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Timber structures — Determination of characteristic values —

Part 1: Basic requirements

Structures en bois — Détermination des valeurs caractéristiques —

Partie 1: Exigences de base

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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 on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 165, *Structural Timber*.

ISO 12122 consists of the following parts, under the general title *Timber structures — Determination of characteristic values*:

— *Part 1: Basic requirements*

— *Part 2: Sawn timber*

Introduction

This International Standard sets out a framework to establish characteristic values from test results on a sample drawn from a clearly defined reference population. The characteristic value is an estimate of the property of the reference population with a consistent level of confidence prescribed in this part of ISO 12122.

It is the intention that this part of ISO 12122 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, this part of ISO 12122 alerts the user to the basic requirements for the determination of consistent characteristic values, but for some classes of products, additional requirements set out in other parts or Annexes to this part give further mandatory detail and explanation. It permits the evaluation of characteristic values on testing of commercial sized specimens.

In some cases, characteristic values determined in accordance with this part of ISO 12122 may be modified to become a design value.

This part of ISO 12122 has the following Annexes:

Annex A presents detail on a number of statistical methods that may be used in the evaluation of characteristic values.

Annex B presents a commentary on the provisions in this part of ISO 12122.

Annex C presents examples of the use of the statistical methods.

Timber structures — Determination of characteristic values —

Part 1:
Basic requirements

1 Scope

This International Standard gives methods for the determination of characteristic values for a defined population of timber products, calculated from test values.

It presents methods for the determination of

a) characteristic value of mean-based properties, and

b) characteristic value of 5th percentile-based properties.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

AS/NZS 4063.2, *Characterisation of structural timber — Part 2: Determination of characteristic values*

ASTM D2915, *Sampling and data-analysis for structural wood and wood-based products*

EN 14358, *Timber structures — Calculation of characteristic 5th percentile values and acceptance criteria for a sample*

3 Terms and definitions

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

3.1
characteristic value
value of a property taken to represent the property of a designated population using a process of sampling, testing of specimens, and analysis

3.2
characteristic value of mean-based property
two alternative presentations of characteristic value for mean-based properties are possible:

a) the mean property obtained from results of tests on the defined product;

b) the mean property with 75 % confidence obtained from results of tests on the defined product

3.3
characteristic value of 5th percentile-based strength property
5th percentile value with 75 % confidence strength property obtained from results of tests on the defined product

3.4
population
all of the structural timber product that meets the description of the population

Note 1 to entry: See Annex B for some examples of the use of the term population.

3.5
sample
number of single members of the population, selected to represent the population

Note 1 to entry: See Annex B for some examples of the use of the term sample.

3.6
specimen
single element used in a test; the element may be a complete member, a member that has been trimmed to length, or a part of a member fabricated for a specific test

Note 1 to entry: See Annex B for some examples of the use of the term specimen.

4 Symbols and abbreviated terms

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

In addition, the following apply:

f_m is the characteristic bending strength

$k_{mean, 0,75}$ is a multiplier to give the mean property with 75 % confidence and is given in Table A1

$k_{0,05, 0,75}$ is a multiplier to give the 5th percentile value with 75 % confidence for a 5th percentile-based property and is given in Table A2

M is the moment capacity

n is the number of specimens in the test data

V is the coefficient of variation of the test data

X_Δ is the target difference between the reported characteristic value and the test result 5th percentile

X_i is a generalized test value

X_{mean} is the average of the individual test values (X_i)

$X_{mean, 0,75}$ is the mean property with 75 % confidence

$X_{0,05}$ is the 5th percentile value from the test data

$X_{0,05, 0,75}$ is the 5th percentile value with 75 % confidence

Z is the section modulus

5 Reference population

The population to which the characteristic value applies 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 limited to:

a) reference to the relevant product standard or 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;

f) treatment of the product;

g) 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.

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 minimize selection bias, and shall be appropriate to the purpose of the characteristic value and the nature of the reference population.

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 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.

NOTE 1 Materials with larger assumed or assigned population coefficient of variation, (V), of the tested properties should have a larger sample size.

NOTE 2 Some product standards may define a minimum number of tests that must be undertaken to determine characteristic values to be used with described products.

NOTE 3 Annex B gives some guidance on selecting sample size.

NOTE 4 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 may have to be sufficient to allow meaningful pooling of the results as indicated in Annex A.

NOTE 5 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 are 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

Test data from the samples shall be compatible with the definition of the population by

a) compliance with the specification of the reference population at the time of testing in accordance with 7.1 and 7.2, or

b) adjustment of test data in accordance with 8.2 where compliance with 7.1 or 7.2 is not achieved.

7.1 Sample moisture content

The sample shall be stored so that the moisture content at the time of test is appropriate to the description of the reference population as detailed in Clause 5.

7.2 Sample temperature

The sample shall be stored and tested so that the temperature at the time of test is appropriate to the description of the reference population as detailed in Clause 5.

8 Test data

8.1 Test method

The test data shall be derived in accordance with an appropriate test method for the properties and for the reference population.

NOTE 1 For tests on some product types, discrimination of results on the basis of failure mode may be required to ensure that the results are compatible with objectives of the test program and the property being determined.

NOTE 2 Test methods involve many variables that may affect results including loading configuration and rates, specimen positioning and measurement methods. The selection of these variables must be appropriate to the objectives of the testing, and may require some adjustments specified in 8.2.

8.2 Test data compatible with product description

Where the characteristic value is applicable to a standard size or moisture content, adjustments to the raw test data may be required. Any adjustment shall be in accordance with appropriate behaviour models and shall be detailed in the report.

NOTE Annex B gives examples of the types of adjustment that may be necessary in response to variation of the specimens from the description of the reference population.

Where test data from a number of different data subsets are to be combined, the basis for the combination shall satisfy the following requirements:

a) The data shall be derived from similar subsets that are standardized using the same adjustment models, and shall satisfy statistical tests for combining the subsets into a single data set;

b) Transformation methods shall be in accordance with appropriate behaviour models and shall be detailed in the report.

NOTE Annex A gives requirements for combining or pooling of data from a number of different test programs.

9 Evaluation of characteristic values for structural properties

9.1 Structural properties

Characteristic values for properties shall be reported in one of two ways according to the use of the product:

a) Material properties — where the determined property is multiplied by a geometric parameter to give a component capacity, or component stiffness;

b) Component properties — where the determined property is a component capacity or component stiffness.

Characteristic values for structural properties shall be classified as those based on the mean of test results and those based on the 5th percentile of test results in accordance with 3.2 and 3.3.

9.2 Characteristic value based on the mean

The mean value of the test values shall be evaluated as either a) or b):

a) the arithmetic average of the test values as

$$X_{mean} = \frac{\sum X_i}{n} \tag{1}$$

where

X_{mean} is the average of the individual test values (X_i);

X_i is a generalized test value;

n is the number of test values.

b) the mean value of a statistical distribution fitted through the test data

For mean-based strength characteristic values, the mean property with 75 % confidence obtained from results of tests shall be evaluated.

NOTE Suitable methods for estimating the mean with 75 % confidence are presented in Annex A.

The characteristic values for modulus of elasticity or modulus of rigidity shall be the mean value.

9.3 Characteristic value based on the 5th percentile test value

The 5th percentile value of the test values shall be evaluated as

a) the non-parametric estimate of the 5th percentile of the test data found by ranking the test data and from the cumulative frequency of the test data selecting the interpolated value at the 5th percentile (see A.2.1 and A.2.2), or

b) the estimate of the 5th percentile of the test data found by fitting an accepted statistical distribution through the test data and selecting the 5th percentile point from the fitted distribution (see A.2.3).

The 5th percentile value with 75 % confidence shall be evaluated.

NOTE Suitable methods for estimating the 5th percentile value with 75 % confidence are presented in Annex A.

10 Report

10.1 General

The report shall include details of the reference population definition, sampling program, description of test pieces, the test method and analysis methods used, and the characteristic values in accordance with 10.2 to 10.6.

10.2 Reference population

The reference population shall be defined as given in Clause 5. Each attribute used to define the reference population shall be detailed in the report. Each of the attributes in the reference population that may affect either the strength or stiffness shall be presented in the report.

10.3 Sampling

The sampling method used to select the test sample shall be described.

The justification of the sample size selected shall be presented. (See 6.2.)

10.4 Test methods

Reporting of testing methods shall either

a) refer to the test standard used, or

b) fully document the test procedures used.

Reporting of test specimen preparation shall include a statistical summary of the characteristics of the sample (e.g. moisture content, temperature, grade marks). This data shall be in sufficient detail to enable the data to be adjusted to different conditions if required.

The test results shall be presented in the report in enough detail to enable the statistical analysis to be checked or repeated. Any adjustment of the test results to ensure compatibility with the product description shall be fully documented, together with references for the modification methods and factors used.

Where applicable for the reference population and the tests undertaken, failure modes in strength tests shall be reported.

10.5 Analysis methods

The analysis method shall be described in detail. For characteristic strength values, the method for estimation of the 5th percentile value with 75 % confidence shall be referenced.

Where pooled data are used, the method of combination of the data shall be described.

Where a distribution is fitted to the test data, all of the defining parameters of the fitted distribution shall be reported, together with goodness of fit parameters.

10.6 Characteristic values

The characteristic values shall be reported together with the *V* of the data that led to their calculation.

Annex A
(normative)

Analysis of data for characteristic values

A.1 Evaluation of mean value with 75 % confidence

Where required, the lower single sided 75 % confidence limit on a mean property shall be found by

$$X_{\text{mean, 0,75}} = X_{\text{mean}} \left(1 - \frac{k_{\text{mean, 0,75}} V}{\sqrt{n}} \right) \quad \text{(A.1)}$$

where

$X_{\text{mean, 0,75}}$ is the characteristic value expressed as the mean value with 75 % confidence;

X_{mean} is the average of the individual test values (X_i);

$k_{\text{mean, 0,75}}$ is a multiplier to give mean value with 75 % confidence and shall be the value obtained in Table A1;

V is the coefficient of variation of the test data found by dividing the standard deviation of the test data by the average of the test data;

n is the number of specimens in the test data.

Table A.1 — $k_{\text{mean, 0,75}}$

Number of specimens n	$k_{\text{mean, 0.75}}$
3	0,82
5	0,74
10	0,70
30	0,68
50	0,68
100	0,68
>100	0,67

A.2 Evaluation of 5th percentile value with 75 % confidence

A.2.1 Use of non-parametric data analysed using ASTM D2915

Where this method is used, the estimation of the 5th percentile value with 75 % confidence using the non-parametric method of ASTM D2915 shall be used without modification.

A.2.2 Use of non-parametric data analysed using AS/NZS 4063.2

Where this method is used, the 5th percentile of the test data shall be evaluated by ranking the test data and determining the 5th percentile of the ranked data. The 5th percentile value with 75 % confidence shall be evaluated from Formula (A.2).

$$X_{0,05,\ 0,75} = X_{0,05}\left(1 - \frac{k_{0,05,\ 0,75}V}{\sqrt{n}}\right) \quad \text{(A.2)}$$

where

n is the number of test values;

$X_{0,05,\ 0,75}$ is the 5th percentile value with 75 % confidence;

$X_{0,05}$ is the 5th percentile from the test data interpolated between the data ranks as necessary;

$k_{0,05,\ 0,75}$ is a multiplier to give the 5th percentile value with 75 % confidence and is given in Table A2;

V is the coefficient of variation of the test data found by dividing the standard deviation of the test data by the average of the test data.

Table A.2 — $k_{0,05,\ 0,75}$

Number of specimens n	$k_{0,05,\ 0,75}$
5[a]	—
10[a]	—
30	2,01
50	1,94
100	1,85
>100	1,76

NOTE Method of analysis: non-parametric AS/NZS 4063.

[a] There are difficulties obtaining a reliable estimate of the 5th percentile value from small data sets.

A.2.3 Evaluation by fitting data to a distribution

Where this method is used, the 5th percentile value with 75 % confidence shall be evaluated from the 5th percentile value of the test data by fitting a distribution through the test data and applying Formula (A.2) with V found by dividing the standard deviation of the test data by the average of the test data.

For this analysis, $k_{0,05,\ 0,75}$ is the multiplier to give the 5th percentile value with 75 % confidence and is given in Table A3. The result will only be valid if the distribution is a good fit to the data. Where a distribution is fitted to the data, goodness of fit parameters shall be evaluated in accordance with A.3.

Table A.3 — $k_{0,05,\,0,75}$

Method of analysis	Log-normal	Normal
Number of specimens n	$k_{0,05,\,0,75}$	$k_{0,05,\,0,75}$
5[a]	1,34	2,05
10[a]	1,28	2,04
30	1,18	2,01
50	1,13	1,97
100	1,07	1,91
>100	1,05	1,90

NOTE 1 Other distributions may be used as long as the values of $k_{0,05,\,0,75}$ can be justified.

NOTE 2 For the log normal distribution, V is the standard deviation of the original data divided by the mean of the original data, not the ratio of the standard deviation of the logarithms to the mean of the logarithms.

NOTE 3 The data presented in this table is sourced from PN 05.2024 FWPA Australia. The data for the log-normal distribution was calibrated for V ranging from 5 % to 55 % and for the normal distribution for V ranging from 5 % to 20 %. The log-normal factors give equivalent results to the non-central student t-distribution presented in EN 14358 and US practice within 1 % for sample sizes of 10 or more.

[a] There are difficulties obtaining a reliable estimate of the 5th percentile value from small data sets.

A.3 Goodness of fit tests for fitted distributions

A distribution is deemed to be a good fit to test data where the Kolmogorov-Smirnov goodness of fit test is significant at the 0,05 or better level.

NOTE Where the data are not shown to be a good fit to the distribution or the data are a collection from a number of distributions, an alternative distribution, or a non-parametric method should be used.

A.4 Pooling of data for analysis

A.4.1 General

Pooling involves the aggregation of data from a number of discrete data sets to capture sources of variation that may not be present within a single subset. Such aggregations may include data from different species of timber, different production methods, or different sized products.

In this clause, the term subset data refers to test data from a single size, grade, product test sample. Pooled data are the sum of all valid subsets as represented in Figure A1.

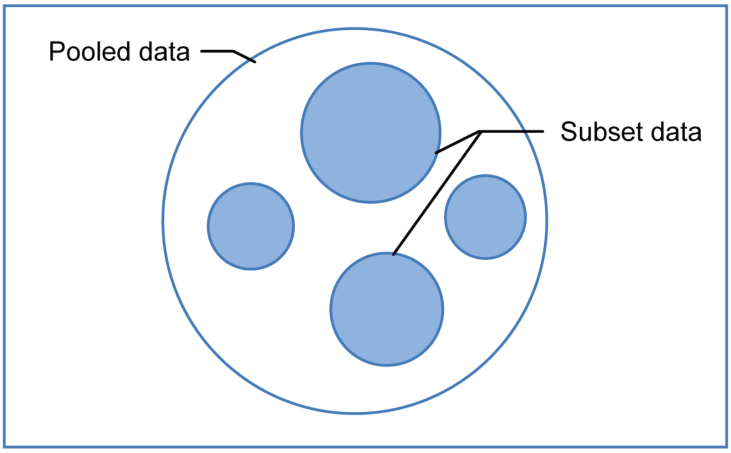


Figure A.1 — Venn diagram for nomenclature for pooling (see Annex B)

A.4.2 Conditions for pooling

Pooling of data are only valid for data from tests on:

a) the same product description (e.g. seasoned sawn timber);

b) the same grade (e.g. stress grade);

c) similar species (e.g. softwoods).

A.4.3 Standardising data

Where the characteristic value is applicable to a standard size or moisture content, adjustments shall use the same models for each data subset. The models shall be appropriate for the material that was tested and shall be detailed in the report.

NOTE For example, where pooling data from timber with non-standard moisture contents, the same moisture content adjustment calculation should be used for all data subsets contributing to the pooled data set.

A.4.4 Requirements for pooling

The pooled subsets shall have

a) similar statistical distributions,

b) similar V,

c) reversibility (if a subset is removed, the characteristics of the pooled data do not change significantly), and

d) convergence (the pooled data have similar characteristics to very large samples of the subsets).

Standard statistical practices shall be used to accept standardized subsets and validate the pooled data.

NOTE An example of some acceptance and validation tests is given in Annex B.

A.4.5 Report

Where pooling is used, the report shall detail

a) the definition of the pooled data,

b) the models of standardizing or adjusting subset data,

c) the justification of pooled subsets including characteristics of statistical distributions, coefficient of variation, reversibility and convergence,

d) the statistical tests and validation, and

e) the author and date of report.

Annex B
(informative)

Commentary

B.1 Commentary on scope

This part of ISO 12122 presents basic requirements for determining characteristic values for structural properties of structural timber products. Other parts in the same series present the detail required for different types of structural timber products.

It gives the overall strategy for determining characteristic values for any timber structural product:

— the products to which the characteristic values apply are described in Clause 5 Reference population;

— a test sample is taken as described in Clause 6;

— if appropriate it is conditioned as described in Clause 7;

— testing is performed and the test data are checked against the requirements for the product as described in the reference population as described in Clause 8;

— an analysis of the test data is performed to evaluate the characteristic properties as described in Clause 9.

This part of part of ISO 12122 presents a uniform methodology for the evaluation of characteristic values. The characteristic values are said to represent the properties of the reference population and in general take into account the statistically expected errors in estimating the properties of a large population from a randomly drawn sample.

Characteristic values for design purposes are generally selected from characteristic values obtained from test results, but may 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: These changes could be due to variations in timber resource quality, production methods or quality of other raw materials;

— Complexity of the reference product: For example, where the reference product has a large number of producers who draw their resource over a large area, then the sampling may not effectively catch all possible combinations of resource quality and production methods. In this way, the sample may not be truly representative and a safety factor may be applied to allow for that;

— Complexity of failure modes: If there are a number of different possible failure modes, or if it is believed that the test may not have fully explored all of them, then there may be reason to use an additional safety factor.

B.2 Commentary on normative references

No commentary.

B.3 Commentary on terms and definitions

All strength characteristic values are an estimate of the population value based on the value from sample tests. Whenever a sample is taken, normal sampling error may mean that the results of the sample may not give exactly the same result as if every piece in the population was tested. Hence, a standard correction to the test result is made to give 75 % confidence.

Most strength characteristic values are based on the 5th percentile strength of the population, so the test data are used to estimate the 5th percentile value and this value is used to estimate the 5th percentile value with 75 % confidence. The two percentiles in the definitions have different meanings. The 5th percentile strength is the strength value that 5 % of the population will be lower than. The 75 % confidence recognizes that the strength calculated as the 5th percentile from a sample may not be the same as the value found if every single piece in the population was tested. The value with 75 % confidence is the value that would have a chance of 75 % of being exceeded if the entire population was to be tested.

For modulus of elasticity, the characteristic value is simply the mean of the test data. This in effect is a 50 % confidence in the estimate of the population mean.

Some strength characteristic values (e.g. bearing strengths) are based on the mean of the test data. For these properties, the mean of the strength test data is used.

It is recommended that the detail of the calculation of the confidence limit for all characteristic values be reported to enable the data to be used to establish values for design or approval purposes.

The collective nouns used to describe groups of timber are as follows.

— Population refers to the all of the timber to which the characteristic value applies. It includes all of the tested material and untested material that meets the definition of the reference population. (See B.5 for further detail on the definition of reference population.)

— Sample refers to the pieces of the reference population taken to represent the reference population. A sample is a number of whole pieces taken from the population and is intended to reflect all of the variants that make up the population. The population is characterized by the sample, so considerable care is required to ensure that the sample is representative. (See B.6 for further detail on sampling and sample size.)

— Specimen refers to a single item that is subjected to test. Specimens are usually cut out of single pieces of timber with one specimen per piece in the sample. In some cases more than one test may be performed on a specimen, e.g. a bending stiffness test and a bending strength test may be performed on the same specimen.

An example of these terms is as follows.

— A producer needs to characterize the bending strength of production of a single product from a single mill during a one month period. The reference population will be all of the products produced by that mill in the one month period. This may typically be 100 000 pieces of timber.

— The sample size is 120 pieces, and this sample will be drawn at random from the reference population over the one month period. The sample rate is a little over 1 in 1 000 pieces of product, and the sample will be the 120 pieces of timber taken from the reference population.

— Each piece of timber in the sample will be cut into a single test specimen in accordance with the test method requirements. Thus, there will be 120 bending test specimens prepared from the sampled timber. After testing there will be 120 data items, one for each test specimen. The single population has had a single sample of 120 pieces taken and yielded 120 test specimens and 120 data points.

B.4 Commentary on symbols

No commentary.

B.5 Commentary on reference population

Characteristic values represent the properties of the material from which the sample was taken. The reference population is a statement of the population from which the sample was taken and hence is directly linked to the characteristic values.

The context for the testing and the use of the characteristic value may affect the way in which the reference population is selected and defined, as shown in the following examples.

— Where the results of testing product drawn from a vast region or a nation are to be used to establish the design characteristics of that product, then the definition of the reference population is necessarily very broad. It will be useful to incorporate as many variations in growing region, production type and even species or species grouping within the definition of the stress-grade as possible. In this case the reference population is the entire production of the defined product for the region or nation.

— Where the results of testing are to be used to check the performance of a single manufacturing unit, then the reference population will only be taken from that manufacturing unit and the value obtained will relate to the manufacture during the sampling period. The reference population will be a selected product or product range from the manufacturing unit.

— Where the results of testing are to be used to verify properties of a single batch then the reference population is taken from one production line over the period in which the batch was produced.

— Different statistical processes must be used for marketplace surveillance so it is not possible to treat a single pack of timber as a reference population. If a whole pack of timber is treated as a reference population and is tested, effectively the sample is the reference population and characteristic value calculations are not appropriate.

A reasonable amount of detail on the reference population is required to enable the structural properties reported as characteristic values to be related to all of the factors that may have influenced them in the production of the material tested.

The list is an example, but the text of the clause indicates that anything in the manufacture of the product that may affect the structural properties must be included in the description.

— The product standard or specification is central to the description of the reference population. In many cases, the specification gives detail on the aspects of production that may affect its structural properties. This would include methods used for seasoning, machining, and grading if appropriate. It also may limit the species that can be used for the product.

— The species from which the sample was drawn constitute the species of the reference population. Where a number of species can be used for a particular product, it is important that all those species are represented in the sample so that they can all be part of the reference population.

— The grade of a product is the direct link with the design structural properties used. It is a very important descriptor.

— Most timber products have size effects, so any statement of properties needs to be associated with particular sizes. In some cases, a characteristic value will be size-specific, and in others, it will be normalized to a standard size. In either case, the cross-sectional dimension that was used as the basis for the characteristic value is important.

— Structural properties (especially the modulus of elasticity) are affected by moisture content in the timber at the time of testing. The moisture content and its relationship with the specification for the product need to be known. Where the product is specified as unseasoned, it is enough to know that the moisture content was above fibre saturation point at the time of testing. Where the product is specified as seasoned, the allowable moisture content range within the definition of the term "seasoned" is part of the definition of reference population.

— It is widely accepted that some treatments have an effect on structural properties. For example, heat treatments can increase density and modulus of elasticity. Thus, where a treatment is applied, some detail about the treatment will be required. Again, where the treatment is a heat treatment, the temperature and duration of the treatment may both be crucial. Where the treatment is an impregnation process, then the pressure of application and the temperature of any redrying may be important.

— Properties of logs and hence, the timber produced from them can change over time. Some of these variations may be seasonal, and others may reflect different silvicultural practices at the time the logs were grown. It is important that the sampling period be a part of the definition of the reference population.

B.6 Commentary on sampling

The key to this requirement is that the sample should be representative of all of the variants in the defined product. For products that are obtained from widely varying geographic regions, or a number of different species, then there may be many combinations of growing environment, species, and production method in the reference population. Each of these combinations must have a large enough sample so that the range of properties in each combination is adequately represented.

B.6.1 Commentary on sampling method

Some testing bodies use stratified sampling to enable all variants in the reference population to be represented. Others use a large sample size randomly obtained to include all of the combinations.

Samples must be randomly taken to avoid any unintended or deliberate bias.

— Unintended bias may be introduced by restricting specimen characteristics. (For example, where longer lengths only are sampled, product obtained by docking is excluded from the sample though it may be part of the reference population.)

— Deliberate bias may be introduced by only sampling from one part of the grade. (For example, if only the specimens with high grading parameters are selected, then features in products that have low grading parameters are not part of the sample, though they may be part of the reference population.)

B.6.2 Commentary on sample size

The key to ensuring a representative sample is to have a large number of pieces. However, a compromise inevitably has to be made between obtaining adequate representation of the reference population and the cost of sampling and testing a large number of pieces.

Evaluation of characteristic strengths requires estimating the population property with 75 % confidence from the test data. This factor is a function of both the sample size and the V of the property. The larger the sample size, the smaller the effect on the confidence limit.

It is possible to use the expected confidence limit to estimate the sample size based on the expected reduction of the characteristic property calculated from the test data.

The estimation of the population property with 75 % confidence is given by:

$$X_{0.05,\,0,75} = X_{0,05}\left(1 - \frac{k_{0,05,\;0,75}\,V}{\sqrt{n}}\right) \quad \text{(B.1)}$$

This can be adapted to give an estimate of n.

$$n = \left(\frac{X_{0,05}\,k_{0,05,\;0,75}\,V}{X_\Delta}\right)^2 \quad \text{(B.2)}$$

where

$X_{0.05}$ is an estimate of the test result 5th percentile. Normally the anticipated design characteristic value is close enough;

X_Δ is the target difference between the reported characteristic value and the test result 5th percentile. ($X_{0,05} - X_{0,05,\,0,75}$);

$k_{0,05,\,0,75}$ is the factor for the 5th percentile value with 75 % confidence taken from Annex A of this part of ISO 12122. It is a function of the analysis method selected and the sample size;

V is an estimate of the coefficient of variation of the population. Without having tested the sample, it is only an estimate.

EXAMPLE Selection of sample size

In this example, bending tests will be performed on a softwood with an expected design value of around 20 MPa. The V is unknown, but conservatively estimated at 45 %. The definition of the reference population includes material that may be drawn from two different regions.

The sample size is required for a difference between test result and characteristic value of 1 or 2 MPa. A log-normal analysis of the data will be used.

To sample the full range of product from both of the growth regions, around 50 pieces need to be taken from each region. This will give a total of around 100 pieces in the aggregate sample.

For a log-normal analysis of the data, $k_{0,05,\,0,75}$ is 1,07 for around 100 specimens.

So for difference = 2 MPa, $n = \left(\frac{20\times 1,07\times 0,45}{2}\right)^2 = 23,2$

So for difference = 1 MPa, $n = \left(\frac{20\times 1,07\times 0,45}{1}\right)^2 = 92,8$

It can be seen that if the sample size is around 100, then the difference could be expected to be around 1 MPa. It is unlikely that all variants of this type of product could be adequately sampled with less than 100 specimens, so the larger sample size is more appropriate.

B.7 Commentary on sample conditioning

The product as tested must still satisfy the product specification. It must be stored in such a way that the condition of the product at the time of testing would still satisfy the specification of the product reference population.

Where it is impractical to condition specimens prior to test, it is permissible to adjust the test data to be equivalent to test data taken at standard conditions, providing good models for those adjustments are documented.

B.7.1 Commentary on product moisture content

In general, a product specification will include limits on its moisture content. For example, if the product is classified as "seasoned", then the relevant International Standard will define "seasoned" with acceptable moisture content for the product.

The product must be stored so that at the time of test, the moisture content of the test specimens must fall within the defined acceptable moisture content range from the product specification.

For example, an "unseasoned" product may be sampled for testing to determine characteristic values. A common definition of "unseasoned" products is one that has a moisture content higher than 25 %. The product must therefore be stored awaiting test so that its moisture content remains above 25 %. For most environments, this will involve storing in a humid atmosphere.

Another example may be a product that has a moisture content specification of: "average moisture content to be between 12% and 15%, with no piece greater than 19%". The timber must be stored in an atmosphere that will give an equilibrium moisture content of 12 % to 15 %, probably near the middle of the range. At the time of testing, moisture contents will be evaluated to ensure that the timber as tested complied with its relatively precise moisture content specification. If the measured moisture contents were outside the range, some adjustment of the results is necessary. These adjustments must use established models of the relationship between the tested properties and moisture content.

B.7.2 Commentary on product temperatures

It is rare for a product to have a temperature range specified. However, timber is generally intended to be used within a temperature range defined by human comfort. Hence, testing at ambient laboratory temperature is generally sufficient.

If a product is specified as appropriate for extreme temperatures (either low or high), then it should be tested under conditions for which its specification is valid.

B.8 Commentary on testing

B.8.1 Commentary on test method

Test methods must be appropriate for the product specified in the reference population. They must anticipate normal failure modes of the product when loaded in service loading. For example, shear tests should produce shear failures, however some shear tests may produce bending failures on some specimens. In estimating characteristic shear strength, data from any other type of failure may be included, but the results must be interpreted as a lower bound estimate of the shear strength of those specimens. Care must be taken in establishing characteristic values where the data includes combined failure modes as the *V* is often underestimated.

Test methods also specify the data to be collected and calculations required to determine failure strength or test modulus of elasticity.

B.8.2 Commentary on test data compatible with product description

Clause 7 described the need to store the test specimens so that their condition matched the requirements of the product specification. However, in spite of efforts to achieve this outcome, there may be some tests in which the measured conditions of the specimens were outside the specification.

Where measurements at the time of testing showed that the specimens were outside the specified conditions of the product, then the raw data must be corrected using an acceptable behaviour model. For example, ASTM D1900 gives methods for correcting results for minor variations between the measured and specified moisture content.

It is also possible to combine test results from samples of different variations of the same product. A common variation would be size. In this case, the raw data can be transformed to a standard size using a documented size effect. This transformation should be one that is appropriate for that specific product and supported by research data or a size effect model in a standard that applies to that product.

See commentary on A.4 for an example of pooling data for different sizes.

B.9 Commentary on evaluation of characteristic values for structural properties

B.9.1 Commentary on structural properties

This clause differentiates characteristic values into two types.

a) Strength and modulus of elasticity, which must be combined with a geometric parameter to calculate a characteristic capacity. An example of this is sawn timber in which the characteristic bending capacity is found by multiplying a characteristic bending strength by the section modulus of the cross-section. In this case, the characteristic value sought is the characteristic bending strength (f_m) of the material, and it can be used for a variety of different cross-sections to deliver different bending moment capacities ($M = f_m Z$).

b) Capacity and stiffness, which can be directly compared with an action effect on the member. An example of this is I-joists. The overall performance of this member is a function of its specific manufacture and its size. The moment capacity (M) must be published directly as it is not possible to characterize the member with a unique bending strength.

Both methods of interpreting data will lead to a characteristic value. For properties in (a) they will be characteristic material properties, and for properties in (b) they will be characteristic component capacities or stiffness. The methods used in this document are compatible with both interpretations. The type of characteristic value reported will be a function of the type of product.

Some characteristic values are based on the mean value and the remainder on the 5th percentile value. Table B1 categorises the characteristic values into either type based on the property represented.

Table B.1 — Classification of characteristic values for structural properties

Characteristic properties/value	Characteristic capacities and stiffnesses	Basis
Bending strength f_m	Bending capacity M	5th percentile
Tension strength $f_{t,0}$ parallel to grain	Tension capacity N_t	5th percentile
Compression strength $f_{c,0}$ parallel to grain	Compression capacity N_c	5th percentile
Shear strength f_s	Shear capacity V	5th percentile
Compression strength perpendicular to grain $f_{c,90}$	Compression capacity perpendicular to grain $N_{c,90}$	Mean
Tension strength perpendicular to grain $f_{t,90}$	Tension capacity perpendicular to grain $N_{t,90}$	5th percentile
Modulus of elasticity E	Flexural stiffness EI Tensile stiffness EA Compressive stiffness EA	Mean (5th percentile)[a]
Shear Modulus G	Shear stiffness GA	Mean (5th percentile)[a]

[a] Some products a 5th percentile value may be required in addition to the normal mean-based value.

B.9.2 Commentary on characteristic value based on the mean

Either the arithmetic average of the test results or the mean of a distribution fitted through the data can be used as the basis of the estimate of the mean for the characteristic value.

For Characteristic modulus of elasticity, the mean is used as the characteristic value, but any strength based on the mean value (e.g. bearing strength) should be modified to give the lower single sided 75 % confidence limit. Normal statistical methods to find the confidence limit on the mean can be used.

B.9.3 Commentary on characteristic value based on the 5th percentile

For most strength properties, the characteristic value is based on an estimate of the 5th percentile value with 75 % confidence. This requires

— estimation of the 5th percentile from the test data, and

— estimation of the 5th percentile value with 75 % confidence from the population estimate obtained from testing of a finite sized sample.

Information supporting both of these steps is given in an Annex A.

B.10 Commentary on report

B.10.1 Commentary on report general

The report must present all of the information that gives a reader sufficient detail to correctly identify the population sampled, the tests performed, all statistical and analytical processes and the limitations on the final characteristic value.

This is necessary to ensure that the characteristic value is not taken out of context and to make correct interpretations of the data presented. In an international environment, it is particularly important that readers are given detail about the sampling program and test methods used, so that any corrections to different national requirements can be devised.

Where the characteristic values are to be used for reliability based design data, then information on the entire distribution may be required in addition to the characteristic value.

B.10.2 Commentary on reference population

The description of the reference population must include any factors that may affect structural properties either in the resource or in the manufacture of the product.

B.10.3 Commentary on sampling

The sampling program must also be described in sufficient detail to clearly define any limitations on the application of the characteristic value. Where the reference population incorporates known variations, then the sampling used to capture those variations must be documented in the report.

The methods and justification used to select sample size should also be presented in the report.

Sample preparation or conditioning should also be detailed so that its condition at test can be related to the specification of the reference population.

B.10.4 Commentary on test methods

The easiest way to refer to the test methods undertaken is to give the detail of the test standard. Where the test standard is not an ISO or readily-available national standard, detail of the test method should be reproduced in the report.

Any deviation from the test standard must be described in detail. Where there is a difference between the test conditions and the specification for the reference product, it may be necessary to modify the results to give them compatibility. These modifications must be described in detail and should include the reference for the modification model.

B.10.5 Commentary on analysis methods

A number of options for analysis methods are presented in Annex A. The method and all of the parameters used must be identified. Where an alternative method (e.g. from a National Standard) has been used, then the reference to it must be complete enough to enable the analysis to be replicated by a third party.

B.10.6 Commentary on characteristic values

The end point of the use of this standard is a characteristic value or a set of characteristic values that relate to the reference population. A large number of assumptions, and behaviour models have been applied to develop the characteristic value or values, and the use of any more than three significant figures implies an accuracy that cannot be substantiated by the process.

B.11 Commentary on pooling of data

Frequently, because of species similarities or marketing convenience, it is desirable to combine two or more species into a single marketing group. Also, characteristic values for a single grade may be derived from test data on a number of sizes. When this is done it is necessary to determine the characteristic values for the combined pooled data. There are no limitations as to how many data subsets can be combined to form pooled data.

Test data from a number of different test programs can be pooled to increase the size of the sample. However, the data must be standardised and sufficient information on the standardization models must be provided in the report to enable comparisons with other standardization methods.

For example, it is common to pool data from tests performed on different sizes of the same product. In this case, size effect factors are used to standardize the data to a single reference size. However, different national standards may use different forms or values of the size effect factors. Sufficient detail in the report will enable an interested party in a different country to use their own size effect factors to check the effect on the characteristic value reported.

The following examples refer to subsets and pooled data depicted in Figure A1.

Example of pooling	Subsets	Pooled data
Species groups	Data for individual species	Data for grouped species
Production sizes	Data for individual sizes: a) size-dependent properties b) size-independent properties	Data for grouped sizes
Production regions	Data from same product collected in regional sampling programs	Data for national population
Production monitoring	Data from the same product manufactured over different time periods	Product data over time

B.11.1 Commentary on methods of pooling

Standard statistical methods for aggregating data use standard statistical tests such as Chi Square, Tukey and Kruskal-Wallis tests, which can be found in most statistical text books.

B.11.2 Example for pooling characteristic values based on mean values

This method is based on grouping requirements in ASTM D1990:2007. It is used for determination of characteristic values for relatively small data sets of lesser volume species that are produced in North America and are not necessarily grouped together. The same characteristic values are applicable whether the species are produced and marketed separately or together.

A nonparametric analysis of variance on each data subset standardised in accordance with A.4.3 is conducted as follows.

a) Rank each subset by mean value.

b) Perform a Kruskal-Wallis test to determine the significance level.

The characteristic value is calculated on data pooled from the subset data as follows.

a) Where the test is not significant at the 0,01 level, the mean characteristic value for the pooled data are the mean of the combined subset data.

b) Where the test is significant at the 0,01 level, the data subset with the lowest mean value is taken as the reference subset. All other subsets are compared with the reference subset to select a grouping of subsets indistinguishable from the reference subset using a Tukey multiple comparison test on the means at a 0,01 significance level. The mean characteristic value for the pooled data is determined from the combined data of all the subsets in this grouping.

B.11.3 Example for pooling characteristic values based on 5th percentile values

This method was based on grouping requirements in ASTM D1990- 2007.

A provisional characteristic value based on all the pooled data standardised in accordance with A.4.3 is calculated in accordance with 9.3. Each of the data subsets are compared with the characteristic value as follows:

a) Determine the percentage of test values less than the provisional characteristic value in each data subset;

b) Perform a Chi Square test to determine if the percentage of pieces below the group value is statistically significant for each species in the group.

NOTE For appropriate sensitivity from the Chi Square test, each data subset should have in excess of 100 test results.

The characteristic value is calculated on data pooled from the subset data as follows:

a) Where the test is not significant at the 0,01 level, the characteristic value for the pooled data are the provisional characteristic value;

b) Where the test is significant at the 0,01 level:

   i. Rank the subsets by percentage of pieces below the provisional characteristic value;

   ii. Begin with the two data subsets with the highest percentage of pieces below the provisional characteristic value;

   iii. Use the Chi Square test to determine if the percentage of pieces below the provisional characteristic value are comparable;

   iv. Where the Chi Square test is not significant at the 0,01 level, add the data subset with the next highest percentage of pieces below the provisional characteristic value;

   v. Repeat steps iii and iv, adding the data subset with the next highest percentage of pieces below the provisional characteristic value until the test is significant at the 0,01 level;

   vi. The characteristic value for the pooled data is determined in accordance with 9.3 from the combined data of the last grouping of data subsets for which the Chi Square test was not significant at the 0,01 level.

Annex C
(informative)

Examples

C.1 Data for examples

The following data taken from tests on 93 specimens of 90 × 35 sawn seasoned structural softwood material is used to illustrate the calculations of characteristic values. The data has been ranked in ascending order of modulus of elasticity and bending strength.

Table C.1 — Raw data

Ranked MOE GPa	**Ranked bending strength** MPa	**Ranked ln(strength)**	**Ranked MOE** GPa	**Ranked bending strength** MPa	**Ranked ln(strength)**
6,52	18,42	2,91	11,71	52,80	3,97
6,58	20,69	3,03	11,76	53,12	3,97
7,53	20,99[a]	3,04	11,76	53,42	3,98
7,63	21,24[b]	3,06	11,84	53,61	3,98
8,34	23,01	3,14	11,89	53,76	3,98
8,40	23,41	3,15	11,90	54,30	3,99
8,59	24,07	3,18	12,00	54,60	4,00
8,79	24,11	3,18	12,01	54,95	4,01
8,82	24,74	3,21	12,26	55,40	4,01
8,85	24,79	3,21	12,41	55,50	4,02
8,91	25,96	3,26	12,52	56,55	4,04
8,97	27,40	3,31	12,58	58,80	4,07
9,12	28,84	3,36	12,64	59,85	4,09
9,32	29,05	3,37	12,70	60,30	4,10
9,38	29,06	3,37	12,81	60,50	4,10
9,43	29,10	3,37	12,89	61,69	4,12
9,50	29,72	3,39	12,92	61,95	4,13
9,57	31,55	3,45	13,06	62,45	4,13
9,62	31,60	3,45	13,07	62,74	4,14
9,91	32,50	3,48	13,39	63,59	4,15
10,03	34,55	3,54	13,39	64,84	4,17
10,18	34,71	3,55	13,46	67,59	4,21
10,26	34,75	3,55	13,47	69,26	4,24
10,26	36,27	3,59	13,54	73,31	4,29
10,31	36,49	3,60	13,55	75,31	4,32
10,32	36,71	3,60	13,66	75,82	4,33
10,33	36,90	3,61	13,87	75,92	4,33

a Third lowest ranked data.

b Fourth lowest ranked data.

Table C.1 *(continued)*

Ranked MOE GPa	**Ranked bending strength** MPa	**Ranked ln(strength)**	**Ranked MOE** GPa	**Ranked bending strength** MPa	**Ranked ln(strength)**
10,44	38,21	3,64	14,02	77,92	4,36
10,44	38,27	3,64	14,27	78,19	4,36
10,45	39,68	3,68	14,42	80,36	4,39
10,55	39,99	3,69	14,57	83,18	4,42
10,56	41,42	3,72	14,74	83,27	4,42
10,60	42,20	3,74	15,28	83,55	4,43
10,61	42,36	3,75	15,52	83,57	4,43
10,62	43,78	3,78	15,67	85,72	4,45
10,65	44,68	3,80	15,79	87,77	4,47
10,77	44,81	3,80	16,25	90,08	4,50
10,88	45,10	3,81	16,26	90,14	4,50
10,90	46,43	3,84	16,32	90,82	4,51
10,99	47,39	3,86	16,33	92,26	4,52
11,02	48,62	3,88	16,40	92,81	4,53
11,24	48,68	3,89	16,81	93,28	4,54
11,35	50,76	3,93	16,87	95,76	4,56
11,35	51,77	3,95	17,05	96,46	4,57
11,48	51,79	3,95	17,06	101,13	4,62
11,48	51,92	3,95	17,10	115,06	4,75
11,63	52,58	3,96			

[a] Third lowest ranked data.

[b] Fourth lowest ranked data.

Table C.2 — Summary of test results

	MOE GPa	**Bending strength** GPa	**For log-normal dist ln(strength)**
n	93	93	93
Average or mean	11,907	54,133	3,897
Standard deviation	2,570	22,948	0,448
V	0,216	0,424	—

Average determined as: $$\bar{X} = \frac{\sum_{i=1,n}[x_i]}{n} \quad \text{(C.1)}$$

Standard deviation determined as: $$s_x = \sqrt{\frac{\sum_{i=1,n}\left[x_i - \bar{X}\right]^2}{n-1}} \quad \text{(C.2)}$$

Coefficient of variation determined as: $$V = \frac{s_x}{\bar{X}} \quad \text{(C.3)}$$

C.2 Characteristic modulus of elasticity

The characteristic value of modulus of elasticity is found using 9.2.

Characteristic value based on the mean (see 9.2).

Characteristic MOE = arithmetic average of MOE values

= 11,9 GPa (directly from the data summary above)

Where the mean modulus of elasticity is required with a 75 % confidence limit, this can be found using A.1.

$$\text{Here } X_{\text{mean},0,75} = X_{0,05}\left(1-\frac{k_{\text{mean},0,75}V}{\sqrt{n}}\right) \quad \text{(C.4)}$$

With:

$K_{\text{mean},0,75}$ = 0,68 (interpolating between n = 50 and n = 100 in Table A1)

$$V = \frac{\text{Standard deviation}}{\text{average}} = \frac{2,570}{11,907} = 0,216$$

n = 93

$$X_{\text{mean},0,75} = 11,91\left(1-\frac{0,68\times 0,216}{\sqrt{93}}\right) = 11,73 \text{ GPa}$$

C.3 Characteristic bending strength

The characteristic value of bending strength is found using 9.3. Three different evaluations will be used as given in A.2.

a) Use of non-parametric data analysed using ASTM D2915 (see A.2.1).

Determine the order statistic for the sample size:

Using Table 2 in ASTM D2915: Order statistic = 4 for n = 102 and = 3 for 78 specimens. Interpolating between these two sample sizes, a sample of 93 specimens corresponds to an order statistic of 3.6.

Determine the characteristic bending strength:

This can be found by interpolating from the data between the third and fourth lowest ranked data. The third lowest data (order statistic = 3) = 20,99, and the fourth lowest data (order statistic = 4) = 21,24.

Therefore, for order statistic = 3,6, characteristic bending strength = 21,14 MPa

b) Evaluation by non-parametric analysis to AS/NZS 4063 (see A.2.2).

The 5th percentile value from the ranked data has an order statistic = 93 × 0,05 = 4,65. By interpolation of the bending strength data above, this equates to:

$X_{0,05}$ = 23,05 MPa

Formula (A.2) gives the characteristic value as a 5th percentile value with 75 % confidence.

$$X_{0,05,\,0,75} = X_{0,05}\left(1-\frac{k_{0,05,\,0,75}V}{\sqrt{n}}\right) \quad \text{(C.5)}$$

With:

$k_{0,05,\,0,75}$ = 1,86 (interpolating between n = 50 and n = 100 in Table A.2)

$$V = \frac{\text{Standard deviation}}{\text{average}} = \frac{22,948}{54,133} = 0,424$$

$n = 93$

$$X_{0,05,\ 0,75} = 23,05\left(1 - \frac{1,86 \times 0,424}{\sqrt{93}}\right)$$

= 21,17 MPa

c) Evaluation by fitting data to a distribution (see A.2.3).

A log-normal distribution was selected for fitting to the data. The logarithms of the strength are shown in the data above:

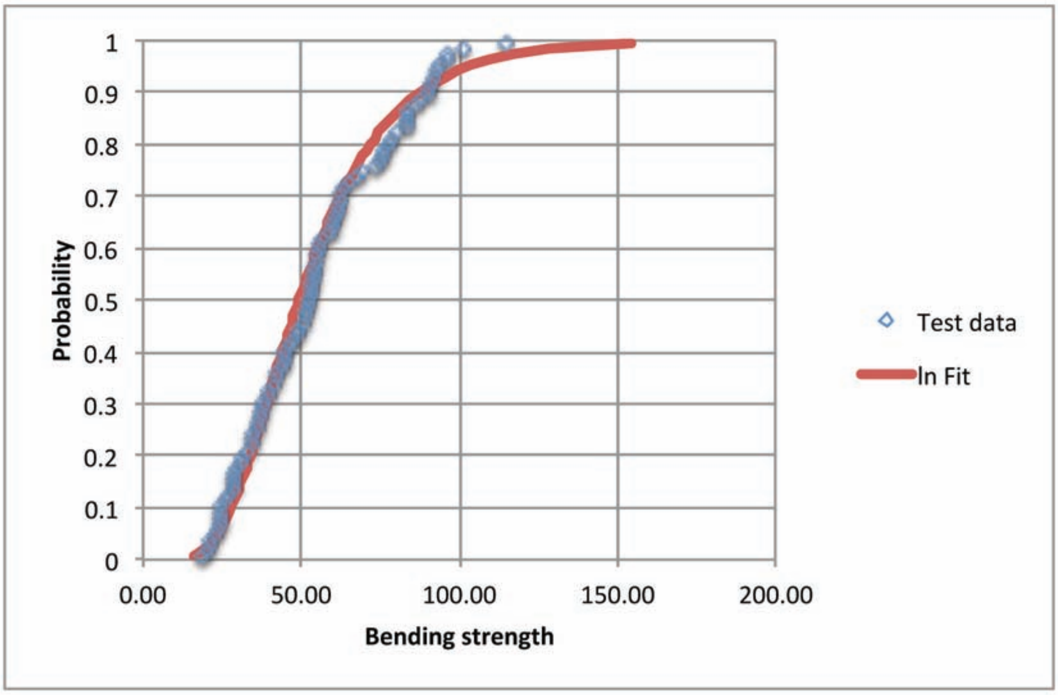
Mean of the logarithms: $m = 3,897$

Standard deviation of the logarithms: $s = 0,448$

The log-normal fit is of the form:

$X_p = \exp[3,897 + Z(p)0,448]$

This is shown in the plot below.



5th percentile value of the distribution is given by:

$X_{0,05} = \exp[3,897 + Z(0,05)0,448] = 23,59$ MPa

The characteristic value is given by Formula (A.2)

$$X_{0,05,\ 0,75} = X_{0,05}\left(1 - \frac{k_{0,05,\ 0,75}V}{\sqrt{n}}\right) \quad \text{(C.6)}$$

With:

$X_{0{,}05,\ \text{log-normal}}$ = 23,59 MPa

$k_{0{,}05,\ 0{,}75}$ = 1,078 (interpolation between n = 50 and n = 100 in log-normal column of Table A.2)

$$V = \frac{\text{Standard deviation}}{\text{average}} = \frac{22{,}948}{54{,}133} = 0{,}424$$

n = 93

$$X_{0{,}5,\ 0{,}75} = 23{,}59\left(1 - \frac{1{,}078 \times 0{,}424}{\sqrt{93}}\right) = 22{,}47\ \text{MPa}$$

The Kolmogorov-Smirnov goodness of fit test can be used to show that:

— Kolmogorov-Smirnov parameter = 0,076.

— Critical value = 0,126. (significance level: 0,05)

Hence, the distribution satisfies the goodness of fit test.

C.4 Comparison of results

The three methods have delivered similar characteristic bending strengths:

— non-parametric data analysed using ASTM D2915 = 21,14 MPa;

— non-parametric data analysed using AS/NZS 4063 = 21,17 MPa;

— data fitted to a log-normal distribution = 22,47 MPa.

Bibliography

[1] ASTM D1990 — *Standard practice for establishing allowable properties for visually graded dimension lumber from in-grade tests of full-size specimens*

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