Guide for the testing and evaluation of timber connection Category D

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AEFAC
Australian Engineered Fasteners and Anchors Council

Contents

REVISION SHEET

Revision Number	Clause/ Figure/ Table	Revision type	Issued on
1.0		Initial release.	20/09/2022
1.1	Section 2.2 Sampling method and sample size. Minimum of 10 test values are recommended for a test series. Section 4.4, Table 2: Sampling factors, k_t. Removed row for n=5 and n=7.	Minor revision.	08/08/2023

PREFACE

This Guide has been developed by the Australian Engineered Fasteners and Anchors Council (AEFAC) Timber Fastening Technical Committee, to assist in the testing and evaluation of timber connections incorporating mechanical fasteners classified in AS 1649 as Category D fasteners.

The procedures of AS 1649 is a ‘soft’ conversion from working stress to limit states design lacking transparency and limited in its coverage, particularly for Category D fasteners.

This Guide adopts a different approach using prototype testing methodology for the derivation of the characteristic values.

This Guide is developed to assist the suppliers of category D fasteners to provide characteristic values and appropriate capacity factors for their fasteners for use in design together with and/or in place of other information provided in AS 1720.1.

Generally, the design capacities for the Category D connections calculated from testing and evaluation in accordance with this Guide may result in higher design capacities than those calculated in accordance with AS 1649:2001 and capacity factors in AS 1720.1:2010. This is partly due to direct calculations of the characteristic capacities from test results as suggested in this Guide.

SECTION 1
SCOPE AND GENERAL REQUIREMENTS

1.1 Scope

This Guide outlines methods for testing timber connections incorporating mechanical fasteners and procedures for the evaluation of the test data to obtain design information for timber connection **Category D** as defined in AS 1649.

The purpose of testing is to determine the load-deformation characteristics of the connection to define failure appropriate for the application.

This Guide describes the derivation of the characteristic capacity (R_k) from first principle and the corresponding capacity factor (ϕ) in accordance with the National Construction Code (NCC) verification method BV1 (NCC, 2019). These values (R_k and ϕ) are to be used together with other applicable modification factors (k_{mod}) specified in AS 1720.1 for design using Eq. 1.

$$Design\ capacity\ of\ connections = R_d = \phi k_{mod} R_k \qquad \text{Eq. 1}$$

The Guide uses information on the characteristics of the fastener, the timber, and the intended uses to devise appropriate tests for the evaluation of the timber connection performance using a **prototype testing methodology**.

The application of the procedure described in this Guide is limited to:

- Connection failure due to failure in the timber, excluding tension perpendicular to grain failure;
- Connection resistance in the timber part(s) of the connection assembly; and
- Seasoned timber.

COMMENTS:

1. The characteristic values can only be defined for an applicable or reference population of connections with reference to a failure mode.
2. In general, $k_{mod} = 1$ if the design conditions are the same as the test conditions. If the design conditions are not the same as the test conditions, then some judgement must be made to determine what other k_{mod} factors specified in AS 1720.1 are applicable, e.g., k_1 the load duration factor for strength. A factor is not applicable if it has already been accounted for in the tests e.g., k_{16} a factor that allows an increase in capacity of a nail in shear if driven through a metal plate (because it has been automatically accounted for in the test).
3. 'Prototype testing methodology' means: (i) full-size specimens shall be used in testing, and (ii) the test specimen shall be designed to suit the purpose of the test. AS 1649 provides some typical test setups.
4. For Category D fasteners, failure can occur in either the metal or the timber. The evaluation procedure in this guide is applicable for timber failure of the connection.
5. Failure can be defined by either maximum load capacity or load capacity at a defined deformation
6. Category D fasteners may be used to join timber with other non-timber members. This Guide is only applicable to the timber part(s) of the connection assembly.

1.2 Definitions

Category D fasteners: are defined in AS 1649 as fasteners acting as brackets capable of transferring load from the face of one joint member to the face of another, the two faces involved usually lying in planes at right angles to each other, see Figure 1. It consists of a pre-formed metal component attached to the structural member with metal fasteners such as nails, screws, and bolts.

Characteristic value: The value of a property taken to represent that of the **reference population**, in this Guide it is taken to be the 5-percentile value with 75% confidence based on a lognormal distribution unless defined otherwise.

Connection: A structural component or system consisting of individual members which are connected/joined with a single or an assembly of fasteners.

Connector: A unit connecting/fastening device, together with other components that may be required, that enables a structural connection to be made between two or more timber members, or between timber and another structural material member.

Fastener: Interchangeably used with the term connector.

Joint group: The classification assigned to a timber species or species group for calculating joint capacity in AS 1720.1. The joint group classification based on timber density is provided in AS 1649.

Joint: Interchangeably used with the term connection.

Reference population: also known as the applicable population, it is the population to which the characteristic value applies.

> COMMENT: ISO 12122 uses the term 'reference population'. The reference population needs to be fully defined as this is the basis for the assessment of the coefficient of variation, an important part of the determination of the characteristic value from test data.

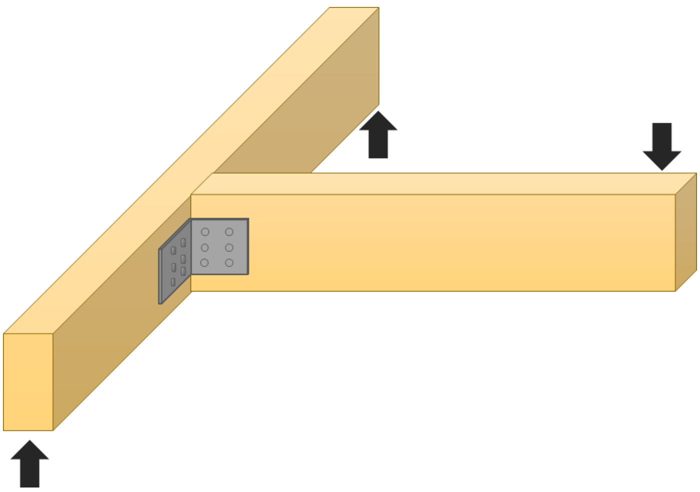


Figure 1: Category D fasteners

1.3 Notations

The following symbols are used in this Guide.

k_{mod}	=	modification factors as specified in AS 1720.1
k_t	=	sampling factor which is a function of the number of tests (n) and the coefficient of variation of the reference population of the connection (V_p)
n	=	number of test values
$\bar{P}$	=	mean value of the strength resistance from the test data which has been corrected for density
P_{acc}	=	load corresponding to the acceptable maximum deformation (δ_{acc}) of the test data
P_{max}	=	maximum load from the test data
P_t	=	strength resistance from the test data
$P_{t,i}$	=	strength resistance from the test data for test value i
$P_{tc,i}$	=	corrected value of the strength resistance from the test data for test value i corrected to refer to $\rho_{m,ref}$
$P_{u/sl}$	=	the strength resistance corresponding to unzipping/unbuttoning/slip effect
R_d	=	design capacity
R_k	=	characteristic value of the strength resistance of the fastener, i.e., characteristic capacity
V_f	=	coefficient of variation as the result of fabrication variation
V_m	=	coefficient of variation as the result of material variation (dependent on the mode of failure and the properties of the timber)
V_p	=	coefficient of variation for the reference population
V_t	=	coefficient of variation of the test results
δ_{acc}	=	acceptable maximum deformation
δ_{max}	=	deformation corresponding to the maximum load (P_{max})
$\bar{\delta_t}$	=	mean deformation corresponding to the test load capacities ($\bar{\delta_t}$) used to calculate the characteristic strength of the fastener
$\delta_{t,i}$	=	deformation corresponding to test load capacity for test value i
$\rho_{m,ref}$	=	mean value of the timber density of the reference population for which the test results are applied
$\rho_{m,test}$	=	mean value of the measured density of all timber pieces of the test specimens
ϕ	=	capacity factor

1.4 Conduct of tests

The conduct of the tests described below are predominantly in accordance with AS 1649 unless specified otherwise.

1.4.1 Apparatus

As per AS 1649, *a testing machine of Class B or better* (in accordance with AS 2193) shall be used to conduct the tests.

All measurements (load, time, and displacement) shall be recorded electronically using a suitable data acquisition system.

It is preferable for connections tested in compression or tension to have the ability for self-alignment.

> COMMENT: As noted in AS 1649, for joints tested in tension, it is preferred for the apparatus used for holding or supporting the specimen to allow for self-alignment. For joints tested in compression, it is preferred for the apparatus used for applying the compression load to allow for self-alignment rather than one that is fixed.

1.4.2 Test conditions for timber specimens

The timber for the test specimens shall be conditioned before and after the assembly of the connection such that when the specimens are tested they are under similar conditions as the actual service conditions of the connection in the structure.

When the purpose of the testing is to compare the performance of connections under similar conditions, then the standard conditions as described in Section 1.4.3 and 1.4.4 shall be used for the specimen conditions and test environment conditions, respectively.

1.4.3 Timber preparation for standard conditions

For standard conditions, the test specimens shall be tested in seasoned conditions and shall be stored to ensure the moisture content of the timber *within the range of 10% to 15%,* as per AS 1649.

> COMMENT: As noted in AS 1649, for most species, an average moisture content of 12% can be achieved if stored in an environment of 65% relative humidity at 20°C for a sufficient period.

1.4.4 Test environment for standard conditions

The test shall be conducted at a *temperature of not less than 20 ℃* unless the test aims to examine the effect of lower temperatures on the connection, as per AS 1649.

1.4.5 Time of testing

The *specimens shall be kept for at least 14 days after assembly*, including the installation of fasteners, before testing to allow for relaxation of the materials, as per AS 1649.

1.4.6 Moisture content and density

The moisture content and density of each specimen shall be determined immediately after testing in accordance with AS/NZS 1080.1, using the oven-dry method, and AS/NZS 1080.3, respectively, as per AS 1649.

It is also suggested, that the density of the timber to be used is determined before preparation of the specimens to ensure the timber density is representative of the reference population.

1.4.7 Number of specimens

The suitable sample size shall be determined in accordance with Section 2.2.

1.5 Assignment of a joint group for test species

To obtain loads for the fastener for a specific joint group provided in AS 1720.1, the mean air-dry density of the selected timber pieces shall be representative of the mean air-dry density of the joint group as provided in AS 1649 and provided here in Table 1.

Where necessary, a correction to the test results for the timber density of the samples shall be applied as specified in Section 4.2.

Table 1: Mean density range for joint groups in accordance with AS 1649:2001 for seasoned timber (group mean air-dry density at 12% moisture content)

Joint group	Minimum density for joint group (kg/m^3)	Maximum density for joint group (kg/m^3)	Average density for joint group (kg/m^3)
JD1	940	-	-
JD2	750	935	842.5
JD3	600	745	672.5
JD4	480	595	537.5
JD5	380	475	427.5
JD6	300	375	337.5

1.6 Design of the testing program

A test series shall be designed for each failure mode.

The sampling shall be in accordance with Section 2.

The testing procedures shall be in accordance with Section 3.

The evaluation shall be in accordance with Section 4.

The test report shall be prepared in accordance with Section 5.

SECTION 2
SAMPLING PROCEDURE

2.1 General

The purpose of sampling is to produce test specimens that are representative of the reference population so that the outcomes from the tests can be used to determine the characteristic values for the reference population.

> COMMENT: For timber connections, the sampling must ensure that the timber densities of the samples are appropriate for the reference population such as joint group JD4.

2.2 Sample method and sample size

The sampling method shall produce a sample that is representative of the reference population. It should aim to minimise bias and consider the variations possible within the reference population which may influence the performance of the fasteners in the tests. The sampling method shall be documented and include the measures taken to ensure the attributes of the reference population (as described in Section 2.6) have been taken into consideration.

The sample size (n) is the number of test values obtained from experimental tests. The sample size shall be selected to represent the reference population and to cover the variation of the product that can affect the tested properties.

In this Guide, a minimum of 10 test values (i.e., n=10) are recommended for a test series. The same failure mode shall be observed for all specimens in a test series.

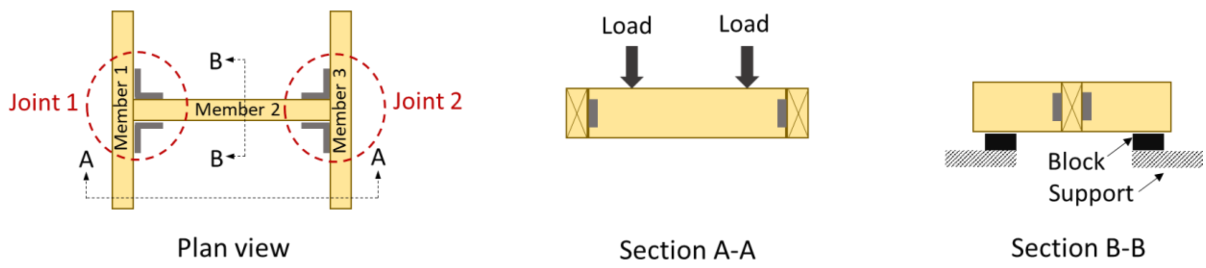
> COMMENT: Testing can be done using a symmetrical setup, such as a H-setup shown in Figure 2, where it is recommended that the difference in the density of timber member 1 and member 3 is not greater than 10% or ±50 kg/m^3, whichever is lower. For this setup, the maximum number of test values that can be taken from a single experiment is two, since two joints are tested and the two test values will have the same capacity.

2.3 Requirements for fasteners

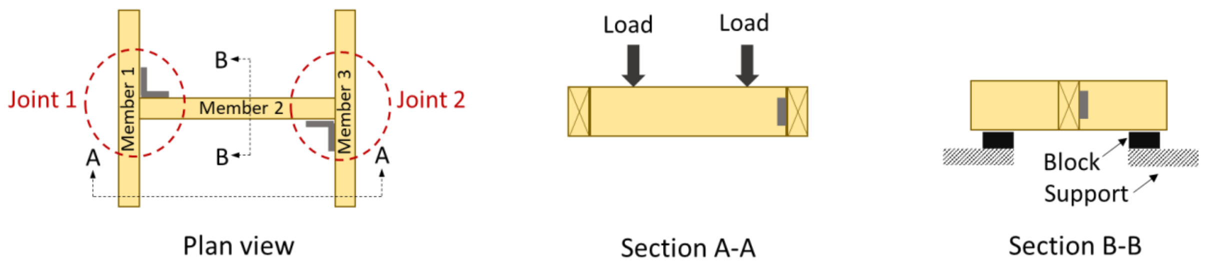
The fasteners used in testing shall comply with the following requirements:

(i) The fasteners shall be representative of commercial production; and
(ii) The fasteners shall be representative of the specifications provided in the test report; precise details of all components including relevant product standards, material properties, and geometry of the fasteners (size, head, shank, etc.) used in tests shall be provided.

COMMENT: Minor details of fastener shape and size may affect the performance of the connections.



(a) Example 1: Maximum sample size from a single test is two (n=2)



(b) Example 2: Maximum sample size from a single test is two (n=2)

Figure 2: H-type assembly for test specimen

2.4 Requirements for timber

The timber used in testing shall comply with the following requirements:

(i) The timber shall be representative of the reference population.

COMMENTs:

1. As noted in AS 1649, for sawn timber of a required species, a random selection of timber members from a sufficiently large parcel, or preferably from several parcels, is usually considered as representative.
2. The reference population may vary with the purpose of the test. A critical part is specifying the applicable timber including the density range (e.g., joint groups). The Australian system of classification for timber separates strength classification (based on bending test) and joint classification (based on density). Therefore, if the strength classification of the timber is known it does not necessarily mean that the joint classification of the timber is known. This is in contrast with the European system where timber is classified based on both bending strength and density.
3. Correction for timber density of the samples should be applied when the timber density of the samples is lower or higher than the mean timber density to which the test results are applied (e.g., joint group), see Section 4.2.

(ii) Timber shall have *no significant strength reducing characteristics* except for *small pin knots, and the like, if typical of the species*, as per AS 1649.

(iii) For tests that aim to produce *general design data*, for example for a joint group, the timber shall be a species that is commonly used as structural timber and shall be positively identified, as per AS 1649.

COMMENT: As explained in AS 1649, when determining design values for a specific joint group, the timber used for the test specimens cannot be broadly classified (e.g., Victorian hardwood) such that it can either be a single species or a mixture of several species with a wide range of strength properties.

(iv) The timber *members in each joint shall be taken from one stick*, or when not practical, *from not more than two, which should be from the same tree or closely matched*, as per AS 1649.

COMMENT: As noted in AS 1649, the orientation of the growth-rings in the members is not important (e.g., quarter sawn, back sawn), unless it is an attribute that requires investigation.

2.5 Requirements for the connection assembly

The test connection assembly shall be representative of the intended application, including the following:

(i) The materials of the connecting components.
(ii) The dimensions of the connecting components.
(iii) The method of assembly and the conditions under which the assembly is installed and stored until tested.
(iv) The details of the fastener(s) including edge and end distances, and spacings.
(v) The application of the load and restraint conditions.

COMMENT: As each type of test is designed to investigate a failure mode, the design of the test assembly must ensure that failure will occur in the area of interest. Other parts of the test assembly may be strengthened to ensure that this will happen.

2.6 Description of the reference population

A full description of the reference population for which the characteristic values apply shall be described in the test report. The description shall include any attributes that may affect the performance of the fasteners obtained from the tests and hence the computed characteristic values.

The reference population shall be described with the following attributes:

(i) For the **fastener component**:
   a. Material of the fastener(s);
   b. Dimensions of the fastener(s) (e.g., the diameter of the shank and head of screws/nails/bolts);
   c. Coating of the fastener(s); and
   d. Any other necessary details.

(ii) For the **timber component**:

a. Timber product standard and/or specification;
b. Species or species group;
c. Density and designated joint group;
d. Designated grade;
e. Size range of the product;
f. Moisture condition;
g. Treatment of the product;
h. Date of when the product was manufactured;
i. Presence or exclusion of specific features in the connection (e.g., knots or finger joints); and
j. Any other necessary details.

(iii) For the **connection assembly**:

a. Material of the connecting components (including any non-timber members);
b. Dimensions and geometry of the connection assembly (e.g., connecting member dimensions, fastener hole diameter and tolerances, end distances, edge distances and connector spacings, angle of load to the grain of the timber);
c. Method of assembly;
d. Condition of assembly (e.g., fasteners installed in dry timber and tested in dry conditions); and
e. Any other necessary details.

SECTION 3
TESTING PROCEDURE

3.1 General

This section describes the test procedure for determining the resistance of Category D fasteners when used with timber members to form a structural connection. The aim of the tests is mainly to provide data from which the characteristic resistance of the fastener is derived for design purposes.

The conduct of the tests shall be in accordance with Section 1.4.

A test series shall be designed for each failure mode.

3.2 Test specimens

The test specimens shall follow the sampling procedure described in Section 2.

The moisture contents and densities of the members comprising each joint shall be determined immediately after testing as specified.

3.3 Design of the test setup

Exploratory testing is to be conducted to gain some insights into the performance of the connection for the design of the test program. These include the identification of relevant test factors considered appropriate for the proposed application including relevant failure modes, sampling, testing condition, edge and end distances, angle of load to the grain of the timber, and minimum thickness of the timber.

The test setup, including the specimen configurations, supports for the specimen, and application of the load, shall be determined in such a way that the actions on the test specimen simulate the actions of the actual service conditions of the joint. For example, supports may be necessary to ensure the specimen is restrained against rotation or overturning unless it is expected that the connection will experience rotation in its service condition.

How the load is to be applied and where the deformation is to be measured can only be decided with reference to the specific situation under investigation. Eccentricities not inherent in the design or resulting from actual service conditions and in advert restraints shall be avoided.

The test setup for three specimen configurations, Type X, Type T, and Type H, provided in AS 1649 may be adopted if suitable.

If exploratory tests indicate that the direction of loading affects the performance of the connection, then two series of tests shall be performed: one series for specimens tested in compression and another one for specimens tested in tension.

> Comment: The behaviour of some types of fasteners may not be the same when loaded in compression and tension.

For specimens tested in compression the following requirements shall be followed to ensure the applied load is axial to the test specimen, as per AS 1649:

(i) *The loaded end surfaces of a specimen to be tested in compression shall be essentially plane, square to the faces, and parallel.*
(ii) *The loading surfaces of the testing machine shall, if fixed, be parallel to within ±0.01 mm across the loaded surfaces of the joint assembly*.

For specimens tested in tension the following requirements shall be followed, as per AS 1649:

(i) *Timber members forming a specimen to be tested in tension shall be extended* from the intended dimension of the specimen *to enable the attachment of suitable loading gear*.
(ii) *The design of the loading gear shall be such as not to affect the performance of the specimen and shall be self-aligning so that the applied load is axial to the test specimen.*

3.4 Application of load

The joints shall be tested in tension and/or in compression, as necessary, in a testing machine with a suitable capacity to achieve the maximum load and deformation capacity.

The performance of the connection shall be assessed by its load-deformation curve. Adequate data points shall be collected to enable the determination of this curve.

For static monotonic loading, the increasing load should be applied continuously throughout the test at a constant rate until the maximum load (P_{max}) is reached. The load shall be applied at a rate such that the maximum load is reached in approximately 5 to 10 minutes.

For ductile specimens, it is advised to continue applying the load after the maximum load has been achieved to obtain sufficient information about the ultimate failure mechanism.

COMMENTS:

1. Typically, the maximum load should not be reached in less than 1 minute and no more than 10 minutes. However, if specimens fail in less than 1 minute, it is important not to discard the results to avoid bias in the sample by removing weak specimens. Instead, it is suggested that more tests are conducted with an adjusted load rate.
2. AS 1649 specifies applying the load at a rate of crosshead movement of 0.06 mm +/- 25% per minute, this can be followed if P_{max} is reached in no more than 10 minutes.
3. Once the maximum load is reached, the load rate can be increased for ductile specimens.

3.5 Measurement of deformation

Deformation (or slip) shall be continuously measured using suitable displacement measurement devices such as LVDTs.

Where possible, two displacement measurement devices should be used to measure the displacement such that the slip of the connection can be taken as the average of the displacement measured by the two devices.

The displacement measurement devices shall be attached such that other sources of deformation which are not related to the connection are minimised or avoided.

3.6 Load-deformation curve

The load and time shall be measured and recorded to correspond with each measurement of displacement (slip) to develop the load-deformation curve.

The load-deformation curve shall be used to determine the test capacity of the connection in accordance with Section 4.1.

The load-deformation curve may also be used to determine the connection stiffness and other strength and serviceability considerations including:

(i) Acceptability of the connection deformation under service.
(ii) Compatibility of stiffnesses for load sharing when several connections are used to carry a single action.

SECTION 4
EVALUATION PROCEDURE

4.1 Test strength resistance and corresponding deformation

The following steps shall be followed to determine the test strength resistance (P_t) from the load-deformation curves:

(i) Determine the acceptable maximum deformation, δ_{acc}, and the corresponding load, P_{acc}. The acceptable maximum deformation, δ_{acc}, is the deformation at which the connection is considered to have failed or is unsuitable for its application.

(ii) Determine the maximum load, P_{max}, and the corresponding deformation, δ_{max}.

(iii) Determine the strength resistance from the test data, P_t:

If $\delta_{max} \leq \delta_{acc},\ P_t = P_{max}$

If $\delta_{max} > \delta_{acc},\ P_t = P_{acc}$

The deformation corresponding to the test load capacity (δ_t) shall be noted for each test, where $\delta_t = \delta_{max}$ or $\delta_t = \delta_{acc}$.

COMMENTS:

1. The population of P_t shall contain only P_{max} or P_{acc} not a mixture of the two.
2. The load-deformation curve should show a gradual increase in load and deformation. If a reduction in the load and/or an increase in deformation with no increase in load (i.e., a horizontal part in the curve) is observed due to unzipping/unbuttoning/slip effect of the fastener/s, where this load ($P_{u/sl}$) is lesser than 80% of the maximum load observed during the test (i.e., $P_{u/sl} < 0.8P_{max}$), then the test load capacity must be taken as $P_{u/sl}$ or the test must be repeated.
3. See Figure 3 for examples of determining the test load capacity from the load-deformation curve.
4. The capacity of the connection should be determined for deformation of the timber members similar to those of the structures in which they are intended to be used. As a guide, it is noted that EN 26891:1991 (ISO 6891:1983) which provides the general principles for the determination of strength and deformation characteristics for joints made with mechanical fasteners, states that the load reached before a deformation of 15 mm should be recorded as the maximum load. Furthermore, ASTM D7147 (2021) which provides the specification for testing and establishing allowable loads of joist hangers (for allowable stress design method), states that for all vertical loads, the load at 3.2 mm (0.125 inch) deformation should be recorded for the test deflection limit load.

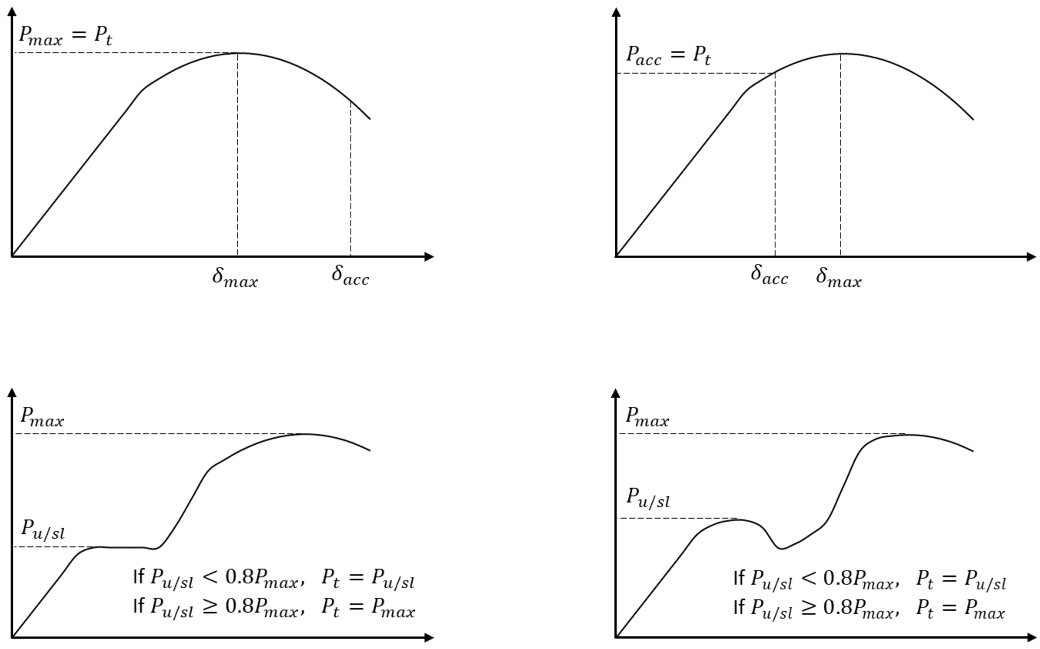


Figure 3: Test load capacity from the load-deformation curve

4.2 Correction of test results for timber density

The test results shall be corrected for timber density as shown in Eq. 2, where for $\frac{\rho_{m,ref}}{\rho_{m,test}} > 1.0$, the correction for density shall only be applied if it is demonstrated that the failure in the timber, rather than failure in the metal, will take place for the fastener installed in timber with the mean value of the timber density of the reference population for which the test results are applied ($\rho_{m,ref}$). The capacity of the connection for failure in the metal can be determined from testing or calculations using engineering principles.

It is important to note that correction for timber density or extrapolation of test results for other reference populations using timber density should only be made for failure modes which are dependent on timber density. Furthermore, it is assumed that perpendicular to the grain tension failure does not govern the failure mode.

$$P_{tc,i} = P_{t,i}\left(\frac{\rho_{m,ref}}{\rho_{m,test}}\right)^{x} \qquad \text{Eq. 2}$$

Where

$P_{tc,i}$	=	corrected value of the strength resistance from the test data for test value i corrected to refer to $\rho_{m,ref}$
$P_{t,i}$	=	strength resistance from the test data for test value i

$\rho_{m,ref}$ = mean value of the timber density of the reference population for which the test results are applied

$\rho_{m,test}$ = mean value of the measured density of all timber pieces of the test specimens

x = 1.0 if $0.90 \leq \frac{\rho_{m,ref}}{\rho_{m,test}} \leq 1.10$

x = 0.8 if $1.10 < \frac{\rho_{m,ref}}{\rho_{m,test}} \leq 1.75$

x = 2.0 if $0.55 \leq \frac{\rho_{m,ref}}{\rho_{m,test}} < 0.90$

COMMENT:

1. The equation for correcting for density (Eq. 2) has been developed to adjust test results when the mean density of the specimens is slightly different to the mean density of the reference population. However, the equation may be used for extrapolation of test results for reference populations with different mean values of timber density for the $\frac{\rho_{m,ref}}{\rho_{m,test}}$ limits provided, and is likely to give conservative results as the value of $x = 2$ or $x = 0.8$ are generally conservative values and are based on values provided in ISO 8970:2020 for various failure mechanisms of nails, staples, and screws in European softwood. For accurate results, it is suggested that more testing is conducted for reference populations with different mean timber densities instead of extrapolation.
2. Extrapolation of test results using the above suggested x-values should not be used for $\frac{\rho_{m,ref}}{\rho_{m,test}}$ lower than 0.55 or higher than 1.75. These limits approximately correspond to two joint groups above or below the joint group which has been tested based on the mean density of the timber samples.

4.3 Estimate of coefficient of variation for the reference population

The coefficient of variation for the reference population, V_p, shall be assessed with reference to a failure mode.

V_p can be calculated using Eq. 3, unless V_t, V_m, and V_f can be determined for which case Eq. 4 can be used.

The coefficient of variation of the reference population shall not be less than 20% for calculating the characteristic value from test results.

$$V_p = \begin{Bmatrix} 0.2 & \text{if } V_t \leq 0.2 \\ V_t & \text{if } 0.2 < V_t \leq 0.4 \end{Bmatrix} \qquad \text{Eq. 3}$$

This procedure is not recommended if $V_t > 0.4$

Where

V_t = coefficient of variation of the test results

$V_t = \frac{standard\ deviation\ of\ the\ test\ results}{mean\ of\ the\ test\ results}$

$$V_p = \sqrt{{V_t}^2 + {V_m}^2 + {V_f}^2} \qquad \text{Eq. 4}$$

Where

V_t = coefficient of variation as the result of theory accuracy when compared with experimental data, when there is no theory V_t can be taken as the variation of the test data

V_m = coefficient of variation as the result of material variation (dependent on the mode of failure and the properties of the timber)

V_f = coefficient of variation as the result of fabrication variation

COMMENTS:

1. V_f is dependent on the variation in geometric properties of the fasteners, generally taken as 5% in steel design practice.
2. The use of predrilled metal plate in bracket usually has the effect of reducing the variability due to load sharing and improves the performance by about 20% as allowed in AS 1720.1 but this is automatically accounted for in the test results.

4.4 Characteristic value from statistics of test results

The characteristic value of the test results shall be calculated using Eq. 5.

The sampling factor, k_t, for 5-percentile value at 75% confidence (assuming a lognormal distribution) are given in Table 2.

Linear interpolation of k_t is allowed between the number of tests (n) and coefficient of variation of the reference population (V_p) provided in Table 2.

$$R_k = \frac{\bar{P}}{k_t} \qquad \text{Eq. 5}$$

Where

$\bar{P}$ = mean value of the strength resistance from the test data which has been corrected for density

$\bar{P} = \sum_{i=1}^{n} \frac{P_{tc,i}}{n}$

n = number of test values

k_t = sampling factor which is a function of the number of tests (n) and the coefficient of variation of the reference population of the connection (V_p)

V_p = coefficient of variation of the reference population of the connection, see Section 3.3

Table 2: Sampling factor, k_t

No of tests, n	Sampling factor k_t for the coefficient of variation of connection reference population V_p		
	0.2	**0.3**	**0.4**
10	1.47	1.80	2.19
20	1.45	1.77	2.15
100	1.41	1.69	2.03

4.5 Determination of the capacity factor

The capacity factor (ϕ) can be calculated using the National Construction Code (NCC) Verification Method BV1 Structural Reliability.

A capacity factor of ϕ=0.7 is obtained by using the target reliability index in accordance with the Verification Method BV1 (ABCB, 2019) by considering different action types (dead, live, cyclonic, and non-cyclonic wind) and the coefficient of variations of the connection reference population.

The capacity factor obtained using Verification Method BV1 is applicable for all Importance Level buildings. However, AS 1720.1:2010 (Table 2.2) suggests different capacity factors based on the application of the structural member (i.e., Category 1, 2, and 3) where the capacity factor decreases by an increment of 0.05 as the Category level increases.

Hence, for simplicity and consistency with AS 1720.1:2010, the capacity factors in Table 3 should be adopted for obtaining design resistance of Category D fasteners where the characteristic value is determined in accordance with this Guide.

Table 3: Capacity factor (ϕ) for Category D fasteners where the characteristic capacity is calculated in accordance with this Guide

Type of fastener	**Application of structural member in accordance with AS 1720.1:2010**		
	Category 1 Structural joints for houses for which failure would be unlikely to affect an area greater than 25 m^2, or joints for secondary elements in structures other than houses.	**Category 2** Primary structural joints in structures other than houses; or joints for house construction for which failure of the joint would be likely to affect an area greater than 25 m^2.	**Category 3** Primary structural joints in structures intended to fulfil essential services or post-disaster functions.
Capacity factor (ϕ) for Category D fasteners where the characteristic capacity is calculated in accordance with this Guide[1]	0.70	0.65	0.60

[1] In this Guide, the characteristic capacity corresponds to the 5-percentile value with 75% confidence based on a lognormal distribution. The capacity factor of 0.7 for Category 1 is the average capacity factor which has been obtained by considering the reliability index of approximately 4.3 for permanent actions, 4 for imposed actions, and 3.7 for non-cyclonic and cyclonic wind actions in accordance with Verification Method BV1 in the NCC (2019).

4.6 Mean deformation from test results

The mean deformation corresponding to the test load capacities ($\overline{\delta_t}$) used to calculate the characteristic strength of the fastener shall be calculated using Eq. 6.

$$\overline{\delta_t} = \sum_{i=1}^{n} \frac{\delta_{t,i}}{n} \qquad \text{Eq. 6}$$

Where

$\overline{\delta_t}$	=	mean value of the deformation corresponding to the load capacities used to calculate the characteristic strength of the fastener
$\delta_{t,i}$	=	deformation corresponding to test load capacity for test value i
n	=	number of test values

SECTION 5
TEST REPORT REQUIREMENTS

A test report shall be prepared with the following information:

(i) Description of the timber, fasteners, and connection assembly including all the attributes of the reference population as stated in Section 2.6.
(ii) The extent and method of sampling.
(iii) Sample size for each test type.
(iv) Details of the test set-up including all significant dimensions and geometry, and direction of the applied load relative to the position of the fasteners and grain direction of the timber, where appropriate.
(v) Details of the loading procedure.
(vi) Photographs of the test set-up and specimens.
(vii) Load-displacement curve for each specimen in the form of a plot or a table.
(viii) The test strength resistance (P_t), maximum load (P_{max}) and corresponding deformation (δ_{max}) or the acceptable deformation (δ_{acc}) and corresponding load (P_{acc}), and the mode of failure for each specimen.
(ix) Summary of the results, including the characteristic value of the strength resistance of the fastener (R_k) and corresponding capacity factor (ϕ), and the mean deformation corresponding to the test load capacities ($\overline{\delta_t}$) used to calculate the characteristic strength of the fastener.
(x) Any special features or deviations that may have any effect on the test results.

REFERENCES

ASTM International (American Society for Testing and Materials). (2021). *ASTM D7147, Standard specification for testing and establishing allowable loads of joist hangers.*

Australian Building Codes Board (ABCB). (2019). *National Construction Code: Volume One and Volume Two - Building Code of Australia*. Retrieved from http://www.abcb.gov.au

Australian Standard. (2005). *AS 2193:2005 (Reconfirmed 2017), Calibration and classification of force-measuring systems*. NSW: Standards Australia

CEN (European Committee for Standardization). (1991). *EN 26891:1991, ISO 6891:193, Timber structures – Joints made with mechanical fasteners – General principles for the determination of strength and deformation characteristics. Brussels: CEN.*

ISO (International Organization for Standardization). (2017). *ISO 12122-6:2017, Timber structures - Determination of characteristic values - Part 6: Large components and assemblies*. Switzerland: ISO

ISO (International Organization for Standardization). (2020). *ISO 8970:2020, Timber structures - Testing of joints made with mechanical fasteners - Requirements for timber density*. Switzerland: ISO

Standards Australia. (2001). AS 1649:2001, Timber - Methods of test for mechanical fasteners and connectors - Basic working loads and characteristic strengths. News South Wales: Standards Australia International

Standards Australia. (2010). AS 1720.1:2010, Timber structures - Part 1: Design methods. New South Wales: SAI Global

Standards Australia/Standards New Zealand. (2000). *AS/NZS 1080.3:2000 (Reconfirmed 2016), Timber - Methods of test, Method 3: Density*. NSW and Wellington: Standards Australia and Standards New Zealand

Standards Australia/Standards New Zealand. (2012). *AS/NZS 1080.1:2012, Timber - Methods of Test, Method 1: Moisture Content*. NSW and Wellington: Standards Australia and Standards New Zealand

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