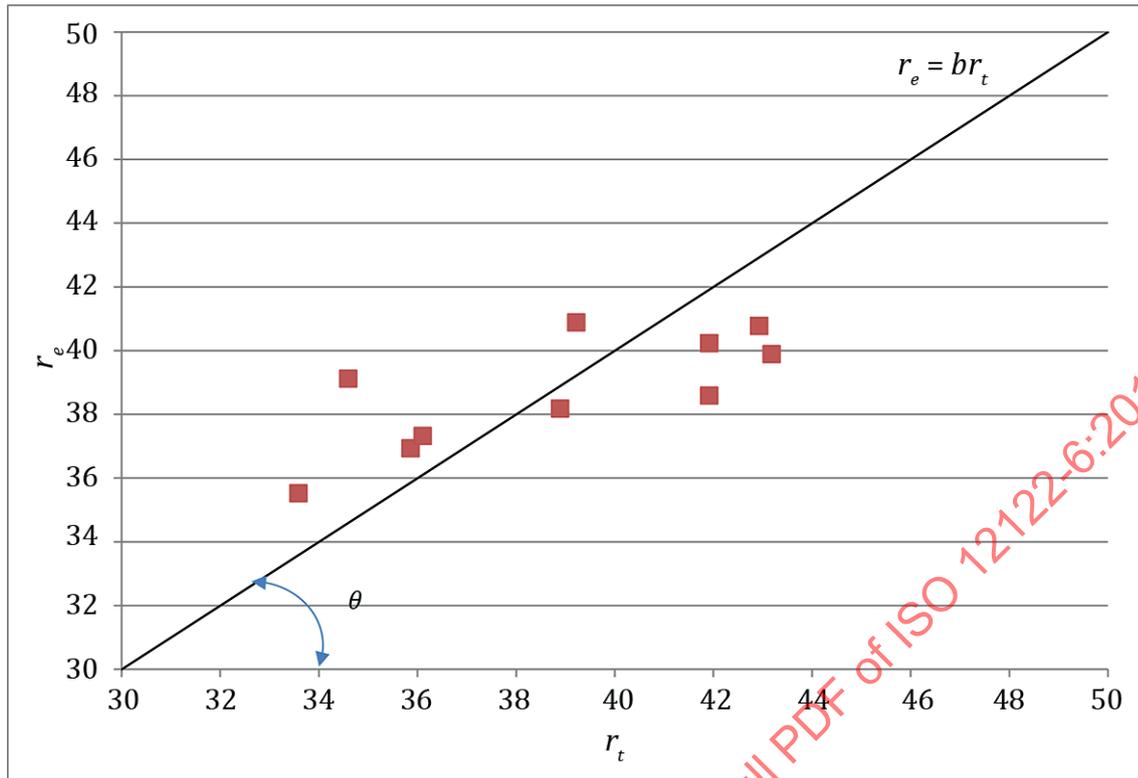


Figure 1 — Experimental resistance versus theoretical resistance ( $r_{ti}, r_{ei}$ ) diagram

If the resistance function is exact and complete, then all of the points will lie on the line  $\theta = \frac{\pi}{4}$ . In practice, the points will show some scatter but the causes of any systematic deviation from that line should be investigated to check whether this indicates errors in the test procedures or in the resistance function.

c) Step 3: Estimate the mean value correction factor  $b$ .

1) Represent the probabilistic model of the resistance,  $r$ , in the format given in [Formula \(9\)](#):

$$r = br_t\delta \tag{9}$$

where

$b$  is the “least squares” best-fit to the slope, given by [Formula \(10\)](#):

$$b = \frac{\sum_i r_{ei}r_{ti}}{\sum_i r_{ti}^2} \tag{10}$$

2) The mean value of the theoretical resistance function, calculated using the mean values,  $X_m$ , of the basic variables, shall be obtained from [Formula \(11\)](#):

$$\begin{aligned} r_m &= br_t(X_m)\delta \\ &= bg_{rt}(X_m)\delta \end{aligned} \tag{11}$$

d) Step 4: Estimate the coefficient of variation of the errors.

The error term,  $\delta_i$ , for each experimental value,  $r_{ei}$ , shall be determined from [Formula \(12\)](#):

$$\delta_i = \frac{r_{ei}}{br_{ti}} \quad (12)$$

e) Step 5: Analyse compatibility.

- 1) The compatibility of the test population with the assumptions made in the resistance function shall be analysed.
- 2) If the scatter of the  $(r_{ti}, r_{ei})$  values is too high to give economical design resistance functions, this scatter shall be reduced in one of the following ways:
  - i) by correcting the resistance model to take into account parameters which had previously been ignored;
  - ii) by modifying  $b$  and  $V_\delta$  by dividing the total test population into appropriate subsets for which the influence of such additional parameters may be considered to be constant.

NOTE 1 [Annex A](#) gives a suitable check to indicate whether the resistance model gives economical results.

- 3) To determine which parameters have most influence on the scatter, the test results shall be split into subsets with respect to these parameters.

NOTE 2 The purpose is to improve the resistance function per subset by analysing each subset using the standard procedure. The disadvantage of splitting the test results into subsets is that the number of test results in each subset can become very small.

- 4) When determining the fractile factors  $k_n$  (see step 7), the  $k_n$  value for the subsets shall be determined on the basis of the total number of the tests in the original series.

NOTE 3 Attention is drawn to the fact that the frequency distribution for resistance can be better described by a bi-modal or a multi-modal function. Special approximation techniques can be used to transform these functions into a uni-modal distribution.

f) Step 6: Determine the coefficients of variation,  $V_{Xi}$ , of the basic variables.

If it can be shown that the test population is fully representative of the variation in the reference population, then the coefficients of variation,  $V_{Xi}$ , of the basic variables in the resistance function shall be determined from the test data.

Since this is not generally the case, the coefficients of variation,  $V_{Xi}$ , will normally need to be determined on the basis of some prior knowledge.

g) Step 7: Determine the characteristic value,  $r_k$ , of the resistance.

The coefficient of variation of  $\delta$  is given by [Formula \(13\)](#):

$$V_{\delta} = \frac{\sqrt{\text{Var}[\delta]}}{E[\delta]} \tag{13}$$

The coefficient of variation of  $r_t$  is given by [Formula \(14\)](#):

$$V_{rt} = \frac{\sqrt{\text{Var}[g_{rt}(\underline{X})]}}{E[g_{rt}(\underline{X})]} \tag{14}$$

The coefficient of variation of  $r$  is given by [Formula \(15\)](#):

$$V_r = \frac{\sqrt{\text{Var}[g_r(\underline{X})]}}{E[g_r(\underline{X})]} = \frac{\sqrt{\text{Var}[\delta g_{rt}(\underline{X})]}}{E[\delta g_{rt}(\underline{X})]} \tag{15}$$

From these expressions, the characteristic resistance  $r_k$  shall be obtained from [Formulae \(16\)](#), [\(17\)](#) and [\(18\)](#):

$$r_k = b g_{rt}(\underline{X}_m) \exp\left(-k_{\infty} \alpha_{rt} Q_{rt} - k_n \alpha_{\delta} Q_{\delta} - 0,5Q^2\right) \tag{16}$$

with:

$$\begin{cases} Q_{rt} = \sigma_{\ln(rt)} = \sqrt{\ln(V_{rt}^2 + 1)} \\ Q_{\delta} = \sigma_{\ln(\delta)} = \sqrt{\ln(V_{\delta}^2 + 1)} \\ Q = \sigma_{\ln(r)} = \sqrt{\ln(V_r^2 + 1)} \end{cases} \tag{17}$$

and

$$\begin{cases} \alpha_{rt} = \frac{Q_{rt}}{Q} \\ \alpha_{\delta} = \frac{Q_{\delta}}{Q} \end{cases} \tag{18}$$

where

$k_n$  is the characteristic fractile factor from [Table 1](#) for the case  $V_X$  unknown;

$k_{\infty}$  is the value of  $k_n$  for  $n \rightarrow \infty$  [ $k_{\infty} = 1,64$ ];

$\alpha_{rt}$  is the weighting factor for  $Q_{rt}$ ;

$\alpha_{\delta}$  is the weighting factor for  $Q_{\delta}$ .

NOTE 4 The value of  $V_{\delta}$  is to be estimated from the test sample under consideration.

**9.3.3 Use of prior test data**

If the validity of the resistance function  $r_t$  and an upper bound (conservative estimate) for the coefficient of variation  $V_r$  are already known from a significant number of previous tests, the following simplified procedure may be adopted when further tests are carried out.

- a) If only one further test is carried out, the characteristic value  $r_k$  may be determined from the result  $r_e$  of this test by using [Formula \(19\)](#):

$$r_k = \eta_k r_e \tag{19}$$

where

$\eta_k$  is a reduction factor applicable in the case of prior knowledge that may be obtained from [Formula \(20\)](#):

$$\eta_k = 0,9 \exp(-2,31V_r - 0,5V_r^2) \tag{20}$$

where

$V_r$  is the maximum coefficient of variation observed in previous tests.

- b) If two or three further tests are carried out, the characteristic value  $r_k$  may be determined from the mean value  $r_{em}$  of the test results by using [Formula \(21\)](#):

$$r_k = \eta_k r_{em} \tag{21}$$

where

$\eta_k$  is a reduction factor applicable in the case of prior knowledge that may be obtained from [Formula \(22\)](#):

$$\eta_k = \exp(-2,0V_r - 0,5V_r^2) \tag{22}$$

where

$V_r$  is the maximum coefficient of variation observed in previous tests, provided that each extreme (maximum or minimum) value,  $r_{ee}$ , satisfies the condition given in [Formula \(23\)](#):

$$|r_{ee} - r_{em}| \leq 0,10r_{em} \tag{23}$$

- c) Values of  $\eta_k$  according to [Formulae \(20\)](#) and [\(22\)](#) are given in [Table 2](#).

**Table 2 — Reduction factor  $\eta_k$**

Coefficient of variation $V_r$	Reduction factor $\eta_k$	
	For 1 test	For 2 or 3 tests
0,05	0,80	0,90
0,11	0,70	0,80
0,17	0,60	0,70

## 10 Reporting

The report shall be determined in accordance with ISO 12122-1.

More detailed description will be required for the reference population to appropriately specify the large components and assemblies that were tested.

More detail will also be required to enable complete specification of the method of test.

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## Annex A (informative)

### Commentary

#### A.1 Commentary on scope

This document presents methods for determining characteristic values for capacity of large components or assemblies that involve some elements of timber. It is to be read in conjunction with ISO 12122-1. Usually, because of the size of the components and the cost of testing them, a small number of tests are performed so a different analysis is required compared with the method outlined in ISO 12122-1.

This document presents a uniform methodology for the evaluation of characteristic values that are consistent with the characteristic values found for other structural timber products. The characteristic capacity delivered is an estimate of the 5-percentile capacity with 75 % confidence.

This document has drawn extensively on analysis methods from Eurocode 0 and has been checked for compatibility with the methods presented in ISO 12122-1.

This document does not establish methods for the determination of design values. These may be determined based on characteristic values from test data, but for large components involving timber will also incorporate safety factors to account for any or all of the following factors:

- expected changes in product or product properties over a long period, which could be due to variations in timber resource quality, production methods or quality of other raw materials;
- expected variations in fabrication of the large component or assembly over a long period which may be a function of workmanship or materials;
- the complexity of the reference population; e.g. where the reference population has a large number of producers who draw their resource over a large area, then the sampling may not effectively reflect all possible combinations of resource quality and production methods; hence, the sample may not be truly representative and a safety factor may be applied to allow for that.

#### A.2 Commentary on normative references

Because there is no restriction on the form of the large components or assemblies, a number of different ISO or national test standards may be applicable. For example, if the component is a shear wall, then ISO 21581 would be an appropriate test standard. However, none have been listed here because it is not possible to anticipate the test standards that may be appropriate for all circumstances and omission of a standard may wrongly indicate that the missing standard is inappropriate.

#### A.3 Commentary on terms and definitions

See ISO 12122-1 for some generic definitions including the definition of characteristic values.

##### A.3.1 Large component or assembly

To be appropriate for the scope of this document, the large component must contain at least one element of structural timber that is part of the load path for the component. The component must also contain some connections that join different elements of the assembly together.

The definition is very flexible to allow a large number of assemblies to qualify. The definition is intended to include:

- a) shear walls;
- b) diaphragm assemblies;
- c) trusses;
- d) space frames;
- e) large complex connections such as nodes in reticulated domes.

### A.3.2 Resistance model

This is a structural behaviour model that is based on the physical behaviour of the assembly and its elements. It is a mathematical tool for predicting capacity from some attributes of the assembly. This definition is also very flexible and is intended to allow classical design models, joint strength relationships and the results of research into timber behaviour. While it is acknowledged that some of these models may involve empirical relationships, the model used should be a documented behaviour model that can be referenced in the report.

### A.4 Commentary on symbols

Many of the symbols used in this document are sourced from Eurocode 0 and have been unchanged so that their origin is clear.

### A.5 Commentary on reference population

There are two aspects of the description of the reference population that affect the testing of large components. The first is the description of the large component itself and the second is the load transfer path through the specimen.

Characteristic values can be taken to represent the properties of the material, geometries and configurations of the test samples. They are also unique to the loading configuration of the test. The reference population is the definition of the parent population to which the characteristic properties are to apply. ISO 12122-1 presents some general requirements for definition of the reference population, but some other features that may influence the structural properties of large components and assemblies include:

- The species, strength class and dimensions of the timber elements will affect structural capacities. As well as the presence or absence of knots or other growth characteristics from the connection zones may affect the performance of the assembly.
- The detail of any connections will also affect structural properties. This may include the specification of the connectors: shape, size, material and method of installation. Method of installation may include a measure of tightness for screws or bolts and depth of driving for nails.
- The geometry of the connection will be important to some failure modes. In particular, variations in end and edge distances and spacings of connectors may influence the failure modes obtained in the tests. Tolerances on connection geometry should be noted and reflected in the sampling (see [A.6](#)).
- The material specification of any non-timber elements in the assembly may affect the structural properties and should be noted in the description of the reference population. This will include grade, thickness, and structural specification. In some instances coatings may need to be specified. (This is particularly important if friction is part of the structural resistance of the assembly.)
- Moisture content of any timber components may affect both the strength of the timber and its connection capacity. The reference population should be specified as a range. Temperature of seasoning may also have an influence on the structural properties of seasoned sawn timber. Range

of seasoning temperatures and method of seasoning may also be important in determining the capacity of the assembly.

The following examples illustrate the description of reference populations for assemblies.

- A node joint to be replicated in a large reticulated dome is to be tested. The node joint has been designed to use welded steel plates and connect timber members from the same structural grades and will be fabricated for one particular building and by one manufacturer. The reference population will be described by the design drawings and specification for the building and will include information on the timber sourced and the tolerances used by the fabricator of the test specimens.
- Trusses of varying geometries using an innovative connection system are to be tested. In this case, there will be only one manufacturer, but there may be a number of different geometries. The suite of different geometries will be used to determine a worst case scenario for the tests. Alternatively, a number of different geometries may be tested and a resistance model used to interpolate between the results. The reference population will describe the range of timber sizes and specifications that may be used with the truss system, and will give detail on the innovative connection system. It will also specify the range of truss spans and loading conditions that are likely to be used with the truss systems.
- A shear wall system that could be built by a number of different builders for use in domestic construction, is to be tested. The size, grade and characteristics of the timber elements in the system will be described. The cladding materials for the shear wall system will also be specified and the fastening details and geometries to be used to connect the elements of the shear wall system. Any tolerances on the connection system will also be specified. In addition the anchorage of the wall system to the substrate should also be specified. Combinations of vertical and horizontal load that will be published as appropriate for the wall will also be specified.

The lists in both ISO 12122-1 and this document are examples, but the intent of [A.5](#) is that anything in the manufacture of the assembly that can affect its structural properties should be included in the description.

The structural setting for the large component includes the definition of the loading and anticipation of failure modes

For larger components, their use within a structure will dictate the load paths through the component. The loading characteristics are also important in the description of the component. The nature of the loading may include the following parameters:

- the direction of application of the loads;
- the points of application of the loads;
- whether the loads are concentrated or distributed, and if concentrated, the area of their point of application;
- the duration of loads likely to be applied, and whether the loads are part of a loading sequence which needs to be replicated (this information may be important in cases of resistance to earthquake actions).

The loading (see [A.8](#)) will need to replicate the character of the anticipated loading in service especially with respect of anticipated extreme event loadings that may be expected for the ultimate load limit states.

Moreover, the failure modes that are expected for the large component or assembly should be anticipated. The design of the test procedure and measurements taken will assist in identifying the failure and the failure load assuming a specific failure mode. This should be declared in the design of the experimental test procedure.

Where the failure mode is not obvious or clearly understood, some pilot tests may be required to identify failure modes. These tests should explore the configuration within the tolerances defined and lead to classification of failure modes and the combinations of parameters that may induce them.

## A.6 Commentary on specimens

In general, timber components may incorporate a large number of variations in raw material, production methods and hence structural properties. The specimens tested should reflect the expected range of properties in the production version of the connections. The variation in the specimens prepared for test should be related to the tolerances declared in the description of the reference population.

The same materials and fabricator anticipated for the final product should be used for the test specimens to ensure that the fabrication methods and techniques for the final product are fairly represented in the test specimens. Where a number of fabricators may be used in production, it is recommended that the test specimens are supplied by more than one of the fabricators. Also if the final products may be constructed of materials drawn from different suppliers or specifications, the range of expected suppliers and specifications is also represented in the specimens.

If the sample size is not sufficient to represent all combinations of variations of tolerances, then:

- the shortfall should be declared in the report on the testing;
- at least some test specimens should be selected with combinations of tolerances expected to give lower capacities.

Guidance on sample size can be found in ISO 12122-1; however, it is recognized that with large components and assemblies, it is generally not practical to test enough specimens for the expected coefficient of variation. The analysis of small sample sizes inevitably gives greater levels of conservatism in the final result.

## A.7 Commentary on sample conditioning

As timber products may experience changes in moisture content during storage, it is important that the moisture condition of the tested components reflects the moisture content described for the reference population. Where the description of the moisture content in the timber elements of the reference population incorporates a large range, the components should be stored in such a way that not all samples have a moisture content at one end of the range.

Otherwise, the requirements of ISO 12122-1 apply.

## A.8 Commentary on test data

### A.8.1 Commentary on loading specification

The test method used should address the normally expected service loadings and extreme event loadings on the large component. These features of the component should have been addressed in the structural setting description of the reference population (see [A.5](#)). The loading attributes specified for the test should include the attributes listed in [A.5](#).

### A.8.2 Commentary on test arrangement

In some cases, the large component or assembly may fall within the scope of a national or ISO test standard. However, in many cases, while the large component may not completely satisfy the requirements for test specimens in some standards, the test method may be adapted to suit the large component. Some examples include:

- ISO 21581 is a test standard for testing shear walls. This standard gives appropriate test details, procedures and loading regimes for components that carry a mixture of vertical loads and horizontal

shear loadings. It may be adapted for components that carry shear loads (loads in opposite directions that are not collinear).

- ISO 19049 is a test standard for testing horizontal diaphragms. This standard have a number of different loading configurations where loads are applied essentially in the plane of large planar components.
- ISO 18402 and ISO 22452 are standards that provide test methods for structural insulated panels, but could be adapted to large planar elements loaded mainly out of plane.
- ISO 13910 presents test methods for most structural properties for sawn timber. Some of the tests outlined in this standard may be appropriate if the component is a prismatic element or linear element subjected to axial or lateral loads.

The support of the component should also address the support of the component in service. Where there is buckling restraint in service, this should be replicated in the test method. Equally important is that the buckling restraint in testing should be no more effective than it is in service.

Boundary conditions of the test specimen should match the expected boundary conditions of the component in service. Some issues that may need to be explored include:

- rigidity of supports: moment resisting or pinned supports;
- position of supports: correctly located on the specimen and giving the appropriate mix of horizontal and vertical support;
- continuity of the specimen at its ends: where the component is continuous with similar components in service, moment restraint may be required at the ends of the specimen.

### A.8.3 Commentary on test data measurements

Data should be measured in such a way that the ultimate load can be recorded.

Where restraints should have special characteristics (e.g. moment resistance), instruments should provide verification that the restraints have exhibited the appropriate characteristics.

Where possible, measurements should be made to identify the failure mode of each test.

Where a resistance model is to be used as part of the analysis, the measurements of attributes of the test specimen should be made before the tests to permit the use of the resistance model in the evaluation of characteristic values.

## A.9 Commentary on evaluation of characteristic values for structural properties

### A.9.1 Commentary on general principles

The characteristic values of the capacity of the reference population can be estimated using two different methods. Both give the characteristic capacity in the same units as the measurement of ultimate capacity.

- The direct analysis method requires no knowledge of the behaviour models for the test specimens. However, the analysis for small numbers of specimens may appear quite conservative. It is therefore recommended that the direct analysis method be used where there are more than 10 test specimens.
- The evaluation using a combination of test data and resistance models links the test data to expected models of component behaviour. Where there is good agreement between the test data and the resistance models used, the conservatism in the estimate of characteristic value is reduced.

Data from small samples underestimates the coefficient of variation of the distribution. Pooling of tests from similar assemblies may give a better indication of coefficient of variation. ISO 12122-1 gives advice on pooling of data from different test programs.

### A.9.2 Direct evaluation from test data only

This analysis method uses normal confidence level indicators to estimate a 5 percentile with 75 % confidence. It operates directly from the mean using variance of the population. It does not require an estimate of the 5 percentile from the test data, but the factors used in the analysis calculate the characteristic values from the mean and variance directly.

Two alternative approaches are presented:

- Estimating the characteristic value using the normal distribution using [Formula \(1\)](#). Values of  $k_n$  are taken from [Table 1](#).
  - Where the mean and the variance is found directly from the raw data, [Formula \(1\)](#) calculates the 5 percentile based on the normal distribution fitted through the data.
  - In some cases, the variance of strength of the reference population is known from other testing. In these cases, the knowledge of the reference population will have indicated that the normal distribution is a good fit to the behaviour data and the known coefficient of variation ( $V_X$ ) is used in [Formula \(1\)](#) with  $k_n$  factors taken from the top row of [Table 1](#). The  $V_X$  is generally taken from tests on a significant number of similar components. For example, where the main failure mode is given by bolted connection failure and  $V_X$  of the strength of similar bolted connections is known from other tests, then this  $V_X$  used.
  - In other cases, there may not be a reliable estimate of  $V_X$  for the reference population. In these cases,  $V_X$  is calculated from the variance of the test data. Because large numbers of tests are required to estimate  $V_X$ , with reasonable accuracy, the estimation of  $V_X$  from relatively small number of tests means that the higher values of  $k_n$  in the lowest row of [Table 1](#) should be used.
- Estimating the characteristic value using the log-normal distribution using [Formula \(4\)](#). Values of  $k_n$  are also taken from [Table 1](#).
  - Where the mean and the variance is found from the natural logarithms of the raw data, [Formula \(4\)](#) calculates the 5 percentile based on the log-normal distribution fitted through the data. This distribution gives a reasonable fit to test data from many timber-based components.
  - Again, in some cases, the variance of strength of the reference population is known from other testing. In these cases, the known coefficient of variation ( $V_X$ ) is used in [Formula \(6\)](#) to estimate the standard deviation of the log-normal distribution and uses  $k_n$  factors taken from the top row of [Table 1](#) in [Formula \(4\)](#) to estimate the characteristic value directly. Where there is no reliable estimate of the coefficient of variation from similar tests, then again the lower row of  $k_n$  factors in [Table 1](#) are used with the  $s_Y$  as the standard deviation of the natural logarithms of the test data ([Formula \(7\)](#)) to estimate the characteristic values directly using [Formula \(4\)](#).

The calculation using the  $V_X$  derived from the test data are statistically similar to the calculation method presented in ISO 12122-1. However, where the coefficient of variation of the reference population is known directly, the characteristic capacity can generally be estimated with less conservatism.

### A.9.3 Commentary on evaluation of characteristic values using combined of test results and resistance model

The use of an accepted resistance model can improve the understanding of the behaviour of the large component. In this case, the resistance model is used to estimate the test data from measurements on attributes of the test specimens. The analysis then becomes one of comparing the test data with the predictions from the resistance model.

The process is laid out in steps to facilitate the analysis:

Step 1 involves the establishment of the resistance model. The model may involve a number of independent attributes. Examples may include density of the timber, dimensions of the component, and dimensions of the connectors. Where there is a small dependence between the variables, this will lessen the effectiveness of the method, but will not compromise the results. While the use of more variables